# ECE 205 “Electrical and Electronics Circuits”

## Spring 2026 – LECTURE 3

MWF – 12:00pm

**Prof. Umberto Ravaioli**

2062 ECE Building

# Lecture 3 - Summary

## Learning Objectives

1. Define Ohm's Law for Resistors
2. Use Ohm’s law to compute voltage and current
3. Combine basic elements to sketch a complete circuit
4. Identify series and parallel combination of resistors
5. Compute equivalent resistance between two terminals

# NOTE

**Posted on Canvas Module Week 1, Lecture 2:**

- **Guided Solution (video) of Worksheet 1**

**Posted on Canvas Module Week2, Lecture 3:**

- **Review Problems on Resistor Circuits (video and slides)**

**Posted on Canvas in both Lecture 2 & 3:**

- **A Note on PrairieLearn Relative Tolerance (IMPORTANT)**

# Office Hours

**Office Hours will start on Monday, January 26, with this calendar:**

- Mondays
  5:00pm to 7:00pm Room 2036 ECEB (TA's)
- Tuesdays
  5:00pm to 7:00pm Room 3036 ECEB (TA's)
- Wednesdays
  2:00pm to 4:00pm Room 2062 ECEB (Ravaioli)

# A “Note” on Class Notes

During the pandemic semesters, Prof. Radhakrishnan preserved online lecture notes, provided on Canvas as useful summaries. However, there may be occasional typos and “mistakes” mostly due to the fact that examples were changed in real time but solutions were not necessarily updated in the notes, causing inconsistencies.

**The lectures slides, presented in class now, have strived to preserve all those original examples, with edits, corrections and updates where necessary, thus removing those possible inconsistencies. Please, refer to the examples as posted in the lecture slides and in the extra problem sets when you study the course material.**

# Remember the notation

$$\boldsymbol{V_{ab} \rightarrow Voltage\ between\ "a"\ and\ "b"}$$

$$\boldsymbol{V_{a} \rightarrow Voltage\ between\ "a"\ and\ ground}$$

# Power

**Power is the rate at which work is dissipated (consumed) or delivered (supplied)**

**differential form (instantaneous)**

$$p = \frac{dW}{dt} = \underbrace{\frac{dW}{dq}}_{v} \times \underbrace{\frac{dq}{dt}}_{i}$$

**constant form (steady-state)**

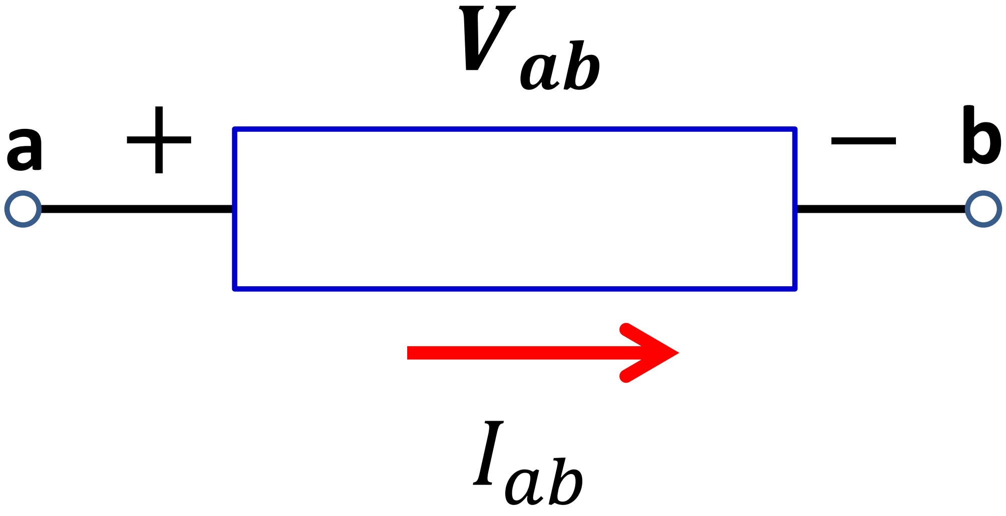
$$\boxed{P = V \times I}$$

$P > 0$ → **Power dissipated or consumed**

$P < 0$ → **Power delivered or supplied**

# Power sign convention

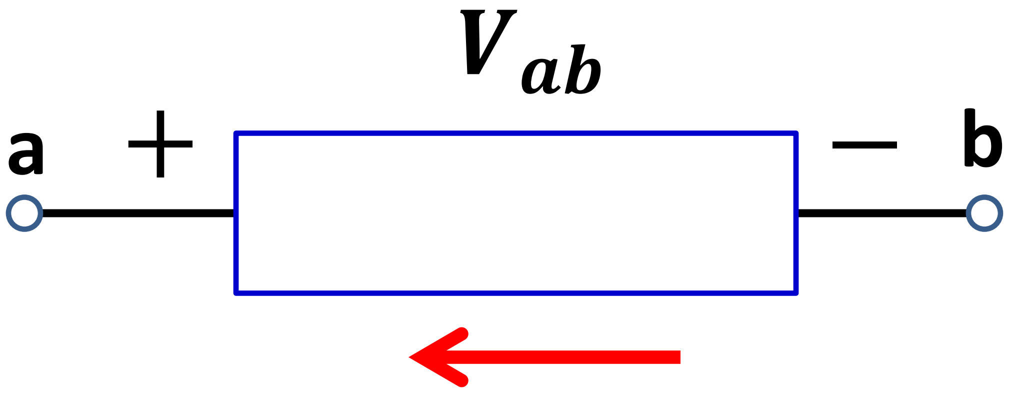
**If current enters the positive end of an element and leaves the negative end, then the element is dissipating power. The power is positive in this case.**



$$\boxed{P = V_{ab} \times I_{ab}}$$

# Power sign convention

**If current enters the negative end of an element and leaves the positive end the device, it is delivering (supplying) power. The power is negative in this case.**



$$I_{ba} = -I_{ab}$$

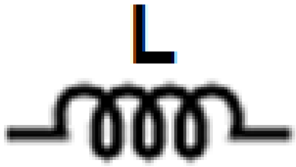
$$\boxed{P = V_{ab} \times I_{ba} = -V_{ab} \times I_{ab}}$$

# Circuit elements and power

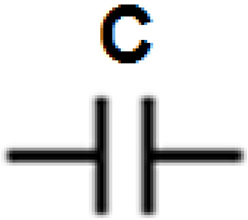
Resistive elements can only consume power

Resistor

Ideal reactive elements can store power from an external source or release stored energy if in transient conditions but do not exchange power in steady-state and never dissipate energy.



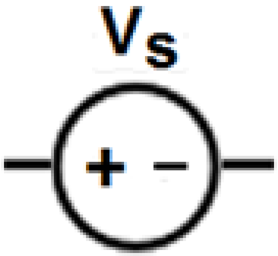
Inductor



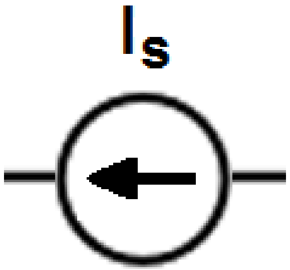
Capacitor

# Circuit elements and power

**Sources can deliver or consume power**



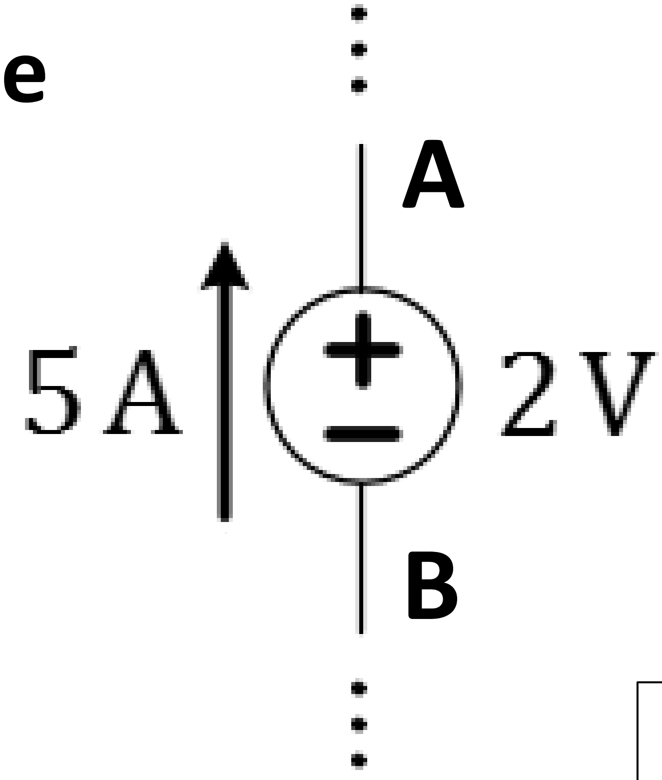
**Voltage source**



**Current source**

**Let’s look at specific examples.**

# Voltage Source



$$\boxed{V_{AB} = 2\ \mathrm{V}}$$

$$\boxed{I_{AB} = -5\ \mathrm{A}}$$

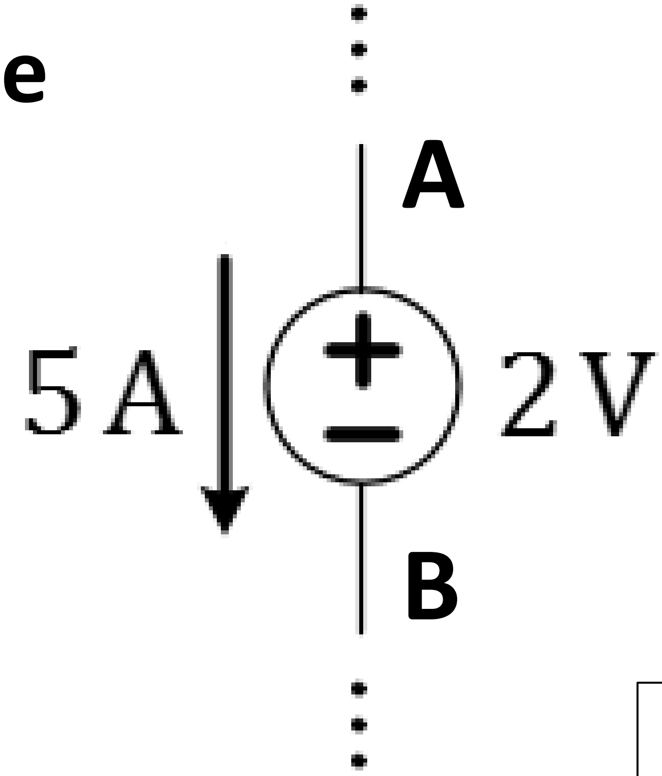
$$\boxed{P = -10\ \mathrm{W}}$$

**DELIVERING POWER**

**VOLTAGE SOURCE ACTS LIKE A PUMP SENDING CURRENT “UPHILL”**

**It GENERATES current that gives power to the rest of the circuit**

# Voltage Source



$$\boxed{V_{AB} = 2\text{ V}}$$

$$\boxed{I_{AB} = 5\text{ A}}$$

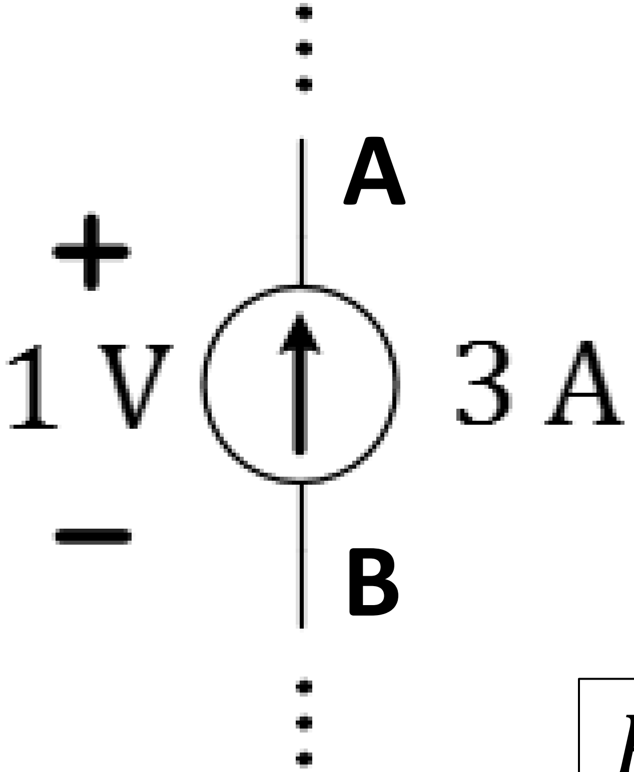
$$\boxed{P = 10\text{ W}}$$

**ABSORBING POWER**

**CURRENT IN VOLTAGE SOURCE IS GOING "DOWNHILL" AS IN RECHARGE MODE**

**It RECEIVES current and power from the rest of the circuit**

# Current Source



$$\boxed{I_{AB} = -3\ \mathrm{A}}$$

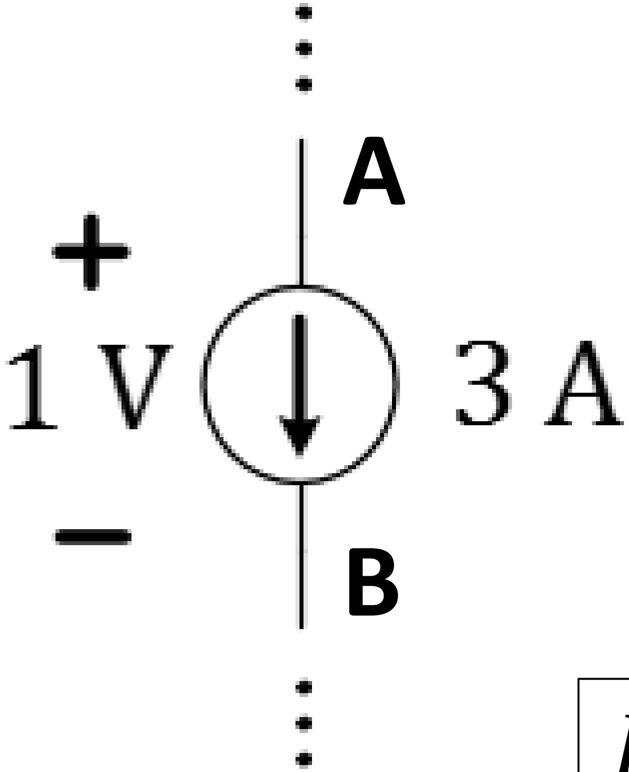
$$\boxed{V_{AB} = 1\ \mathrm{V}}$$

$$\boxed{P = -3\ \mathrm{W}}$$

**DELIVERING POWER**

**CURRENT SOURCE ESTABLISHES “UPHILL” VOLTAGE PUMPING ENERGY INTO THE REST OF THE CIRCUIT**

# Current Source



$$\boxed{I_{AB} = 3\ \mathrm{A}}$$

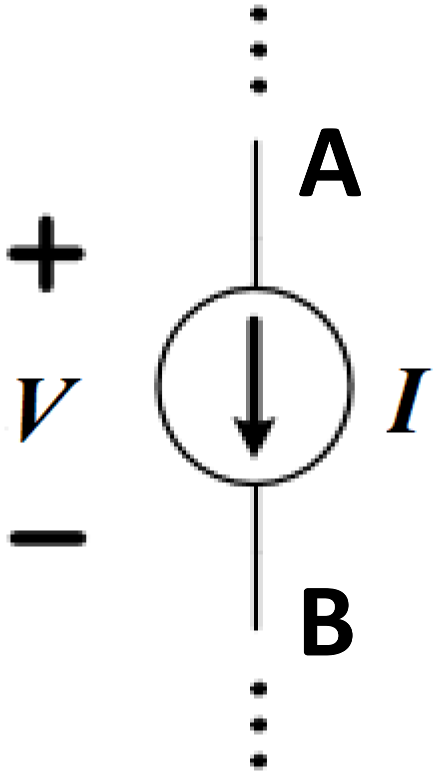
$$\boxed{V_{AB} = 1\ \mathrm{V}}$$

$$\boxed{P = 3\ \mathrm{W}}$$

**ABSORBING POWER**

**VOLTAGE DROP IS IMPOSED BY THE REST OF THE CIRCUIT WHICH MAKES CURRENT GO “DOWNHILL”**

# IMPORTANT



**The Voltage across a current source depends on the rest of the circuit. Most often, it can be determined only after solution of the problem.**

# Ideal Sources

**These are limit cases which simplify the study of circuits. In this course, we will assume that sources are ideal.**

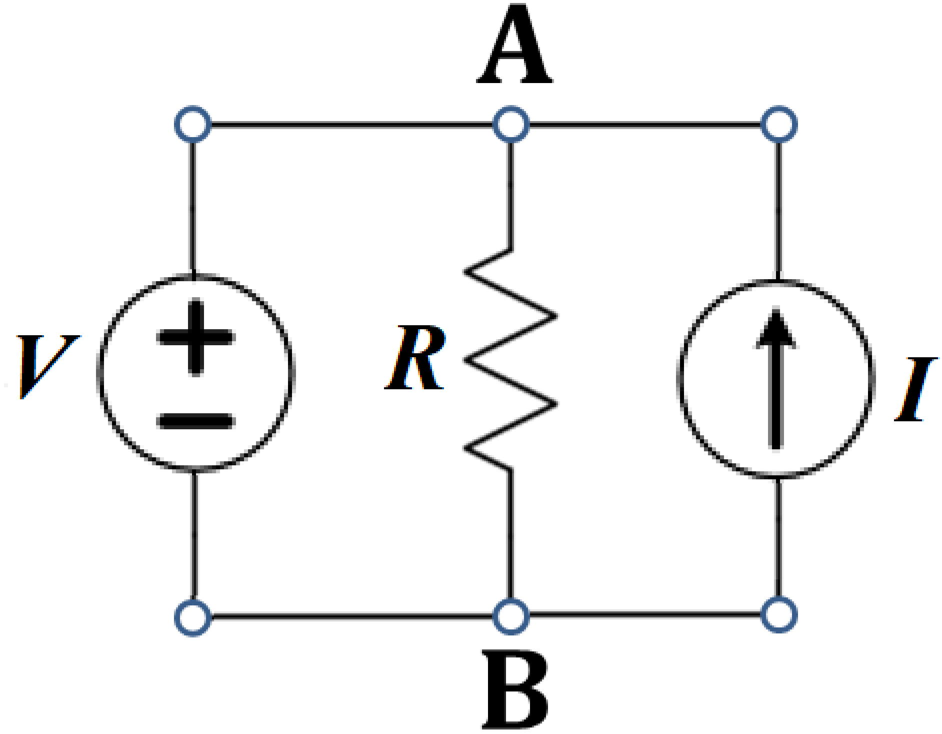
**IDEAL VOLTAGE SOURCE**

An ideal voltage source has zero internal resistance and can drive up to infinite current, in limit conditions.

**IDEAL CURRENT SOURCE**

An ideal current source has infinite internal resistance and can have up to infinite voltage across its terminals, in limit conditions.

# Circuit brain teaser



Assume ideal sources

Hint: the voltage across the current source is

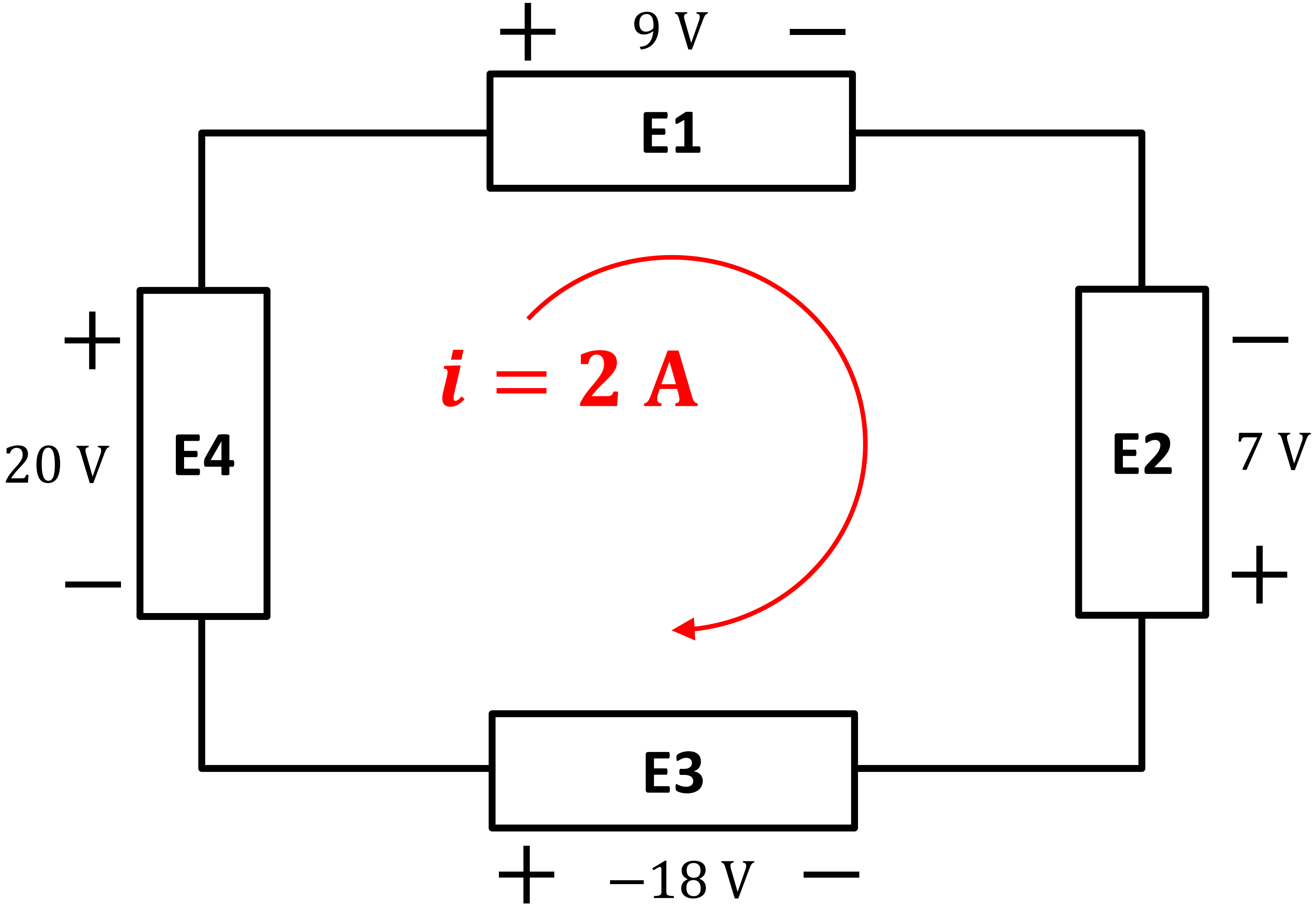
$$\mathrm{V}_{AB} = V$$

## How does this circuit operate?

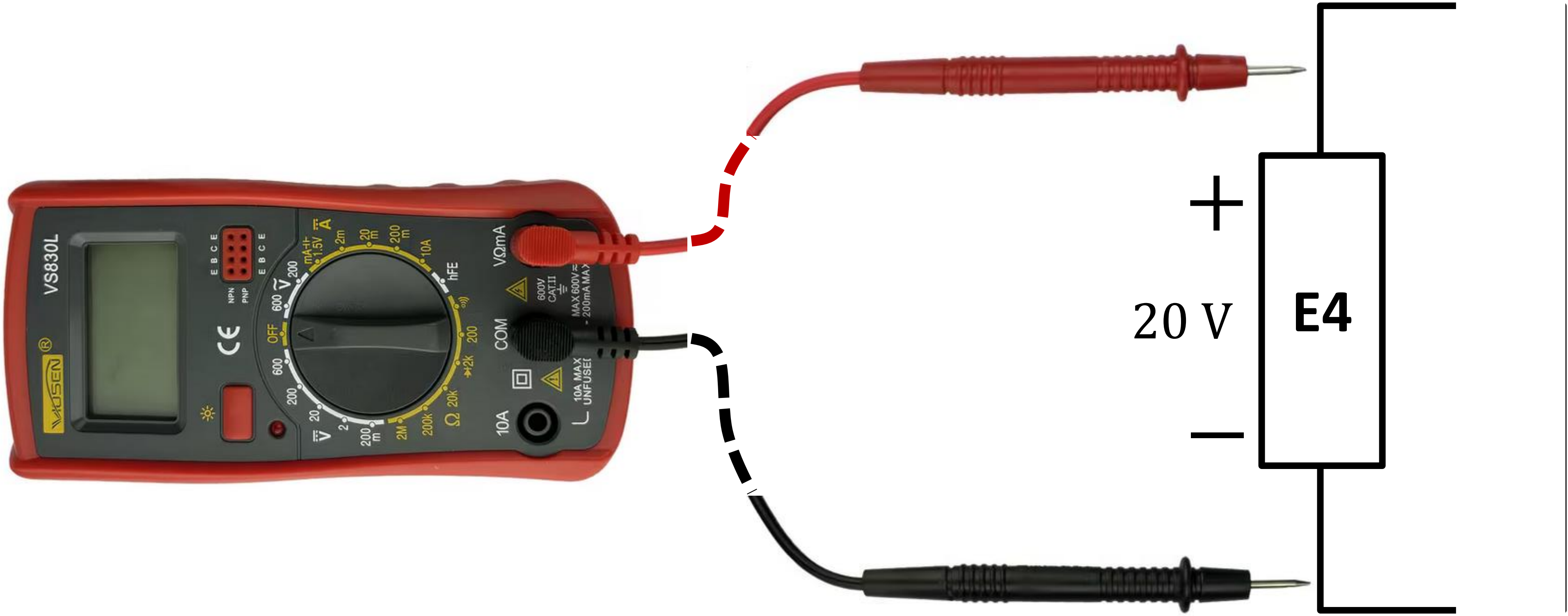
(guided solution posted on Canvas within Lecture 5 module)

# Example (class brainstorming)

## Find the power consumed or supplied by each element.



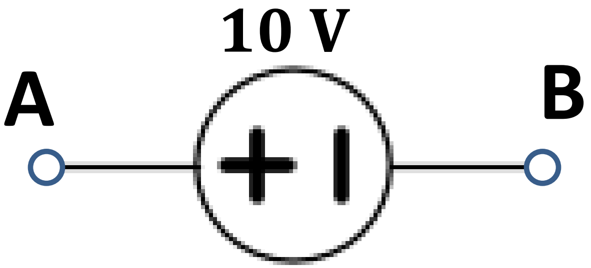
**Hint: imagine that the voltages and polarities across each element have been measured with a voltmeter.**



# Electrical Circuit

An **electrical circuit** is made up of **electrical elements.** Initially, we will look at circuits with these elements:

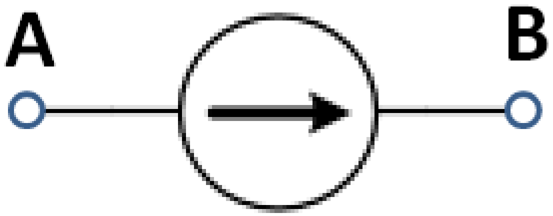
1)



**Ideal Voltage Source**

$$\boxed{V_{AB} = V_A - V_B}$$

2)



**Ideal Current Source**

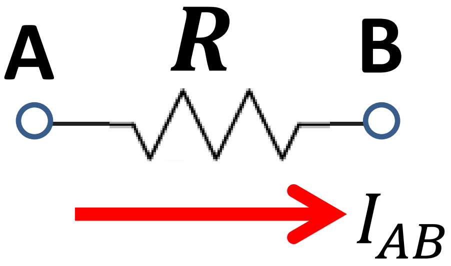
$$\boxed{I_{AB}}$$

3)

**Wire (ideal conductor)**

$$\boxed{V_{AB} = 0\ \text{V}}$$

4)



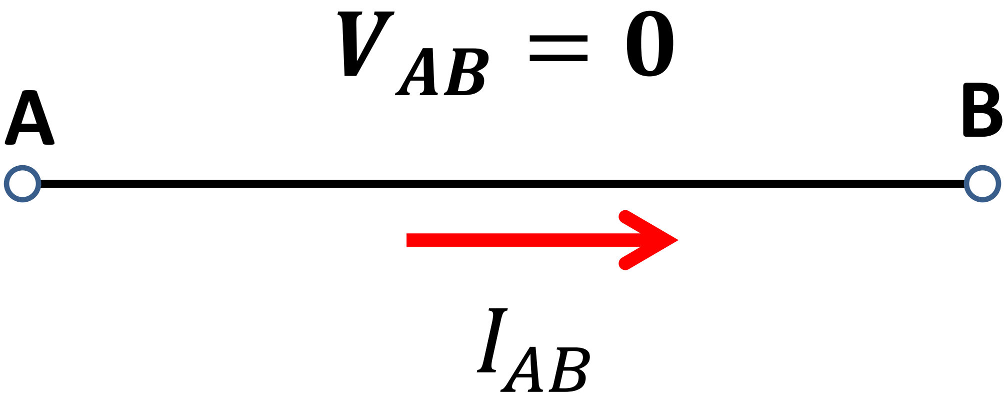
**Resistor**

$$\boxed{V_{AB} = I_{AB}\,R}$$

Ohm's Law

# Ideal Wire

Wires are represented by unbroken lines. Wires are assumed to be ideal conductors, i.e., the voltage difference between two point on a wire is zero (equipotential). Two points in a circuit that are connected by a wire are said to be **shorted** together.

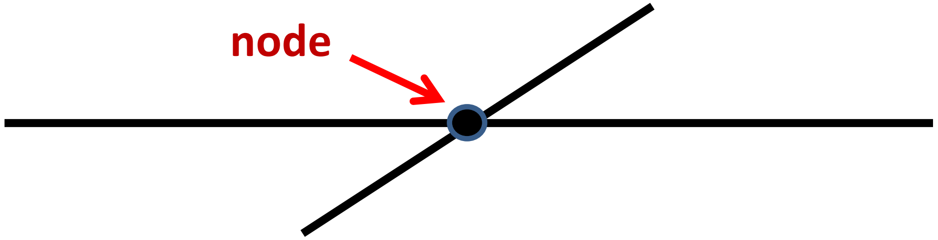


$$\boldsymbol{V_{AB} = 0}$$

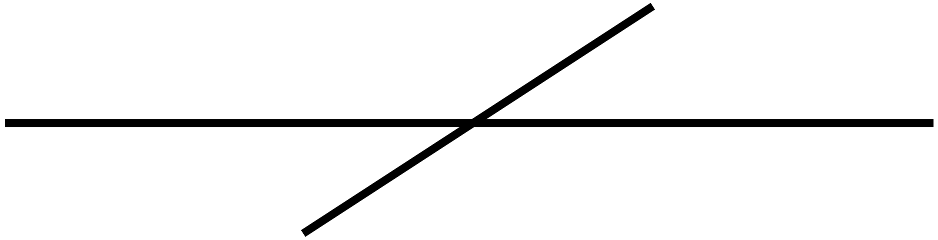
$I_{AB}$

# Crossing Wires in Circuit Schematics

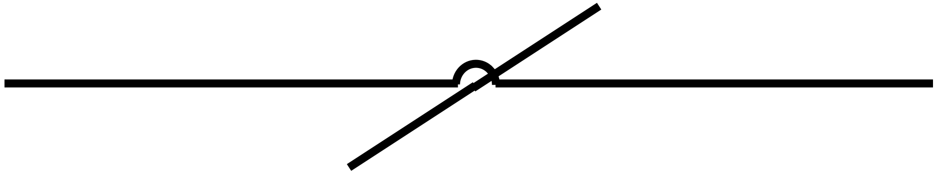
These two wires cross AND make contact



These two wires cross AND DO NOT make contact



To avoid confusion you may also draw like this



# Resistor

A resistor is an element which requires a certain effort on the part of the voltage to push a current through it. The resistance $R$ is quantified by:

$$\boxed{R = \frac{\rho\,\ell}{A}}$$

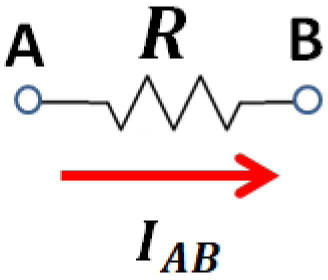
$\rho$ **Resistivity of the material**

$\ell$ **Length**

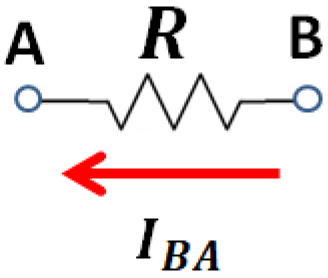
$A$ **Cross-sectional area**

# Ohm’s Law (formulated in 1827)

Ohm's law captures the relationship between voltage across a resistor and current through it. Ohm's law can have the following two forms,



$$V_{AB} = I_{AB}R$$



$$V_{AB} = -I_{BA}R$$

# Observations on Ohm’s Law

$$V = IR$$

For the same current, a higher resistance cause a higher voltage drop at the terminals

$$I = \frac{V}{R}$$

For the same voltage at the terminals, a higher resistance cause a smaller current

# Observations on Ohm's Law

$$I = \frac{V}{R}$$

For low resolution $R$, **a small voltage may cause a high current**.

$$V = IR$$

For large resistance $R$, **a small current may cause a high voltage**.

# And no matter what you are doing, never write these:

$$\xcancel{V = \frac{I}{R}}$$

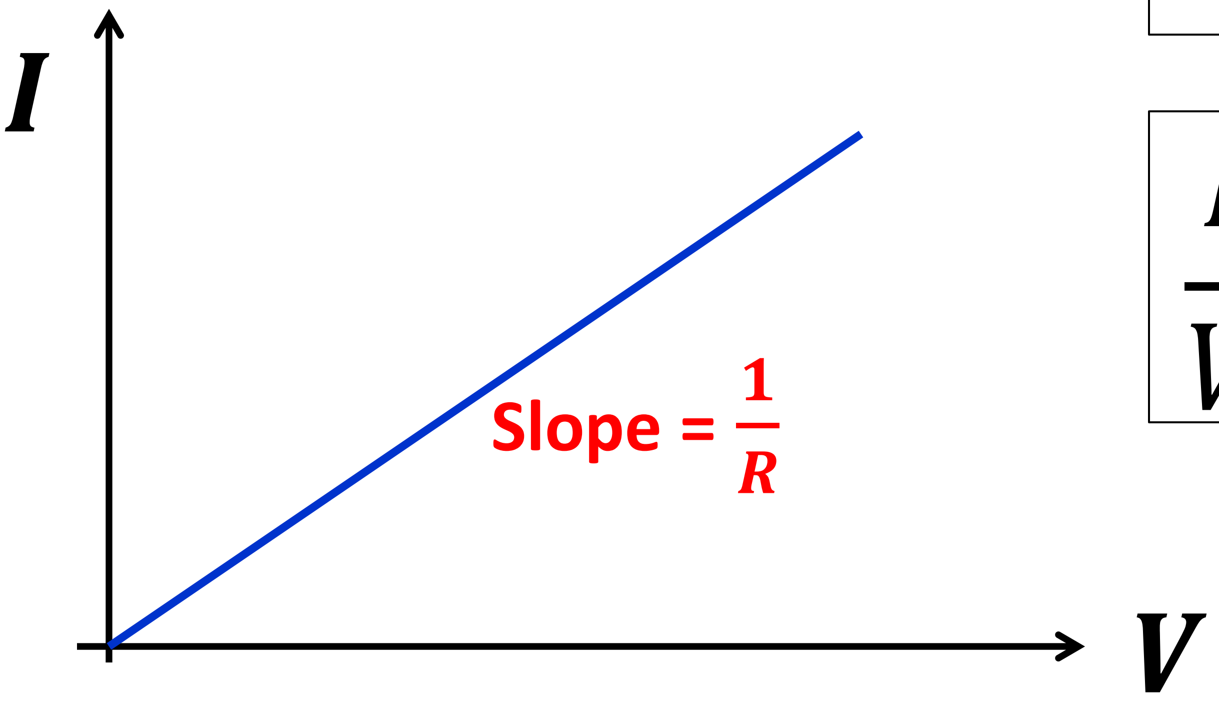
$$\xcancel{I = VR}$$

# Current-Voltage or I-V Curves

I-V curves capture the relationship between current and voltage. For a **resistance**, the I-V is linear (straight line)

$$\boxed{V = IR}$$

$$\boxed{\frac{I}{V} = \frac{1}{R}}$$

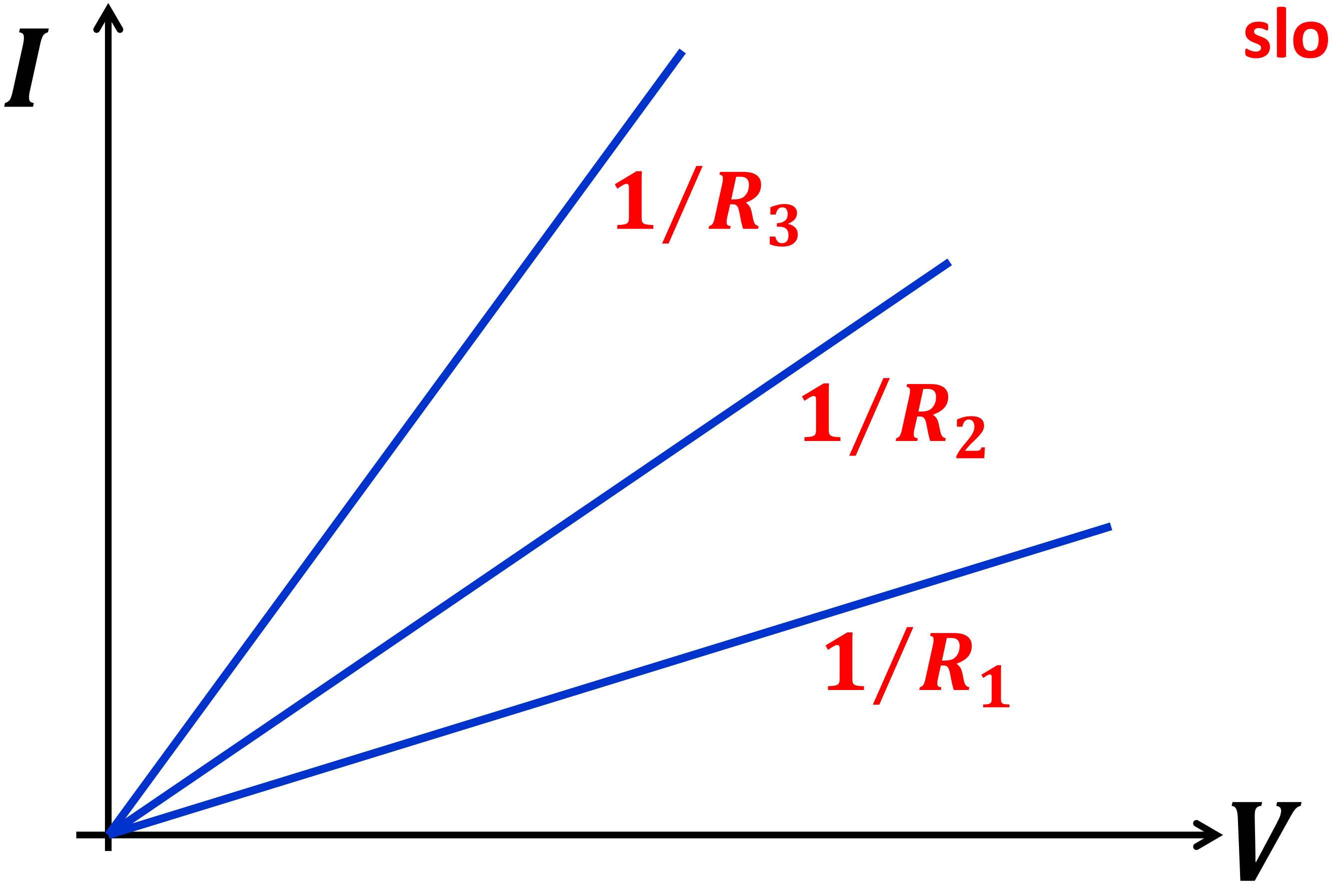


The inverse of the slope represents the resistance

$$\boxed{R_1 > R_2 > R_3}$$

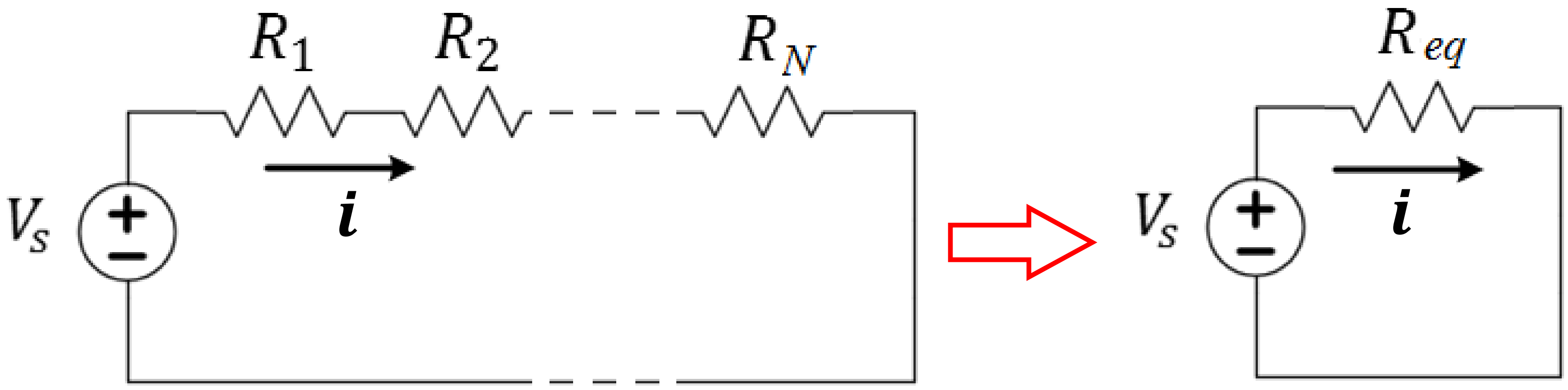
$$\boxed{\frac{I}{V} = \frac{1}{R}}$$

slope



**The smaller the slope, the higher the resistance**

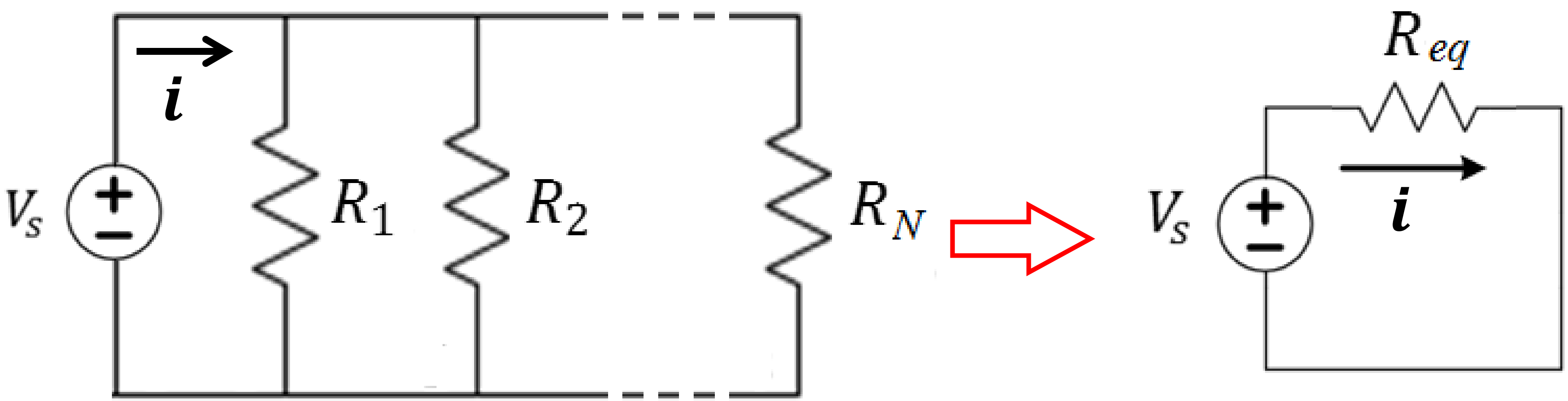
# Series connected resistors



**$N$ resistors connected in series can be replaced by an equivalent resistor $R_{eq}$**

$$R_{eq} = R_1 + R_2 + \cdots + R_N = \sum_{k=1}^{N} R_k$$

# Parallel connected resistors

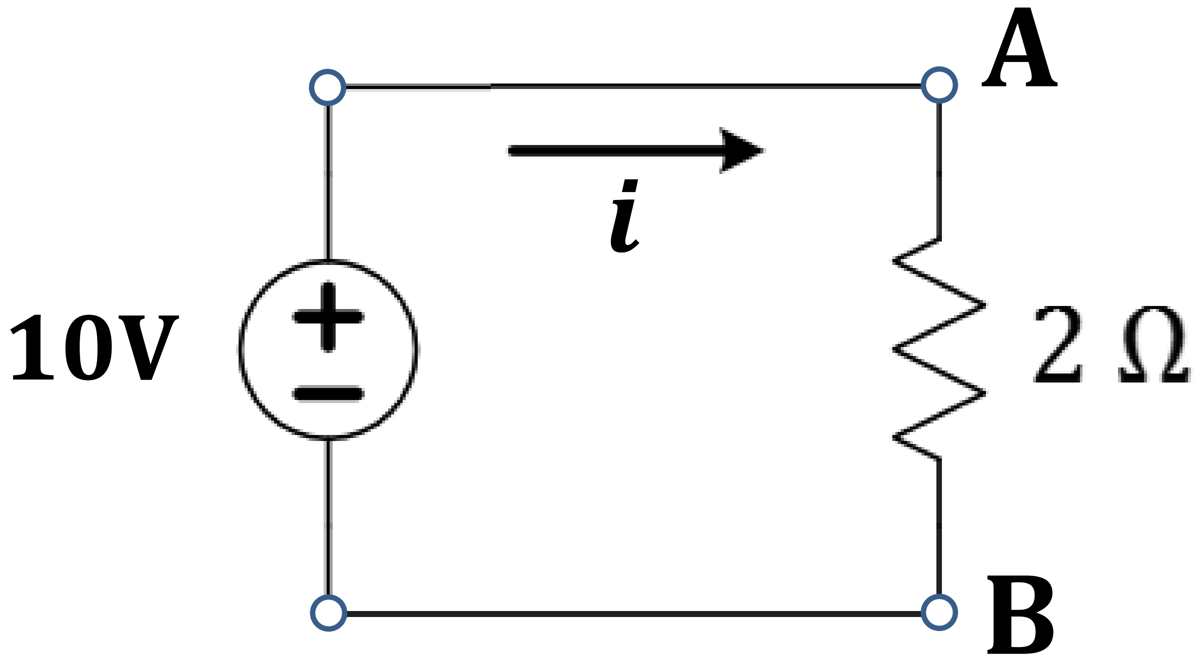


$N$ **resistors connected in series can be replaced by an equivalent resistor** $R_{eq}$ **given by**

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_N} = \sum_{k=1}^{N} \frac{1}{R_k}$$

# Example 1

**Find the current $i$ in the circuit below**



# Example 1

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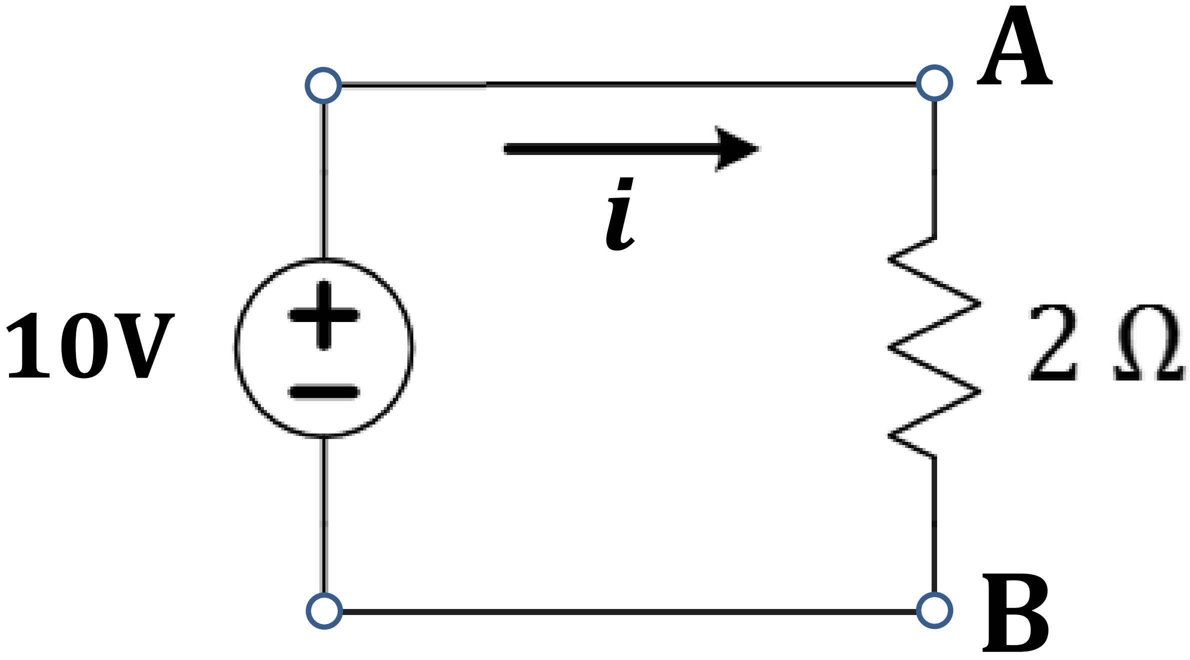
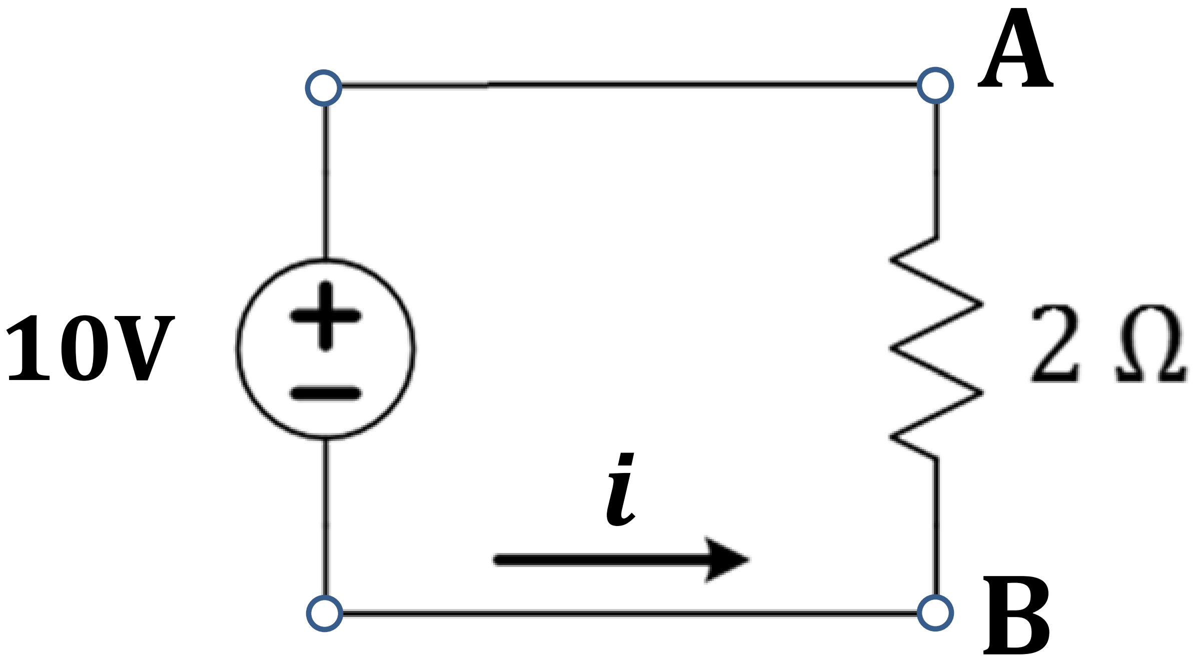


$$\boxed{V_{AB} = 10V = i_{AB} \times R = i_{AB} \times 2}$$

$$\boxed{i = i_{AB} = V_{AB}/R = 10/2 = 5\ \text{A}}$$

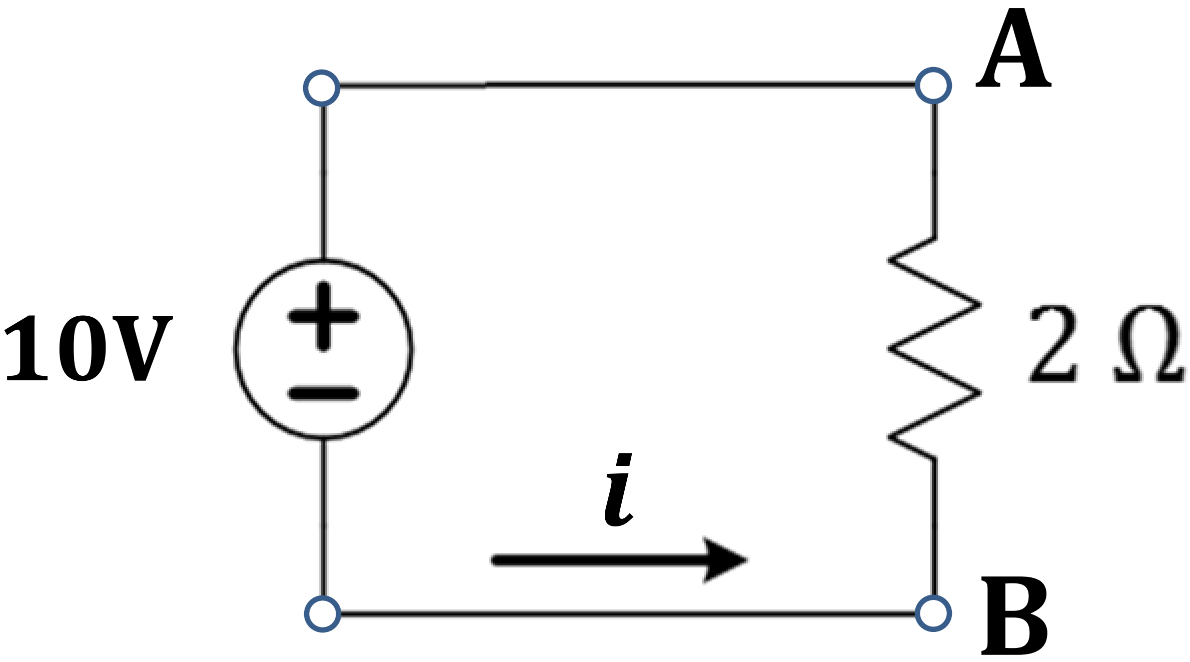
# Example 2

**Find the current $i$ in the circuit below**



# Example 2

**Find the current $i$ in the circuit below**

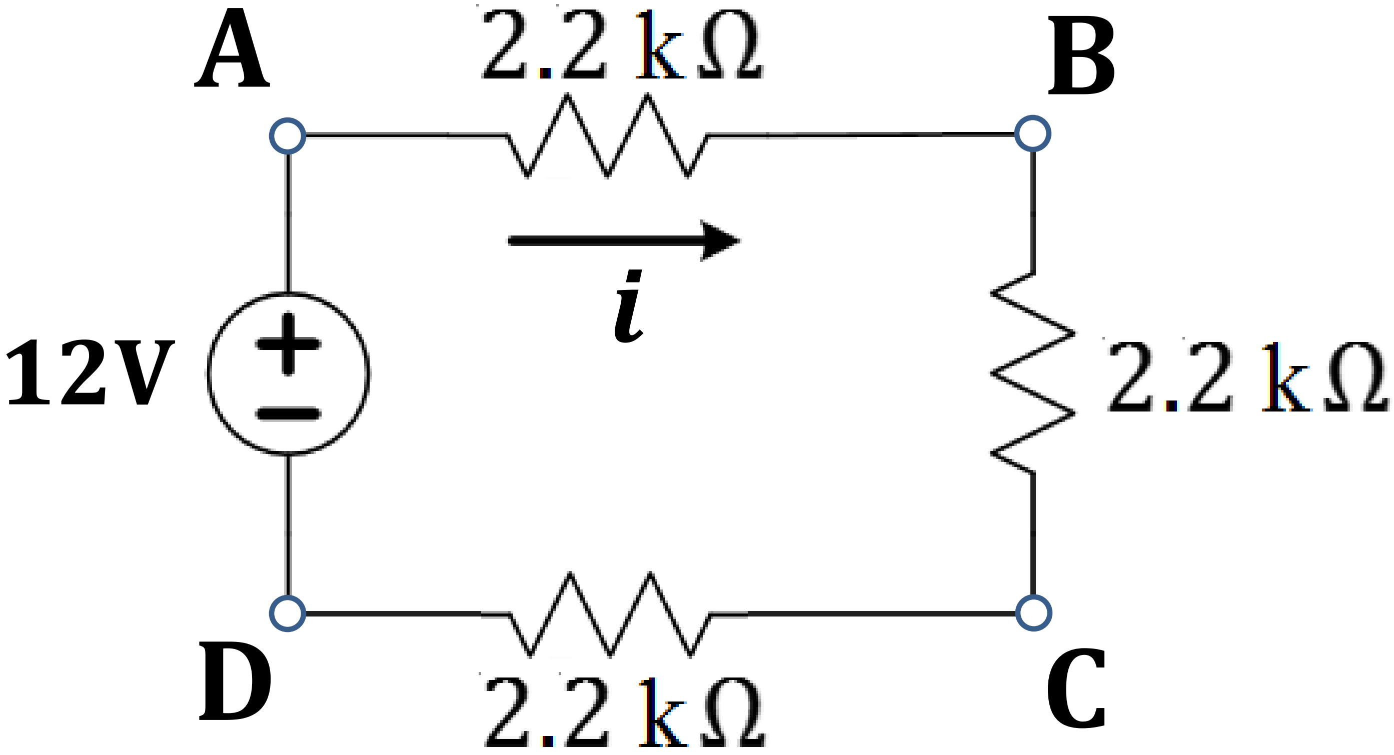


$$\boxed{V_{AB} = 10V = i_{AB} \times R = i_{AB} \times 2}$$

$$\boxed{i = i_{BA} = V_{BA}/R = -V_{AB}/2 = -5\text{ A}}$$

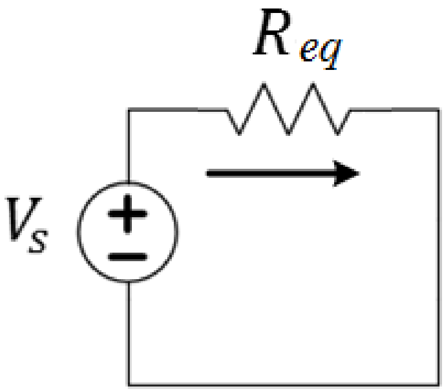
# Example 3

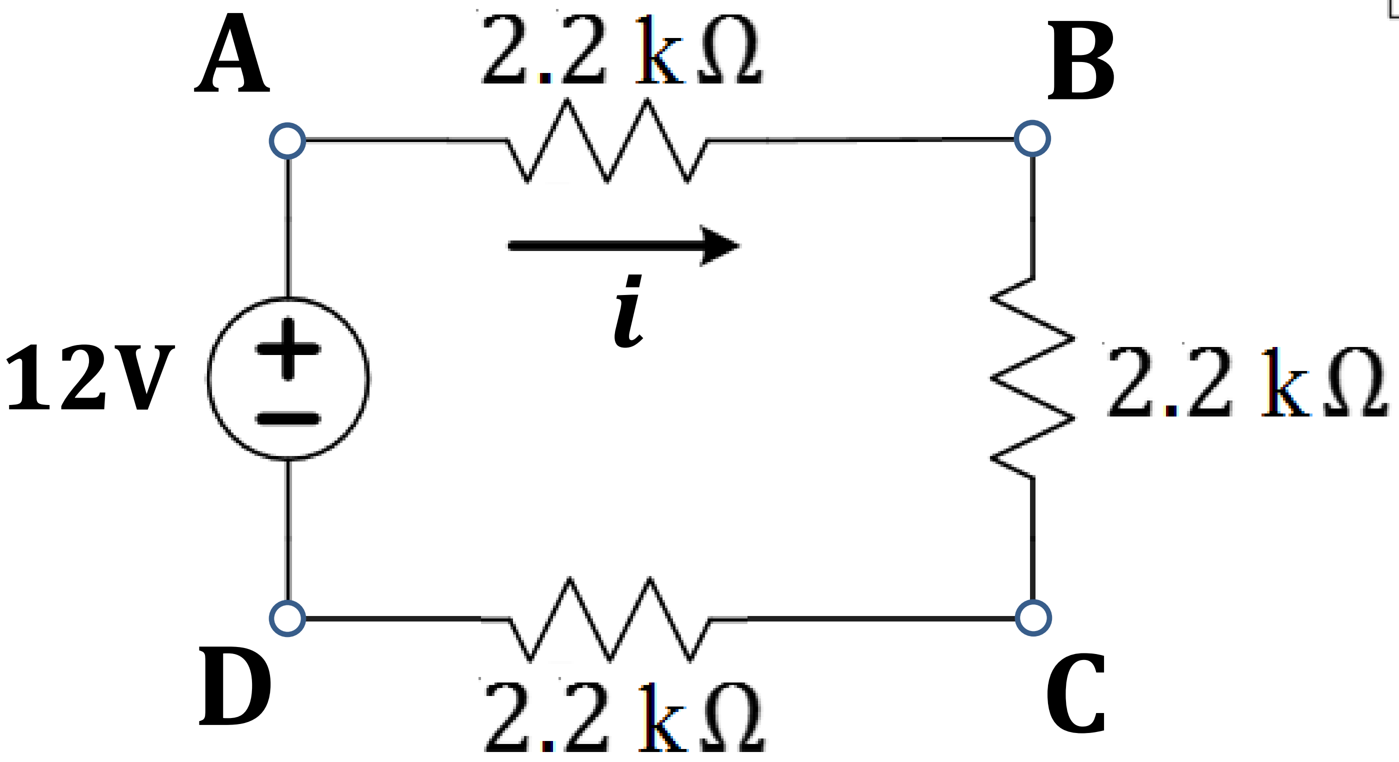
**Find the current $i$ in the circuit below**



# Example 3

Find the current $i$ in the circuit below

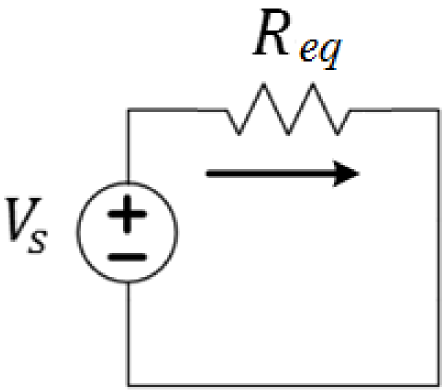


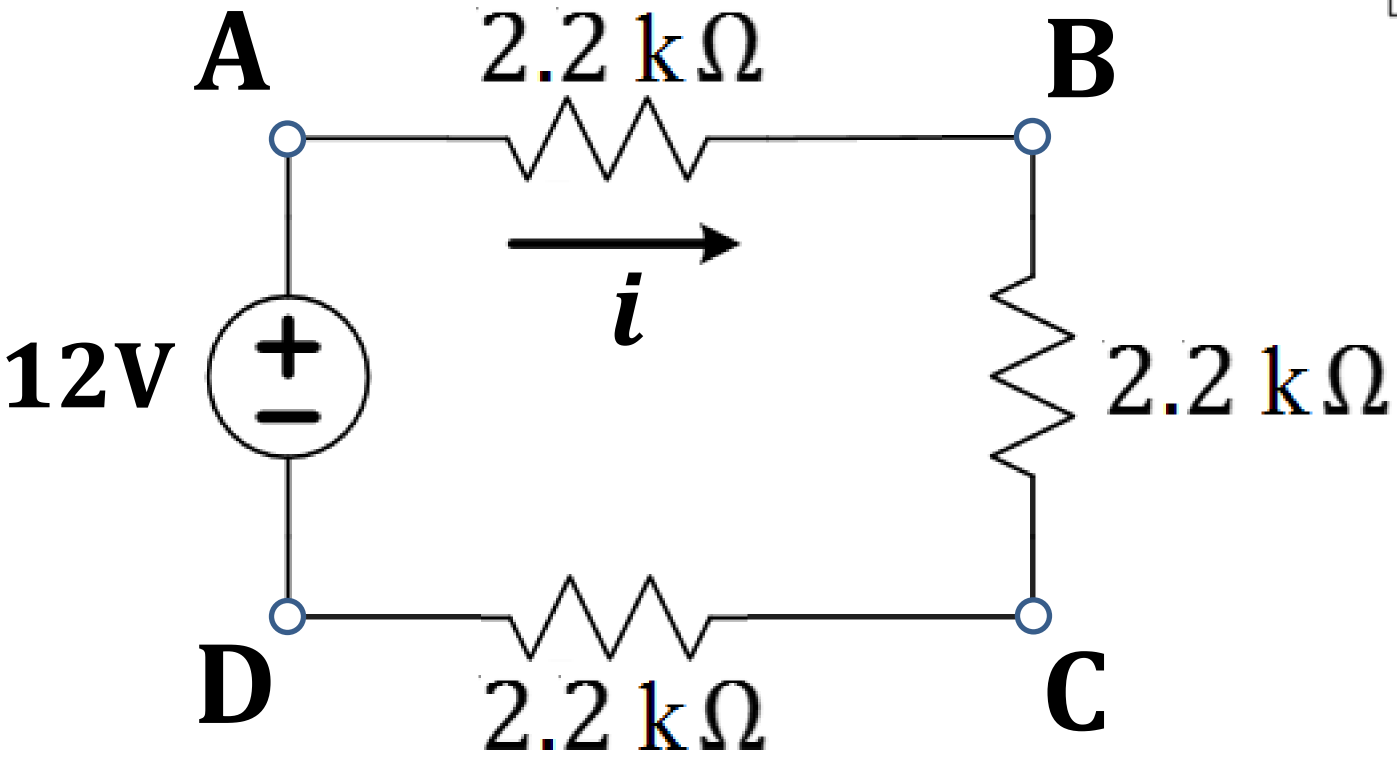


$$R_{eq} = R_{AB} + R_{BC} + R_{CD} = 6.6\ \text{k}\Omega = 6{,}600\Omega$$

# Example 3

Find the current $i$ in the circuit below

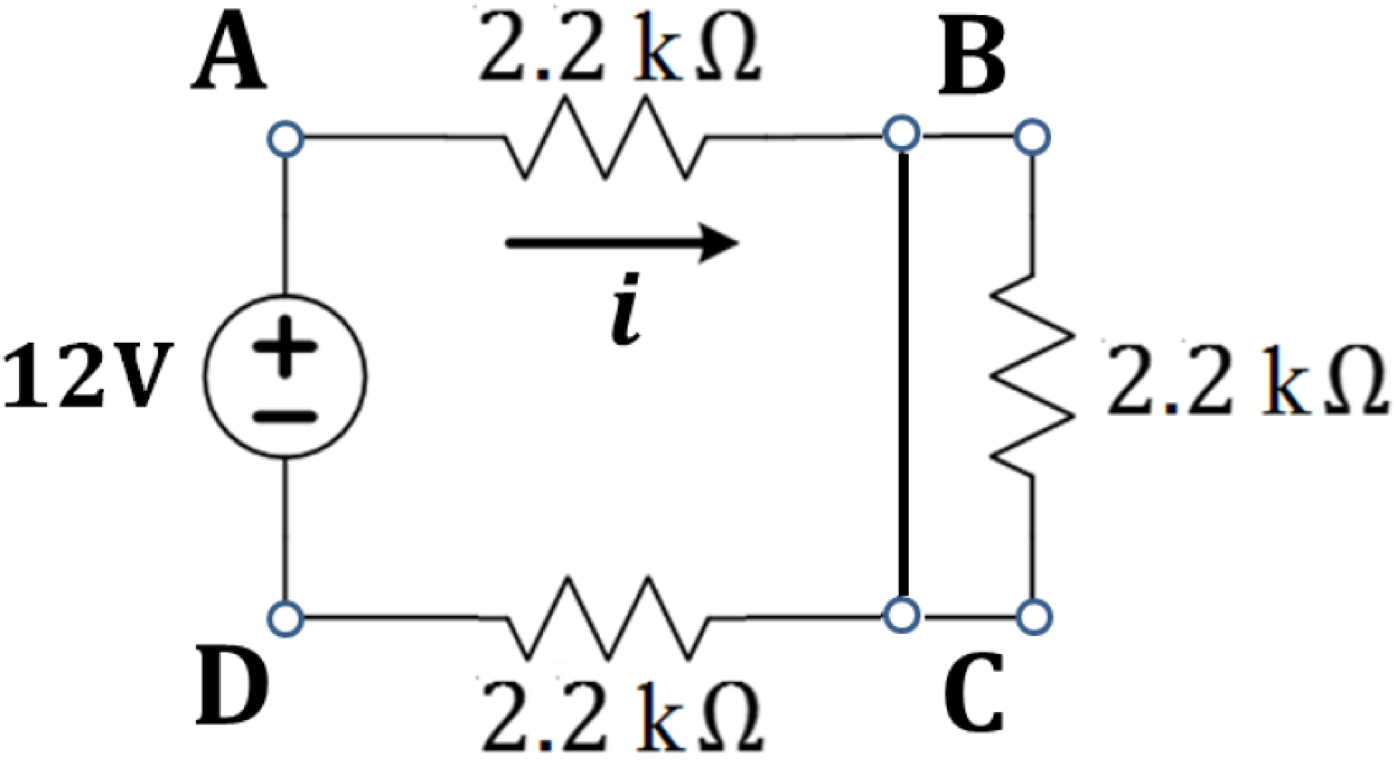




$$\boxed{i = 12/6{,}600 = 0.00\overline{18}\ \mathrm{A} = 1.\overline{81}\mathrm{mA}}$$

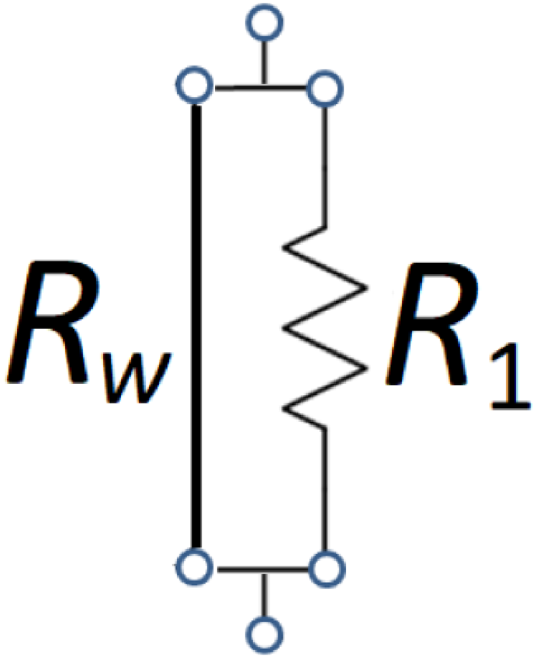
# Example 3

If you “short-circuit” a resistor with a zero-resistance wire



$$\boxed{i = 12/4{,}400 = 0.00\overline{27}\ \text{A} = 2.\overline{72}\text{mA}}$$

## Parallel between an ideal wire and a resistor



$$\boxed{R_{eq} = \left[\frac{1}{R_w} + \frac{1}{R_1}\right]^{-1}}$$

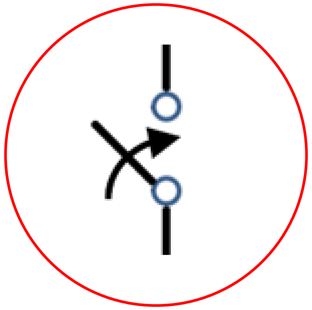
$$R_{eq} = \left[\frac{1}{0} + \frac{1}{R_1}\right]^{-1}$$

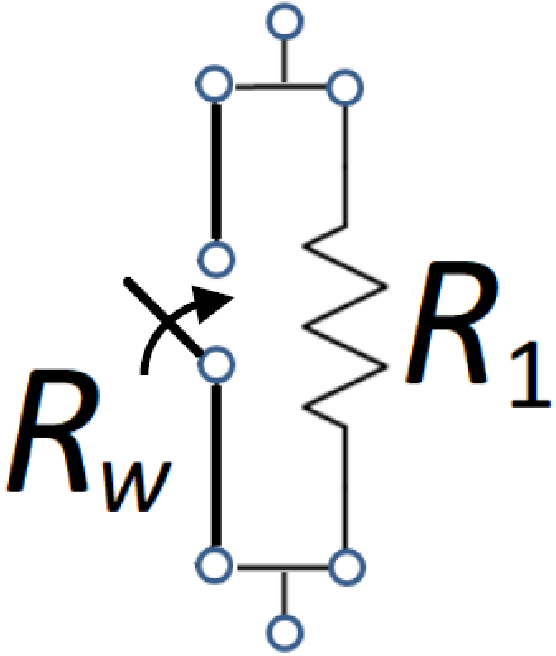
$$R_{eq} = \left[\infty + \frac{1}{R_1}\right]^{-1} = [\infty]^{-1} = 0$$

Current only flows in the wire regardless of $R_1$

# Parallel between an ideal wire and a resistor

Symbol for a switch



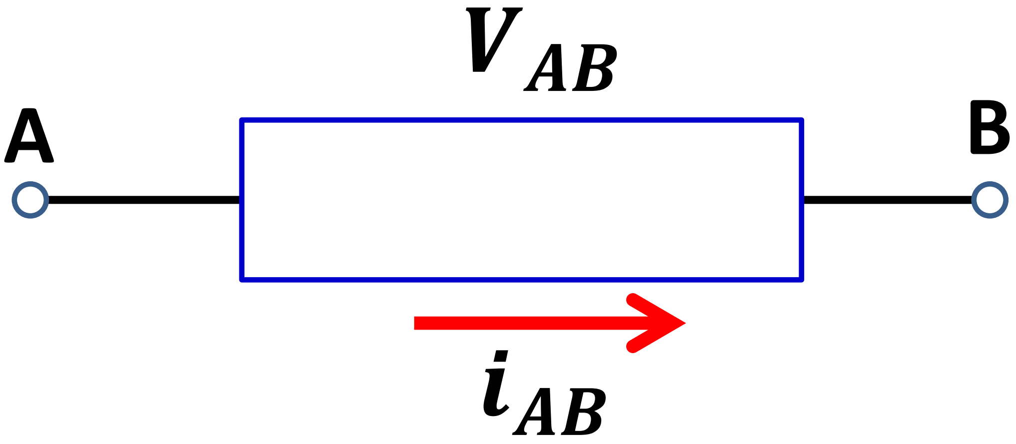


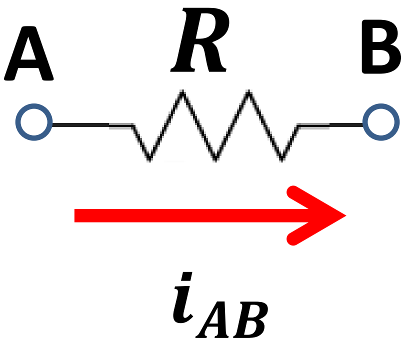
You can add a switch to turn on or off the effect of the shorting wire

# Power

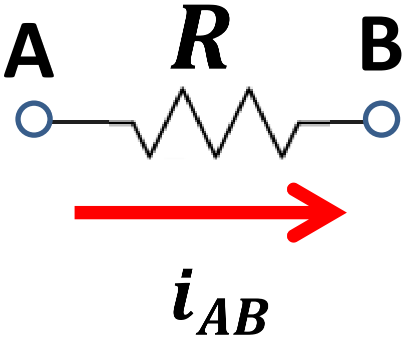
**As discussed earlier, the power dissipated by an electrical element is given by**

$$\boxed{P = V_{AB} \times i_{AB}}$$





# Power



The voltage $V_{AB}$ across a resistor is

$$\boxed{V_{AB} = i_{AB} \times R}$$

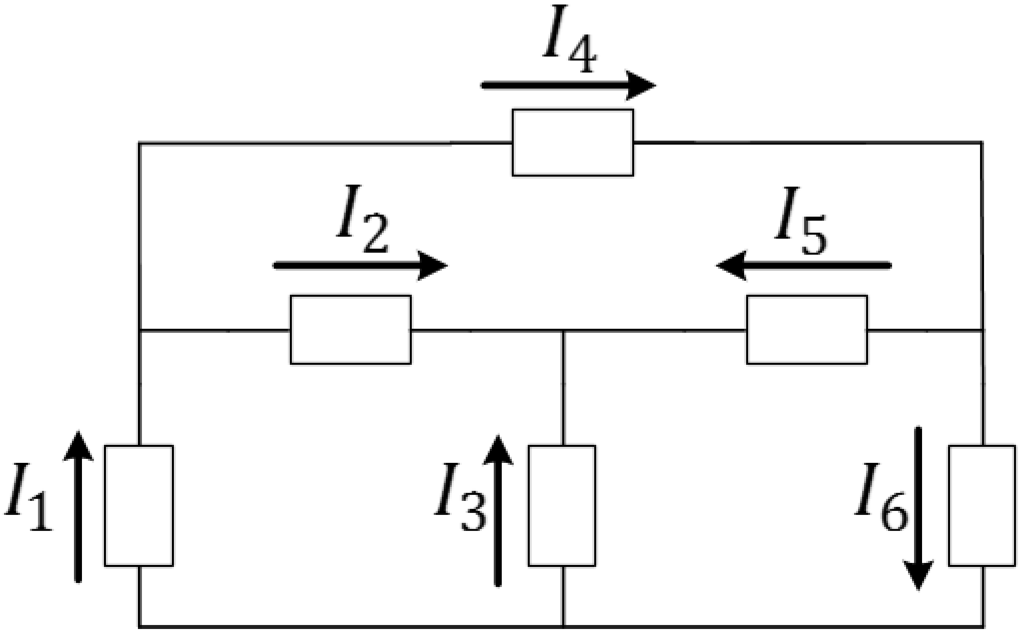
which gives the power

$$\boxed{P = V_{AB} \times i_{AB} = i_{AB} \times R \times i_{AB}}$$

$$\boxed{P = i_{AB}^2 R}$$ or $$\boxed{P = \frac{V_{AB}^2}{R}}$$ [Watts]

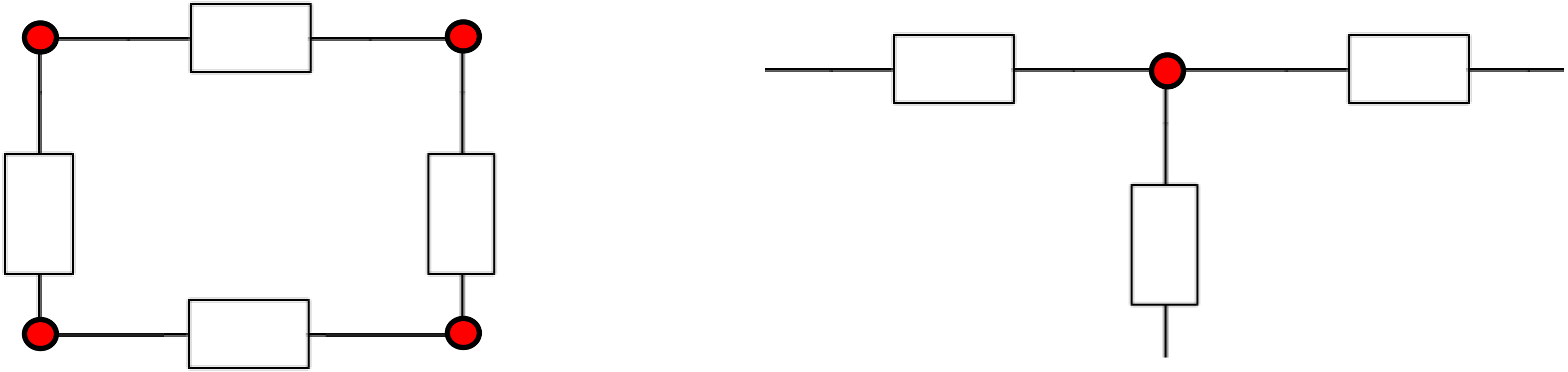
# Electrical Circuit

An electrical circuit is a network of electrical elements interconnected in a closed path such that currents can continuously flow. Example:



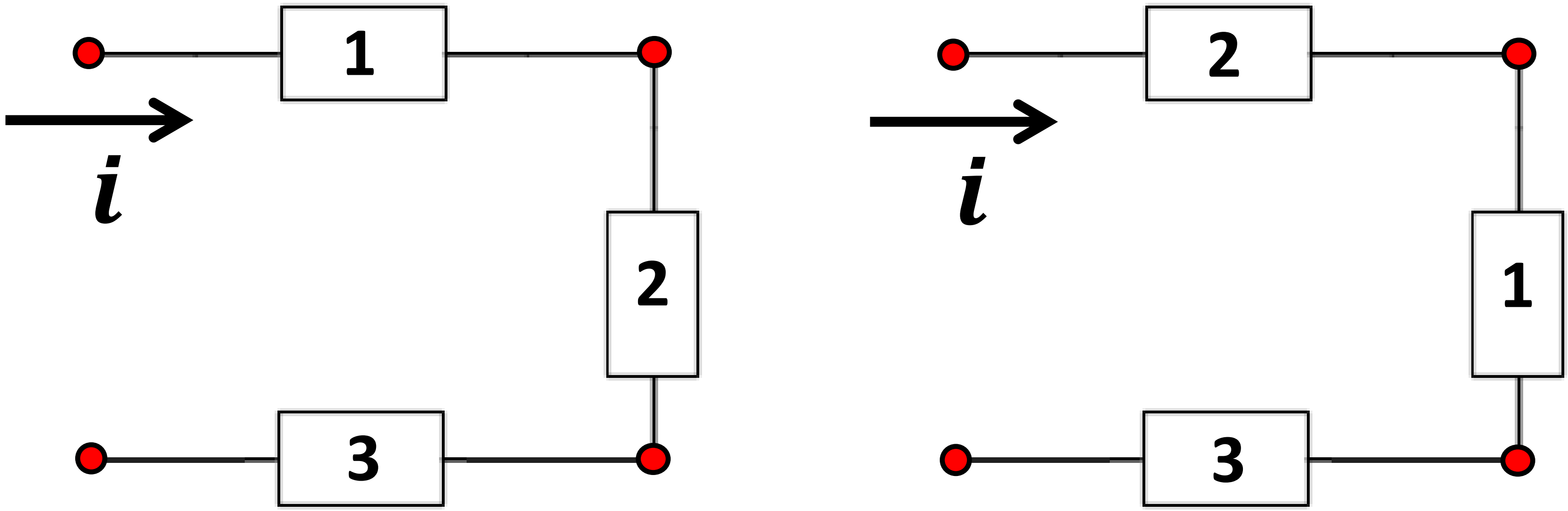
# Circuit Node

Node is a point at which two or more elements are connected. Examples:



# Series connected elements

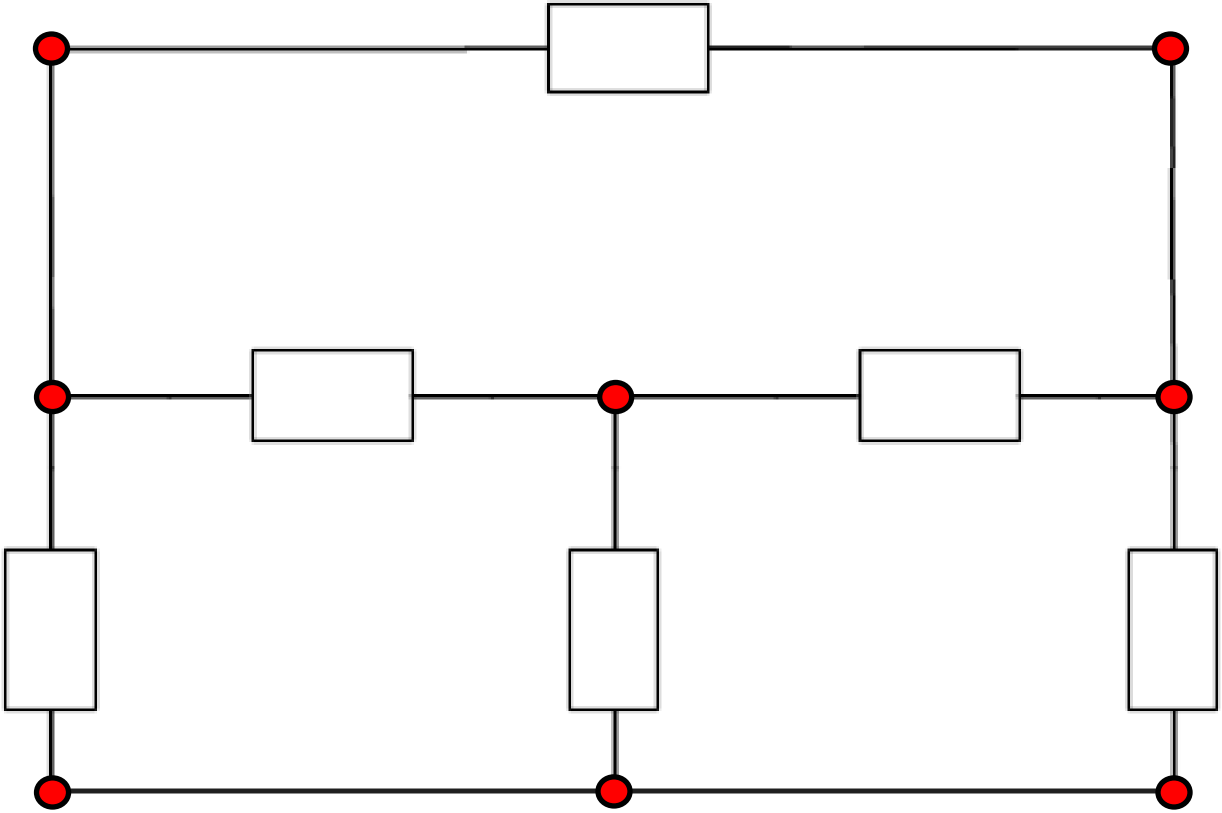
Elements are said to be connected in series if: 1) they share only one common node with other elements in the series and 2) they all carry the same current.



**It does not matter if the order of series elements is changed, the current flowing is the same (commutative property).**

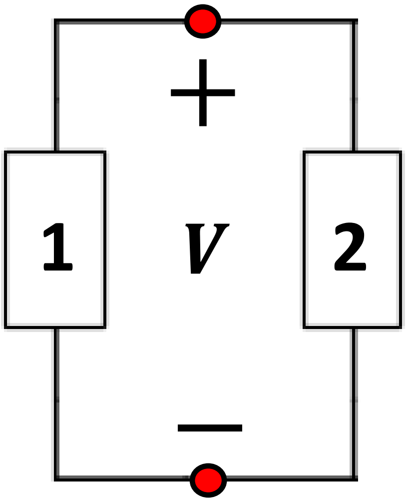
# Question

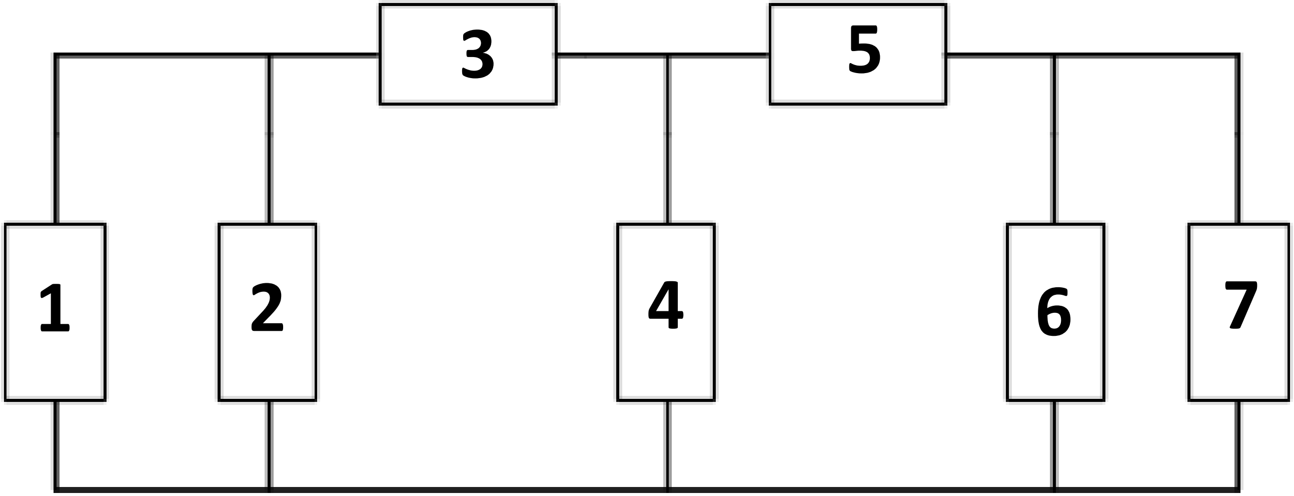
Which elements in the circuit below are in series?



# Parallel connected elements

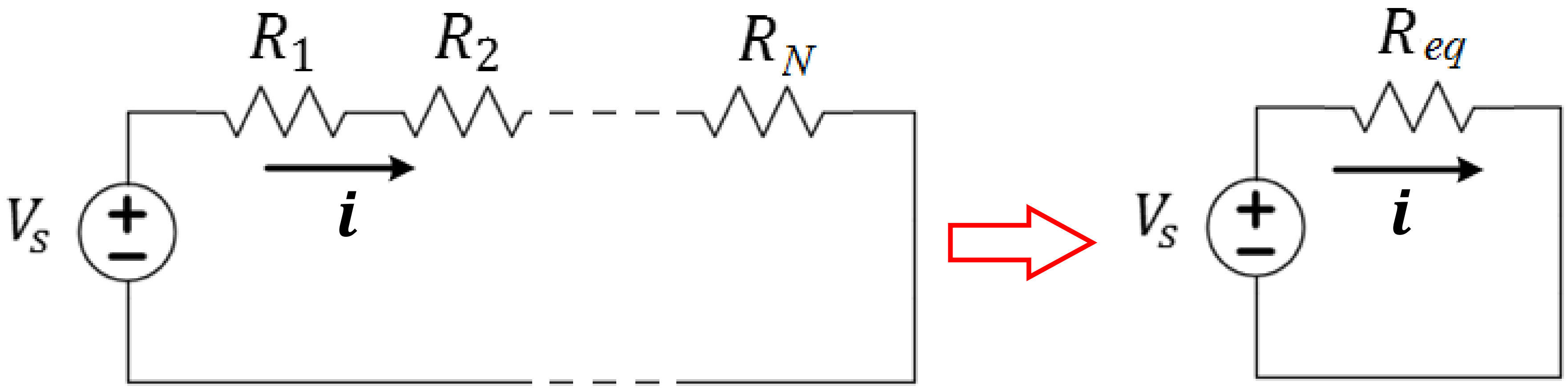
Elements are said to be connected in parallel if: 1) they all share both terminal nodes and 2) they have the same voltage across them.





**Which elements in the circuits above are connected in parallel?**

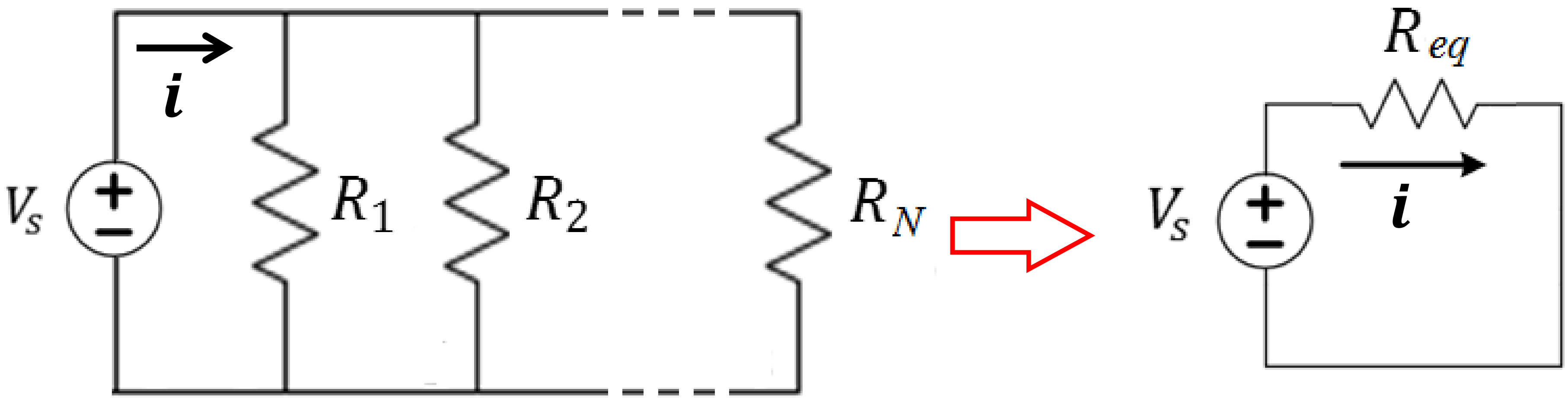
# Series connected resistors



***N*** **resistors connected in series can be replaced by an equivalent resistor** $\boldsymbol{R_{eq}}$

$$R_{eq} = R_1 + R_2 + \cdots + R_N = \sum_{k=1}^{N} R_k$$

# Parallel connected resistors

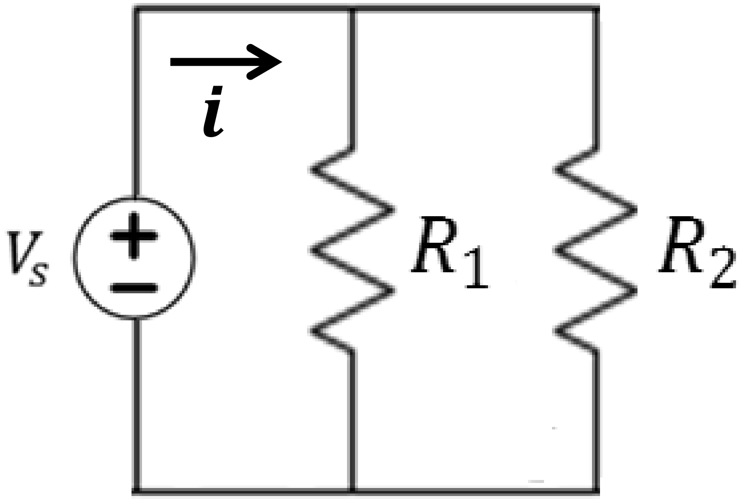


$N$ resistors connected in series can be replaced by an equivalent resistor $R_{eq}$ given by

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_N} = \sum_{k=1}^{N} \frac{1}{R_k}$$

# Special case: Two parallel resistors

$$R_{eq} = \left(\frac{1}{R_1} + \frac{1}{R_2}\right)^{-1} = \frac{R_1 R_2}{R_1 + R_2}$$



**If the resistors are identical**

$$\boldsymbol{R_1 = R_2 = R}$$

$$R_{eq} = \frac{RR}{R+R} = \frac{R}{2}$$

# Corollary: *N* identical parallel resistors

**$N$ identical resistors in parallel have an equivalent resistance**

$$R_{eq} = \frac{R}{N}$$