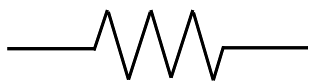
ECE 101 Exploring Electrical Engineering

- ***Circuits 2***
- Resistor
- Series and parallel connection of resistors
- Voltage Dividers
- Voltage & Current Sources

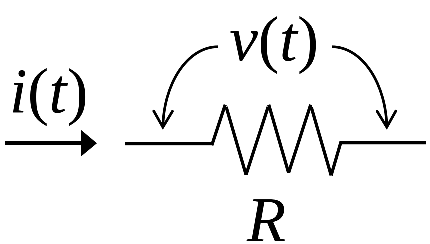
Many of the slides are modified from course notes by P.K. Wong and M. Holtzman

Resistor

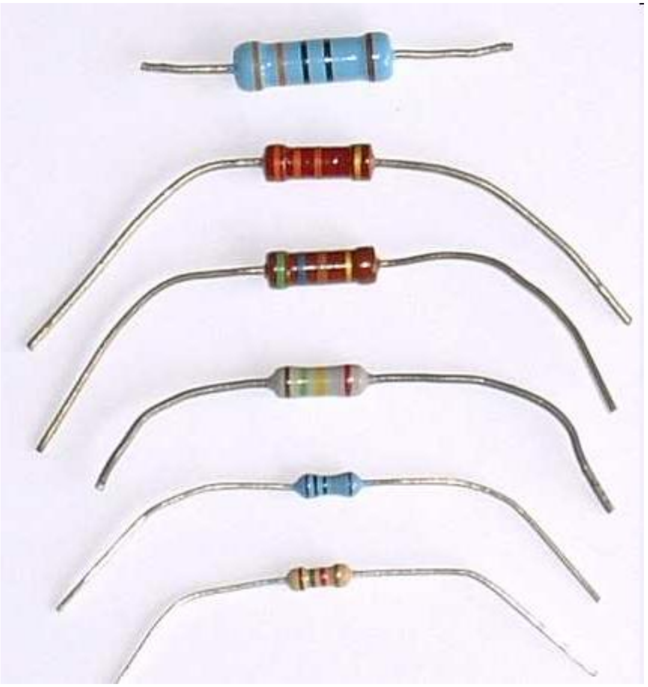
- A *resistor* is a passive electronic component that obeys Ohm's Law. It has resistance R.

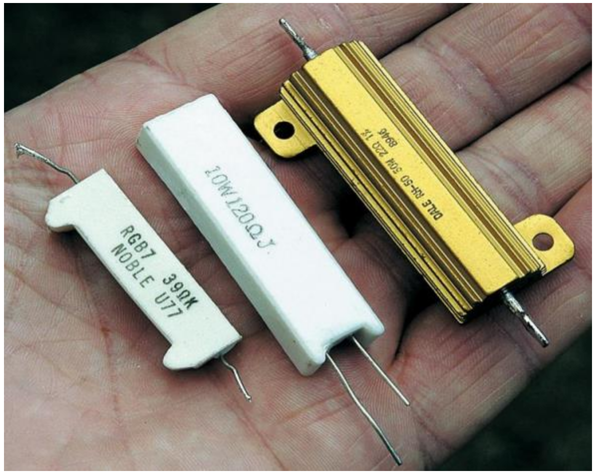
- SI Unit: ohm (Ω)
- Symbol: 

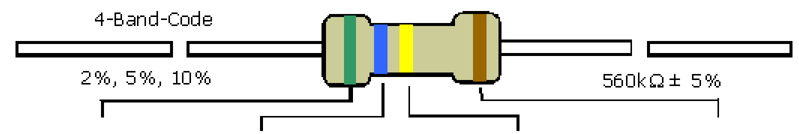
- I-V relationship: $v(t) = R\,i(t)$



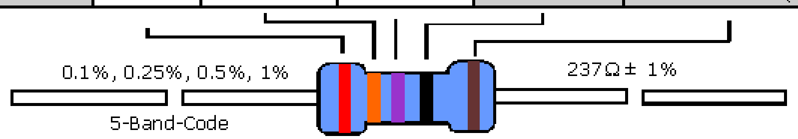
$$i(t) = \frac{1}{R} v(t)$$

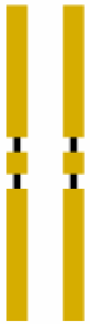






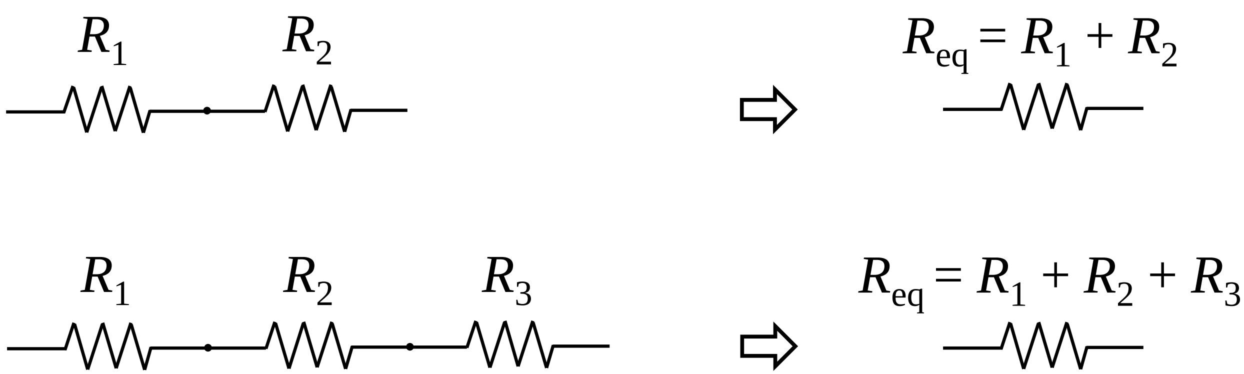
COLOR	1st BAND	2nd BAND	3rd BAND	MULTIPLIER	TOLERANCE
Black	0	0	0	1Ω	
Brown	1	1	1	10Ω	± 1% (F)
Red	2	2	2	100Ω	± 2% (G)
Orange	3	3	3	1KΩ	
Yellow	4	4	4	10KΩ	
Green	5	5	5	100KΩ	±0.5% (D)
Blue	6	6	6	1MΩ	±0.25% (C)
Violet	7	7	7	10MΩ	±0.10% (B)
Grey	8	8	8		±0.05%
White	9	9	9		
Gold				0.1	± 5% (J)
Silver				0.01	± 10% (K)





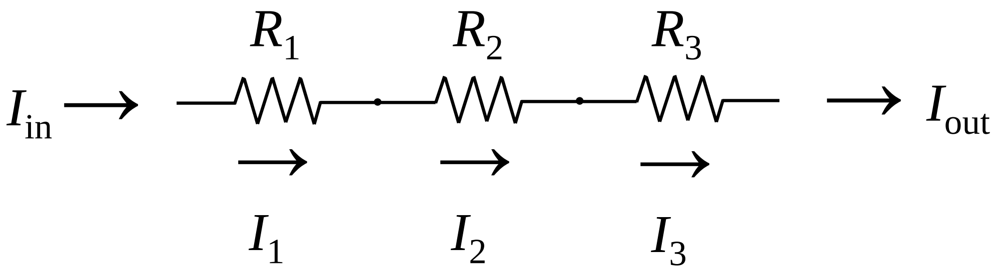
Resistors Connected in Series (end-to-end)

- If N resistors are connected in series, with the i-th resistor having a resistance R_i , then the equivalent resistance R_{eq} is:



$$R_{\text{eq}} = \sum_{i=1}^{N} R_i$$

Properties of Series Resistances (DC):

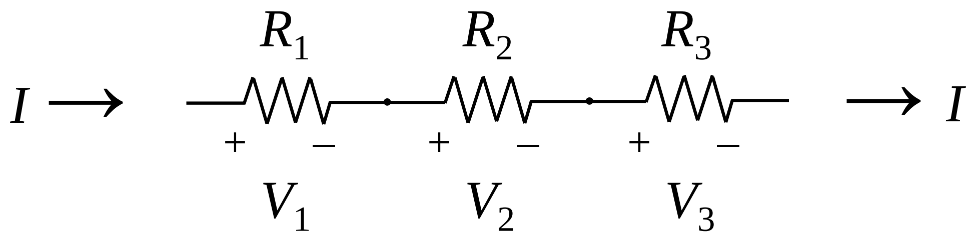


- The amount of current I_{in} entering one end of a series circuit is equal to the amount of current I_{out} leaving the other end.

- The current is the same through each resistor in the series and is equal to I_{in}.

$$\boldsymbol{I_{in} = I_{out} = I_1 = I_2 = I_3}$$

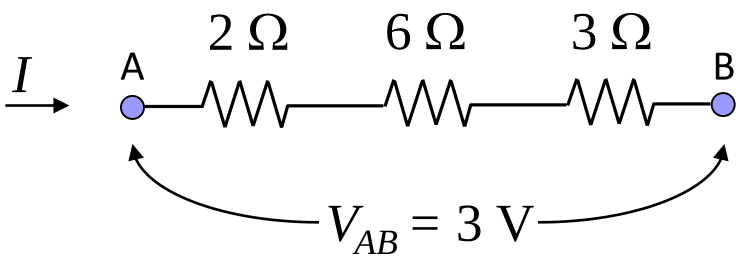
- The amount of voltage drop across each resistor in a series circuit is given by Ohm's Law.



$$V_1 = IR_1 \;,\; V_2 = IR_2 \;,\; V_3 = IR_3$$

- By convention, the resistor terminal that the current enters is labeled "+", and the terminal the current exits is labeled "–".
- **KVL**: total voltage drop = sum of individual drops (watch out for sign!)

Example:



a) Calculate the current I that flows through the resistors.
b) Find the voltage drop across the 6 Ω resistor.

Solution:

a) Approach – Use Ohm's law: $I = \dfrac{V_{AB}}{R_{eq}}$

Calculate the equivalent resistance: $R_{\text{eq}} = (2+6+3)\,\Omega = 11\,\Omega$

Calculate the current: $I = \dfrac{3\text{ V}}{11\,\Omega} \approx \underline{\underline{0.273\text{ A}}}$

b) Use Ohm's law again: $V_6 = IR_6 = (0.273\text{ A})(6\,\Omega) \approx \underline{\underline{1.64\text{ V}}}$

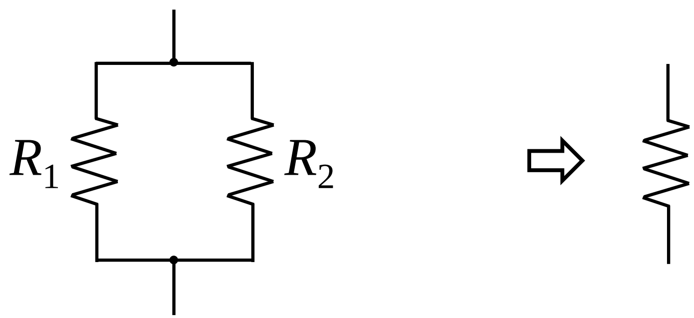
Example:

- 100 V Source, 5 and 20 ohm resistors in series; find R_s, I, P, V_1, V_2
- 100 V Source, 5 and 20 ohm resistors in parallel; find R_p, I, P, I_1, I_2

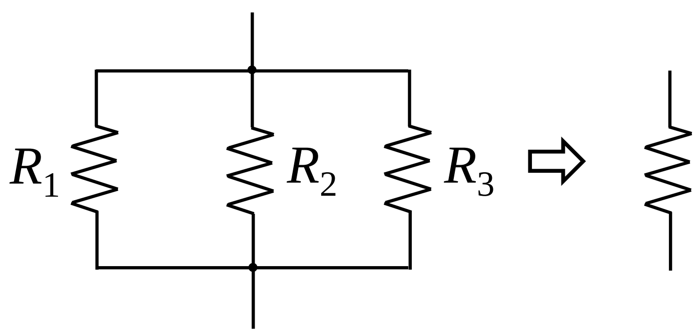
Resistors Connected in Parallel (side-by-side)

- If N resistors are in parallel, with the i-th resistor having a resistance R_i , then the equivalent resistance is:

$$R_{\text{eq}} = \left(\sum_{i=1}^{N} \frac{1}{R_i} \right)^{-1}$$

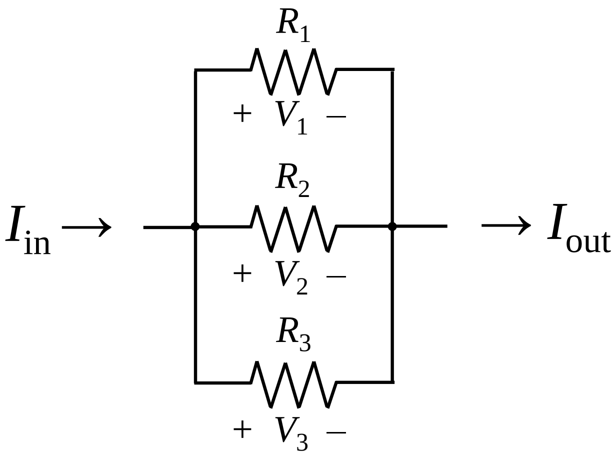


$$R_{\text{eq}} = \left(\frac{1}{R_1} + \frac{1}{R_2} \right)^{-1} = \frac{R_1 R_2}{R_1 + R_2}$$



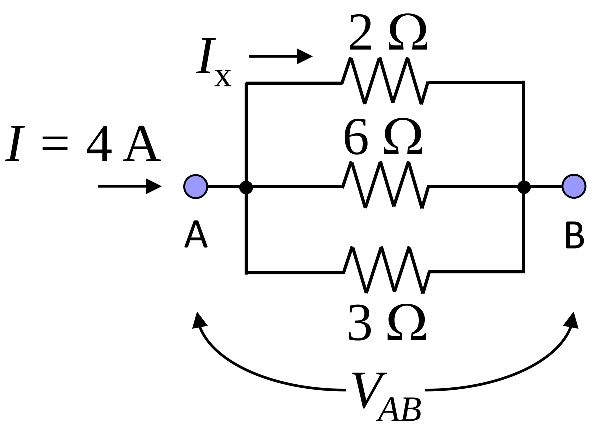
$$R_{\text{eq}} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \right)^{-1}$$

Properties of Parallel Resistances (DC):



- The amount of current I_{in} entering one end of a parallel circuit is equal to the amount of current I_{out} leaving the other end: $\boldsymbol{I_{in} = I_{out}}$
- For parallel resistors, the voltage drop across each resistor is the same: $\boldsymbol{V_1 = V_2 = V_3}$
- KCL: Σ (sum) of currents entering a node = Σ (sum) of currents leaving a node

Example:



a) Find the current I_x through the 2 Ω resistor.
b) What is the power dissipated by the 3 Ω resistor?

Assume 3 significant figures.

Solution:

a) Approach – Use Ohm's law: $V_{AB} = IR_{eq}$

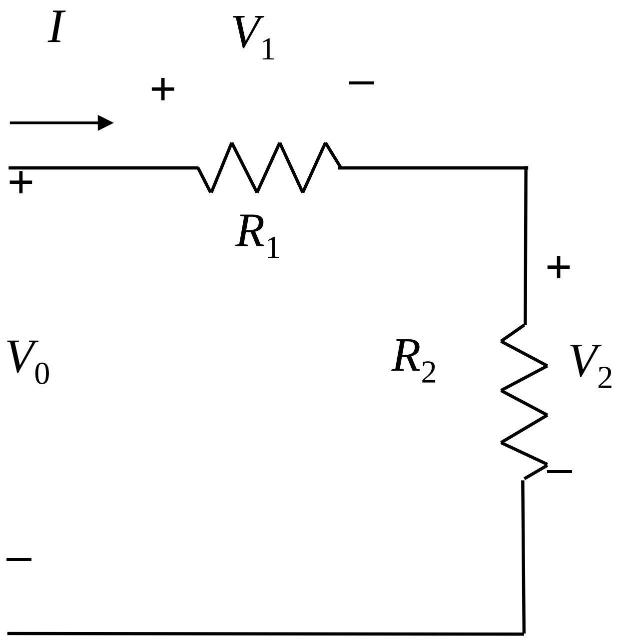
Calculate the equivalent resistance: $R_{eq} = \left(\frac{1}{2} + \frac{1}{6} + \frac{1}{3}\right)^{-1} \Omega = 1\,\Omega$

Calculate the voltage drop: $V_{AB} = (4\text{ A})(1\,\Omega) = 4\text{ V}$

Find the current: $I_x = \frac{V_{AB}}{2\,\Omega} = \underline{\underline{2.00\text{ A}}}$

b) Use power equation: $P = \frac{V_{AB}^2}{3\,\Omega} \approx \underline{\underline{5.33\text{ W}}}$

Voltage Divider

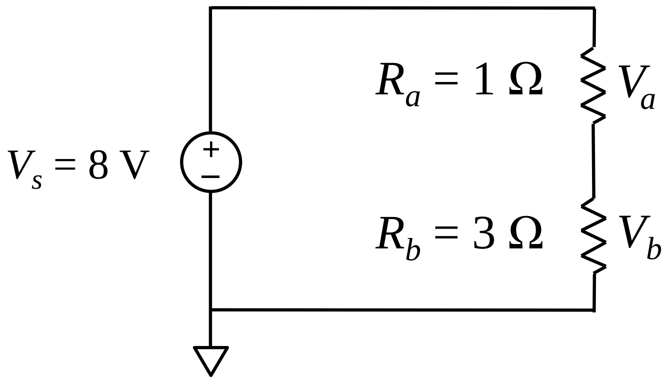


Voltage Divider

$$V_1 = \frac{R_1}{R_1 + R_2} V_0$$

$$V_2 = \frac{R_2}{R_1 + R_2} V_0$$

Example:



What is the voltage drop across R_a?

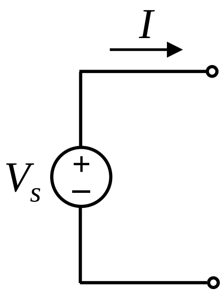
$$V_a = \frac{R_a}{R_a + R_b} V_S \qquad V_a = \frac{1\,\Omega}{1\,\Omega + 3\,\Omega}\left(8\text{ V}\right) = 2\text{ V}$$

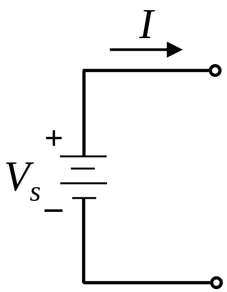
What is the voltage drop across R_b?

$$V_b = \frac{R_b}{R_a + R_b} V_S \qquad V_a = \frac{3\,\Omega}{1\,\Omega + 3\,\Omega}\left(8\text{ V}\right) = 6\text{ V}$$

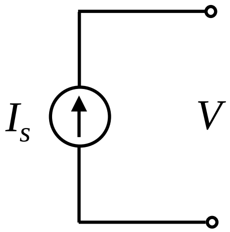
DC Voltage & Current Sources

- An ideal DC voltage source outputs a constant voltage regardless of the amount of current through it.





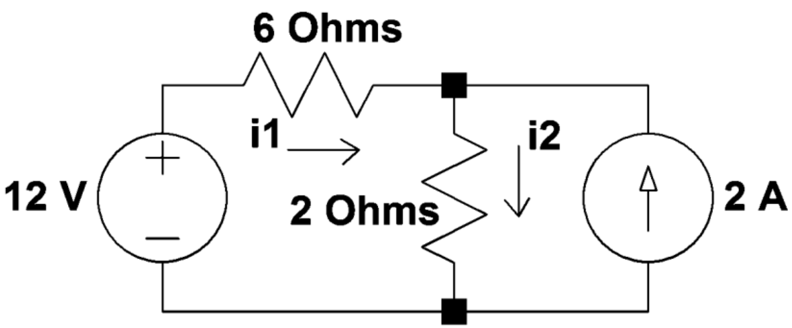
- An ideal DC current source outputs a constant current regardless of the amount of voltage across it.



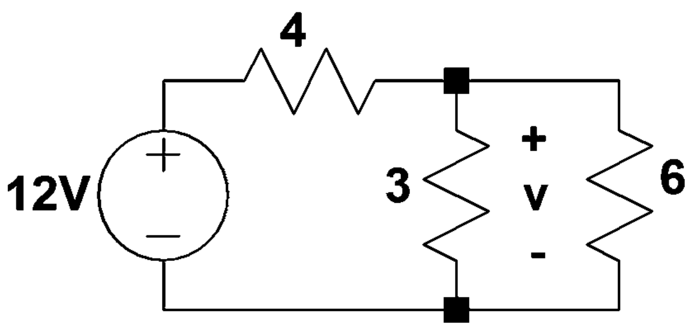
Prefixes – common engineering style

- 10^{-9} nano n
- 10^{-6} micro m
- 10^{-3} milli m
- 10^{3} kilo k
- 10^{6} mega M
- 10^{9} giga G

More circuit examples



Find currents i_1 and i_2



Find voltage v

Further questions:

1. Find the power in each resistor in the series and parallel examples.
2. Are household appliances connected in series or parallel? Why?