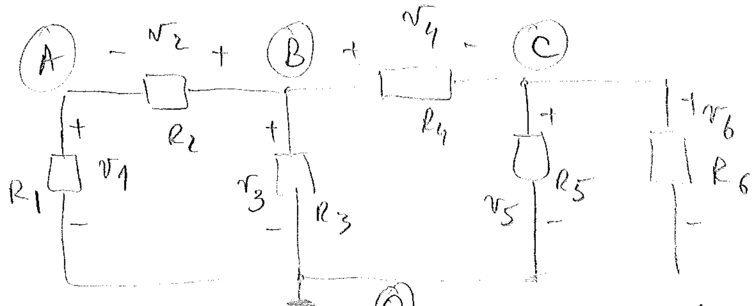
Kirchhoff's Voltage Law (KVL)

- At any instant the sum of voltage rises around a loop must equal the sum of voltage drops around that loop:
- In other words: the algebraic sum of voltages around a loop is zero:

(1) $\sum v_{RISE} = \sum v_{DROP}$ or (2) $\sum_{\ell} v_{\ell} = 0$

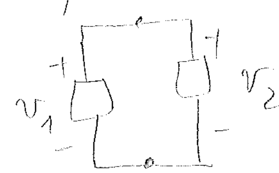


- Let's traverse (walk) the loops in clockwise direction:

Loop $R_1 R_2 R_3$: $v_1 + v_2 = v_3$

Loop $R_3 R_4 R_5$: $v_3 = v_4 + v_5$

Loop $R_5 R_6$: $v_5 = v_6$ ← you already knew this:

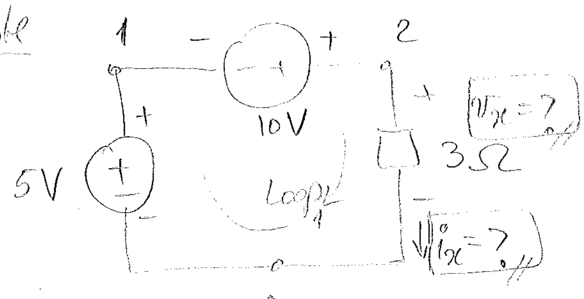


Loop $R_1 R_2 R_4 R_5$: $v_1 + v_2 = v_4 + v_5$

Loop $R_1 R_2 R_4 R_6$: $v_1 + v_2 = v_4 + v_6$

Loop $R_3 R_4 R_6$: $v_3 = v_4 + v_6$

Example

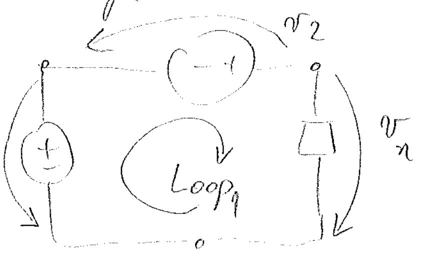


Loop1 KVL: $5V + 10V = v_x \Leftrightarrow v_x = 15V$

Ohm's law: $i_x = \frac{v_x}{3\Omega} = \frac{15V}{3\Omega} = 5A$

$i_x = 5A$

Note: Using voltages marked with arcs:

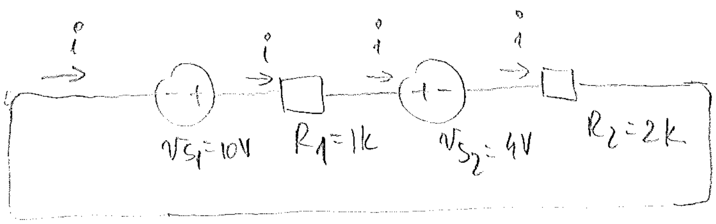


$v_1 + v_2 = v_x$

$-v_1 - v_2 + v_x = 0$

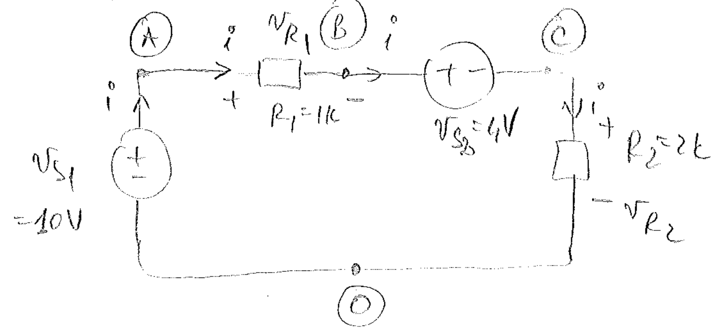
Simple-loop circuit

- The concept of <u>series connection</u> of circuit elements.



(!) The current thru each element is the same in a series of individual elements.

- You must agree that this is the same as:



a) $i = ?$

Use KVL and Ohm's law:

$$v_{S_1} = v_{R_1} + v_{S_2} + v_{R_2}$$

$$v_{S_1} = i \cdot R_1 + v_{S_2} + i R_2$$

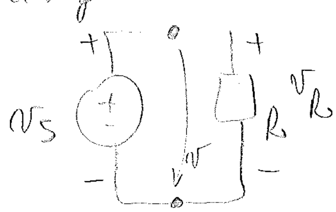
$$v_{S_1} = i(R_1 + R_2) + v_{S_2} \Rightarrow \boxed{i = \frac{v_{S_1} - v_{S_2}}{R_1 + R_2}} = \frac{(10-4)\,V}{3k\Omega} = \frac{6V}{3k\Omega} = 2\,mA.$$

b) Power consumed by R_2, $P_{R_2} = ?$

$$P_{R_2} = v_{R_2} \cdot i = (R_2 \cdot i) \cdot i = R_2\, i^2 \text{ : absorbed!}$$

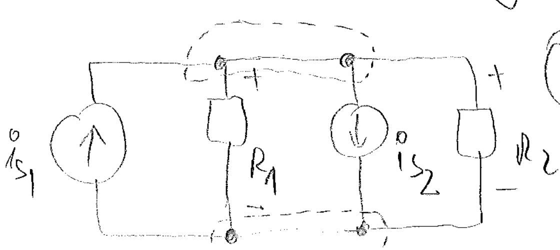
what is power consumed by v_{S_1}?

- In the particular case of only 2 circuits elements we get for example:



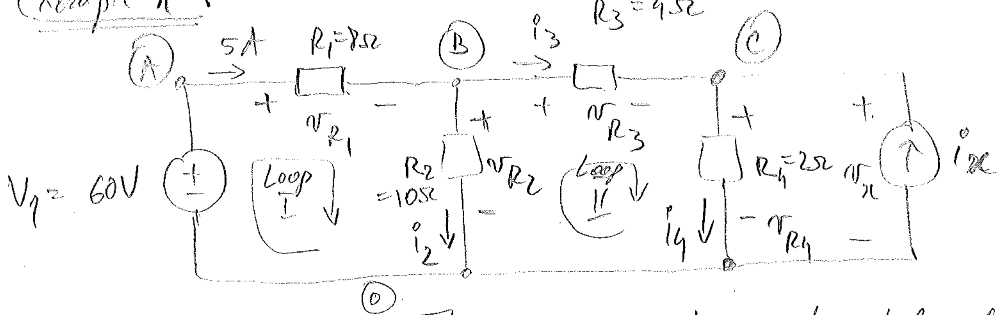
$v_S = v_R = v.$

This can be generalized to connecting any number of elements between this single-pair of nodes:



(!) The voltage across all elements is the same!

Example 1 :



The approach is to contemplate for a little the circuit!

$v_x = ?$

$v_{R_4} = v_x$.

But we do not know v_{R_4} yet.

- We note that in the left side we have $V_1 = 60V$.
- Also: $v_{R_1} = R_1 \cdot 5A = 8\Omega \cdot 5A = 40V$
- Applying KVL for loop I: $V_1 = v_{R_1} + v_{R_2}$

$$60V = 40V + v_{R_2} \Rightarrow v_{R_2} = 20V$$

- Having v_{R_2}, we could try moving on with KVL for loop II:

$$v_{R_2} = v_{R_3} + v_{R_4} \Rightarrow v_{R_4} = v_{R_2} - v_{R_3} = 20V - v_{R_3}$$

$$\Rightarrow v_{R_4} = 20V - R_3 \cdot i_3$$

- Use KCL for node (B): $5A = i_2 + i_3 \Rightarrow i_3 = 5A - i_2$

$$= 5A - \frac{v_{R_2}}{R_2} = 5A - \frac{20V}{10\Omega} = 3A.$$

$$\Rightarrow v_{R_4} = 20V - 4\Omega \cdot 3A = 8V.$$

$$\boxed{v_x = v_{R_4} = 8V}$$