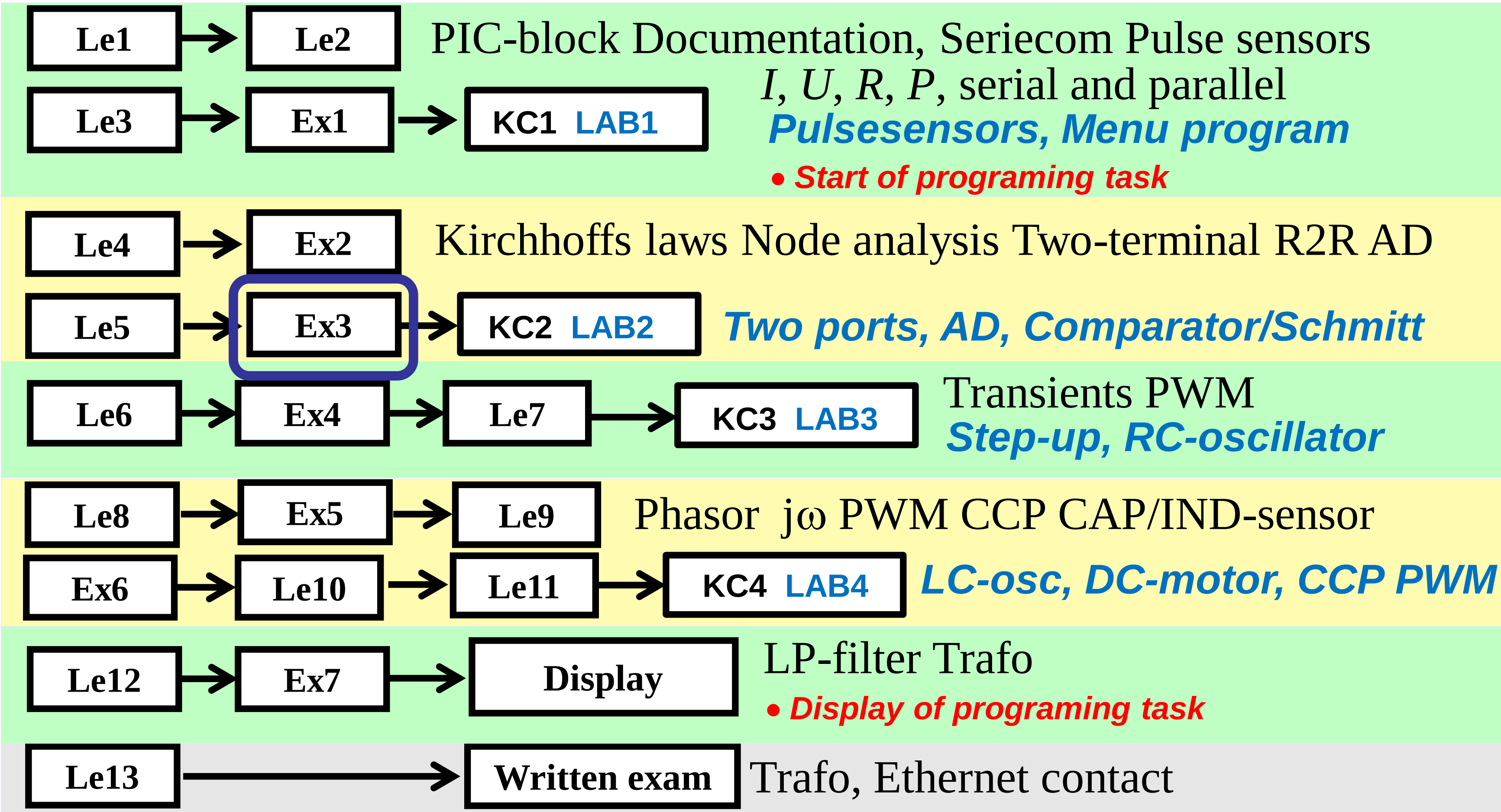
IE1206 Embedded Electronics



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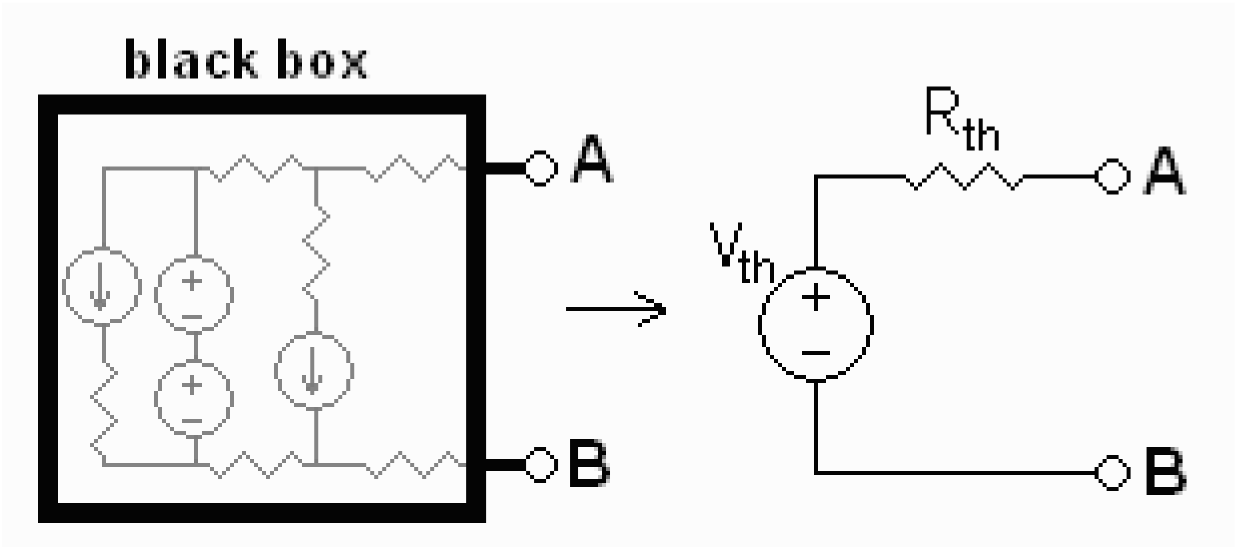
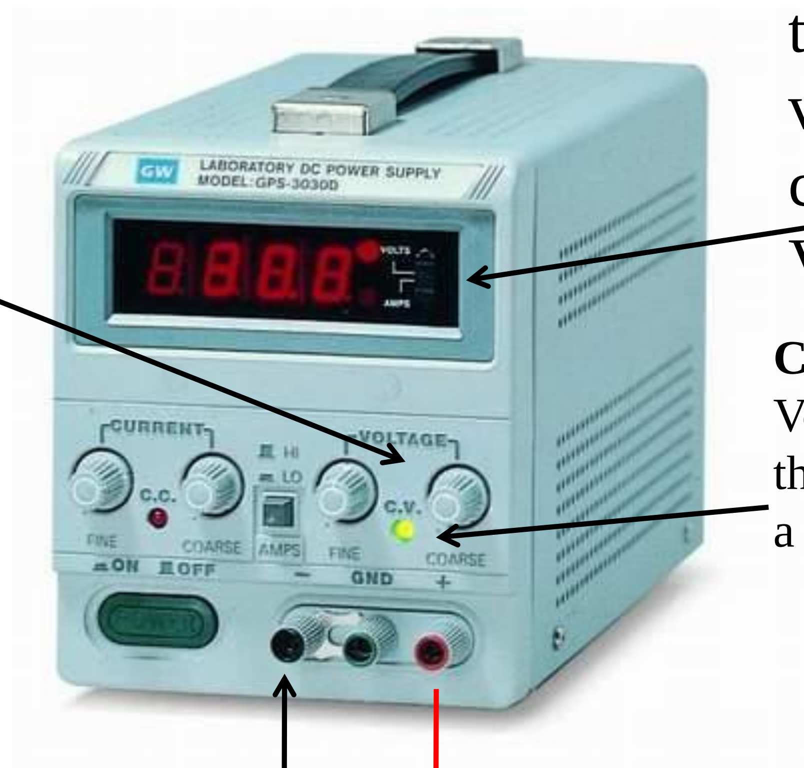
Two terminal circuits – Black box



? **=** **!**

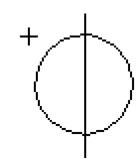
The power supply

VOLTAGE
knob to set the constant voltage. Coarse and fine adjustments.



Buttons to select the display of voltage or current.
Voltage / Amps

C.V. Continuous Voltage. Led indicating that the unit operates as a voltage generator.



+ and – poles

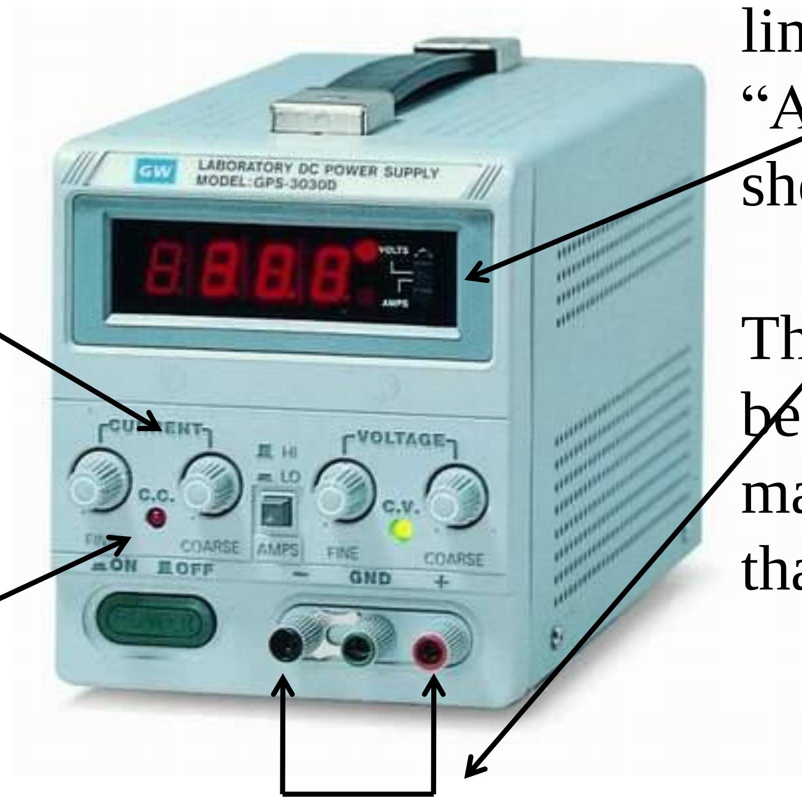
\-

\+

(GND is to connect the metal casing to +/- to suppress interference).

The power supply

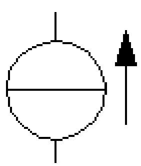
CURRENT knob to set the current limit. Coarse and fine adjustments.



To set the current limit you show “Amps” and then short voltage poles.

The set current then becomes the maximum current that can occur.

C.C. Continuous Current. Led indicating that the unit operates as a current generator.



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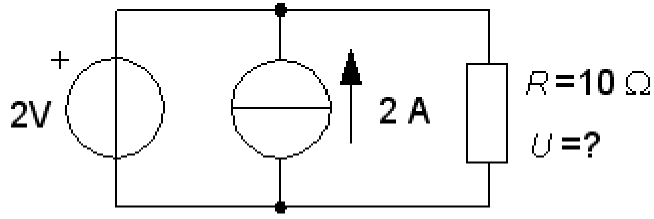
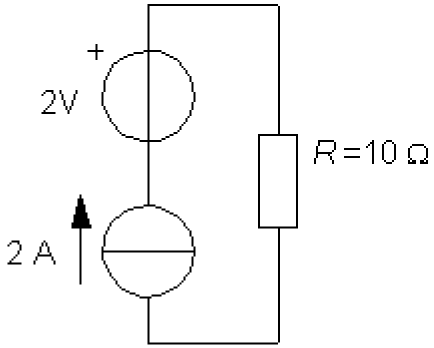
Voltage and Current generator

(Ex. 8.1) What value will the *U* get in these idealized and usually unrealistic circuits?





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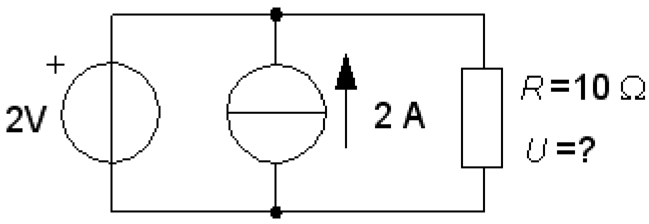

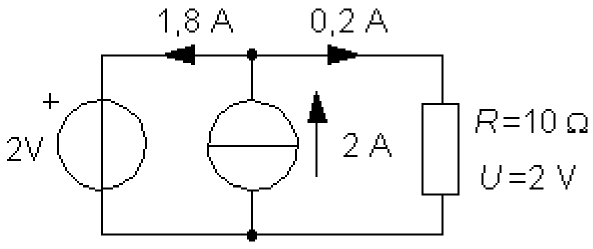

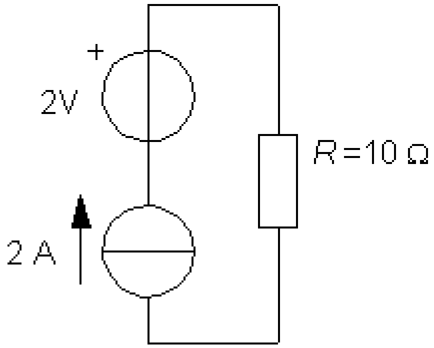

Voltage and Current generator

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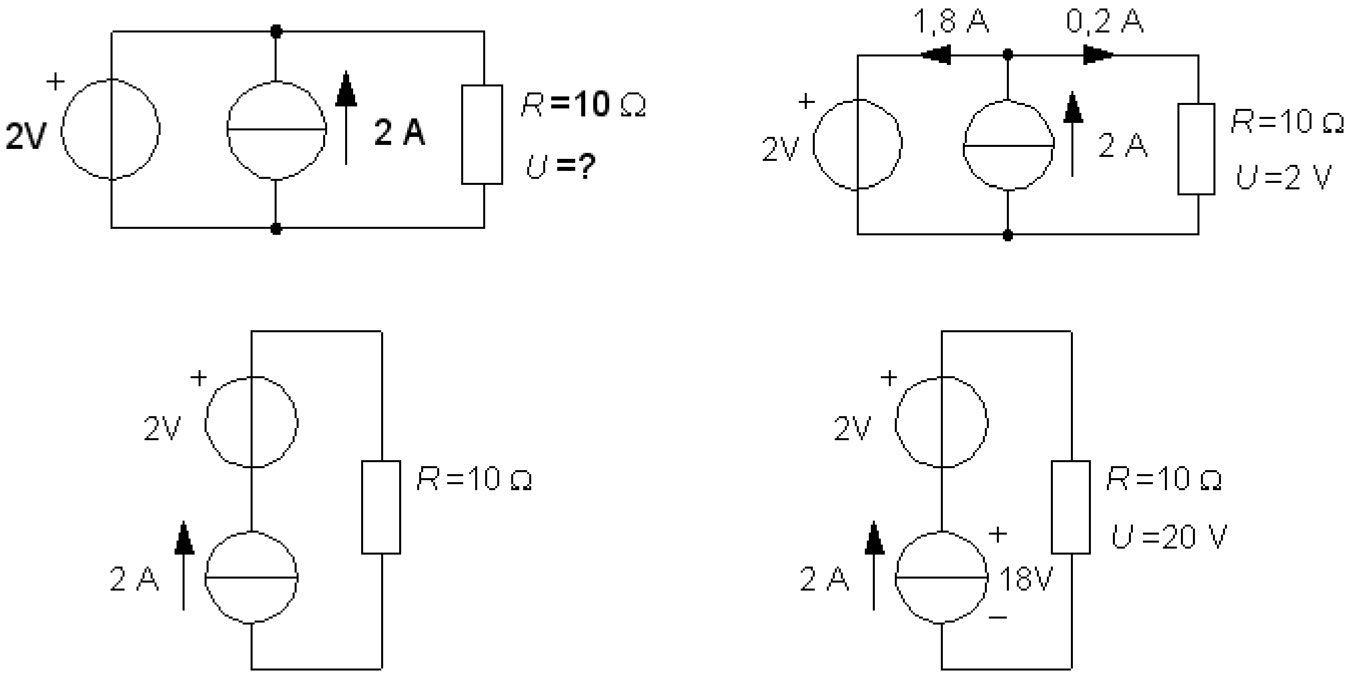

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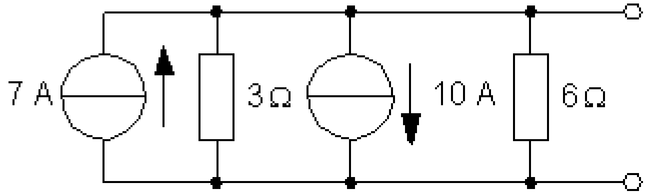
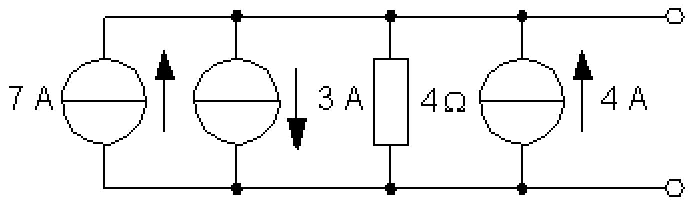
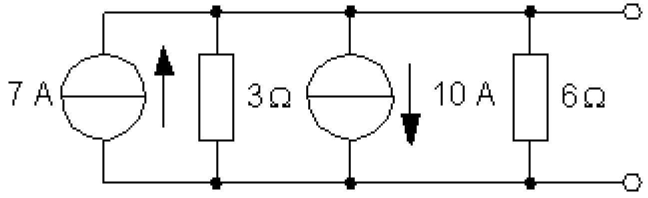
Simplify … (8.2)



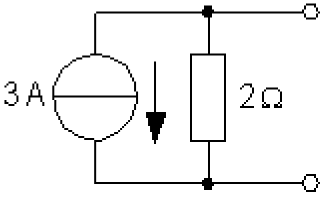


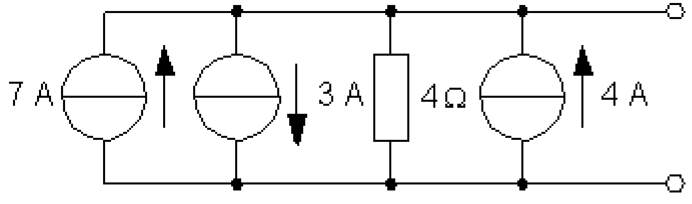
Simplify … (8.2)



$$7-10=-3$$

$$\frac{3\cdot 6}{3+6}=2$$





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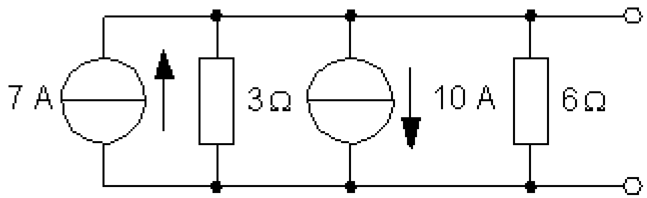

$$7-10=-3$$

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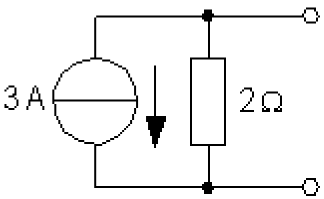

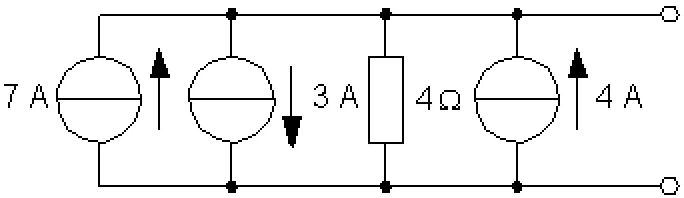

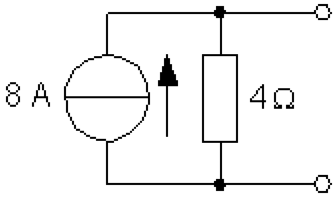

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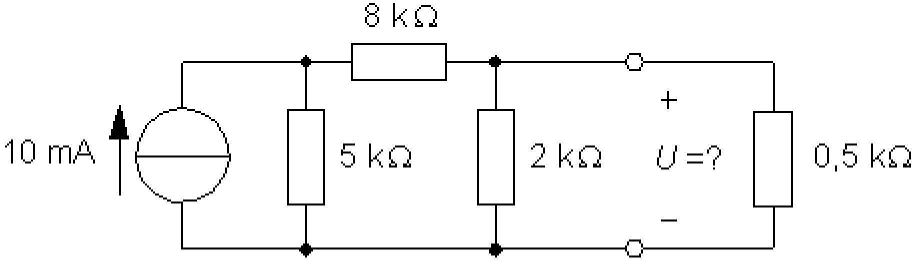
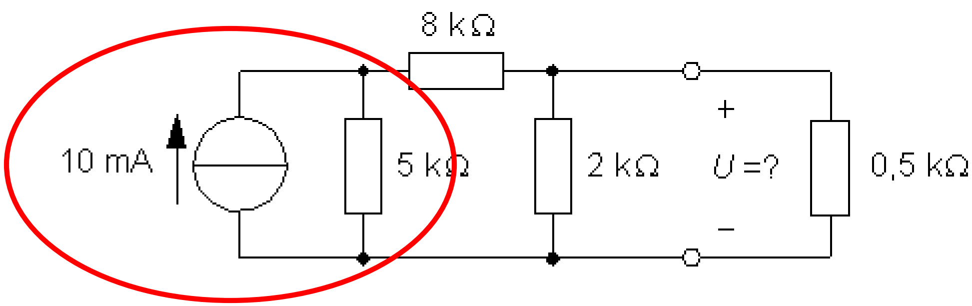
Equivalents step by step …

(8.4) Electronics prefix [V] [kΩ] [mA]

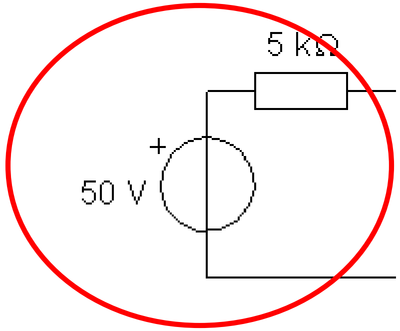


Equivalents step by step …

(8.4) Electronics prefix [V] [kΩ] [mA]



10·5=50



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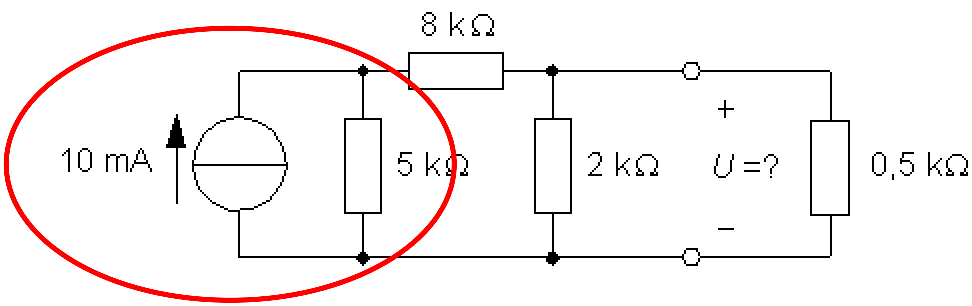

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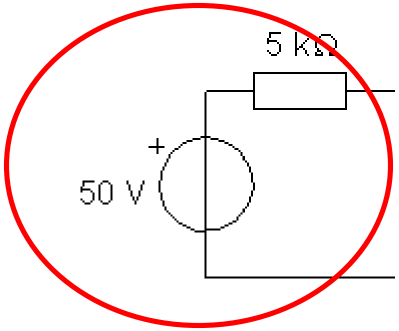
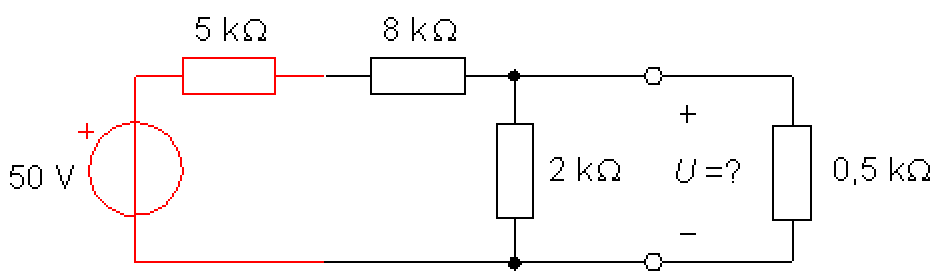
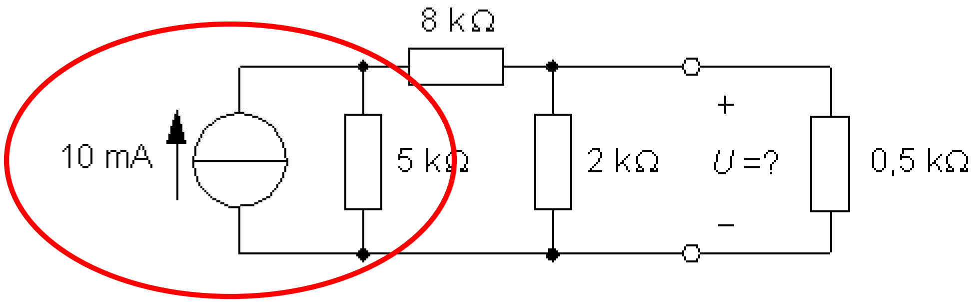


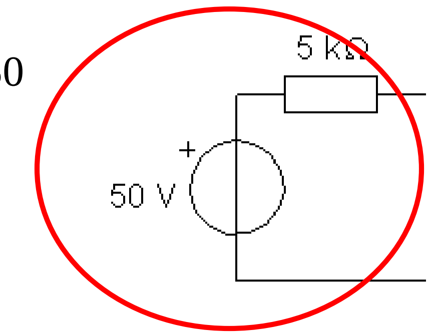


Equivalents step by step …

(8.4) Electronics prefix [V] [kΩ] [mA]

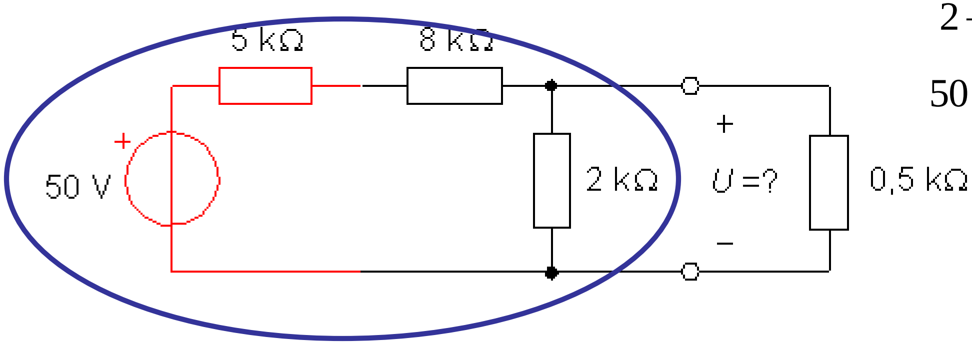


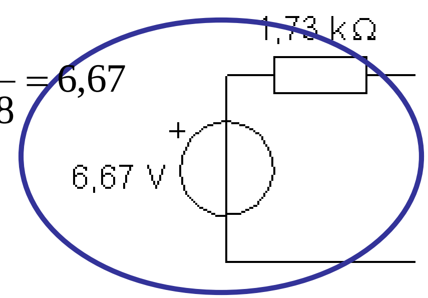
$10 \cdot 5 = 50$



$$\frac{2 \cdot (5+8)}{2+5+8} = 1{,}73$$

$$50 \cdot \frac{2}{2+5+8} = 6{,}67$$





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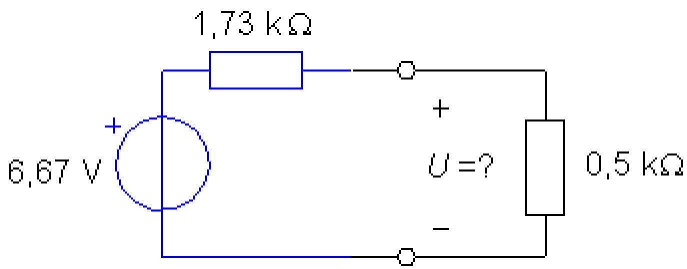
At last …



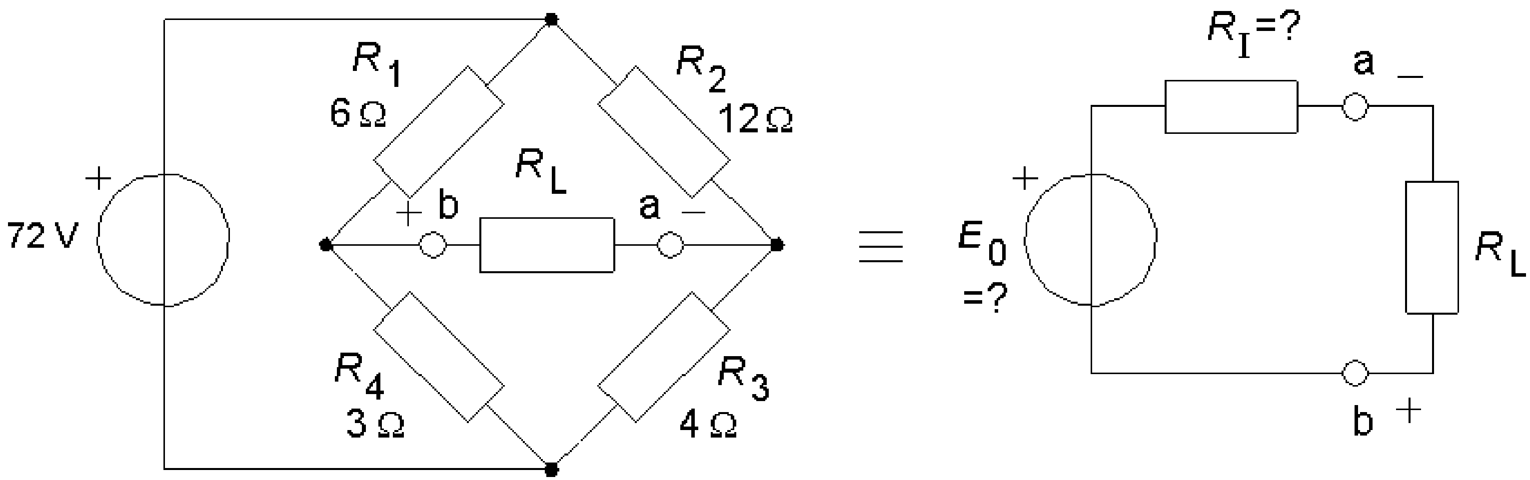
Voltage divider:

$$U = 6{,}67 \cdot \frac{0{,}5}{0{,}5 + 1{,}73} = 1{,}49 \text{ V}$$

- Step by step the circuit gets simpler while the numerical values becomes more complicated!

You will need a calculator. Even with adapted numbers in the exercises you can come to select a computation path that generates unwieldy decimal numbers towards the intended simple answer.

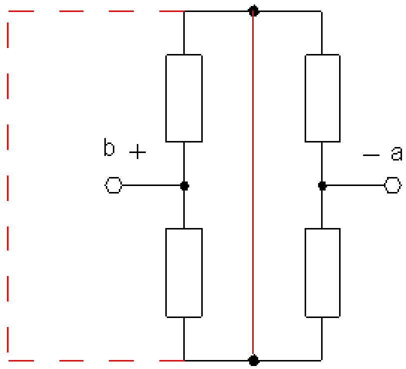
(Wheatstone bridge equivalent)

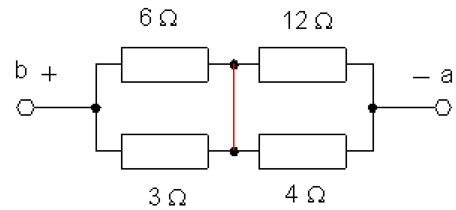


Determine the Wheatstone bridge Thevenin equivalent.

(Determine R_{I})

Voltage turned down to zero





$$R_{\mathrm{I}} = \frac{6 \cdot 3}{6+3} + \frac{12 \cdot 4}{12+4} = 5\,\Omega$$

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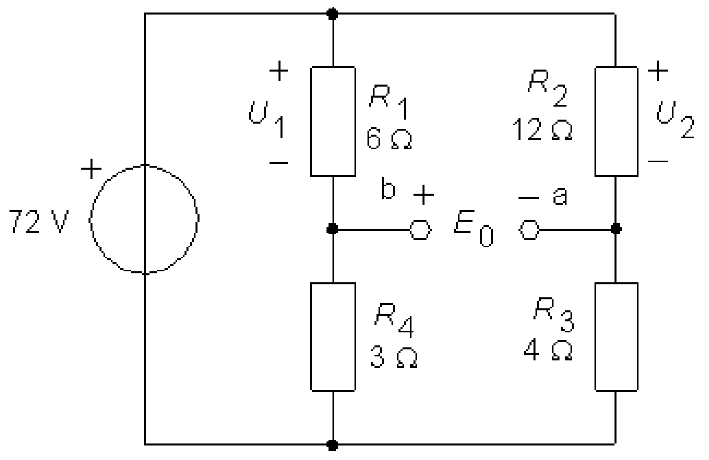
(Determine E_0)

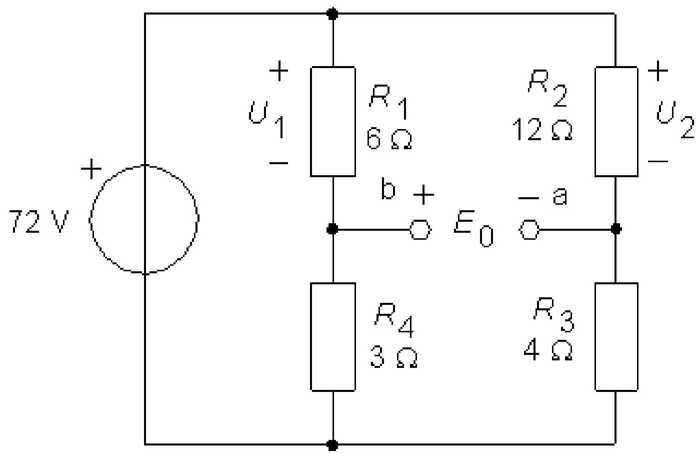


$$U_1 = 72 \cdot \frac{6}{6+3} = 48$$

$$U_2 = 72 \cdot \frac{12}{12+4} = 54$$

$$E_0 = 54 - 48 = 6 \text{ V}$$

(Determine R_I E_0)

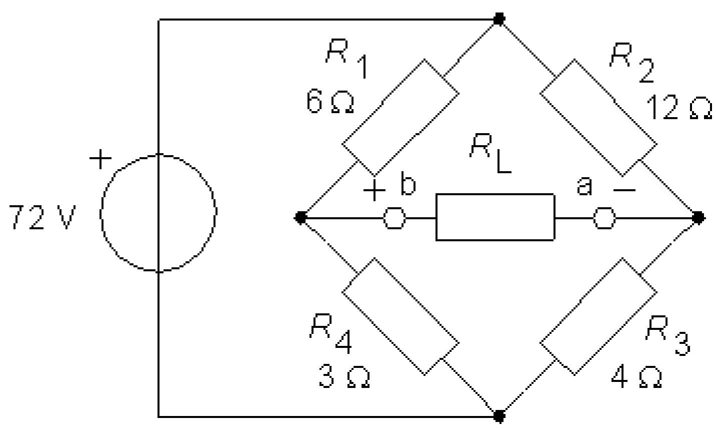


$$U_1 = 72 \cdot \frac{6}{6+3} = 48$$

$$U_2 = 72 \cdot \frac{12}{12+4} = 54$$

$$E_0 = 54 - 48 = 6 \text{ V}$$

Done!



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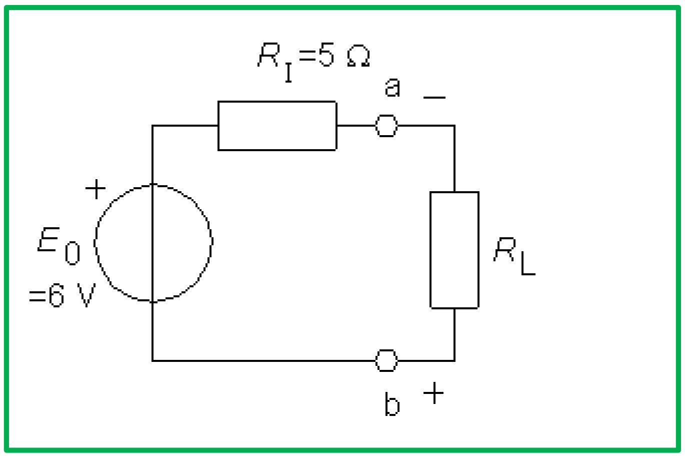
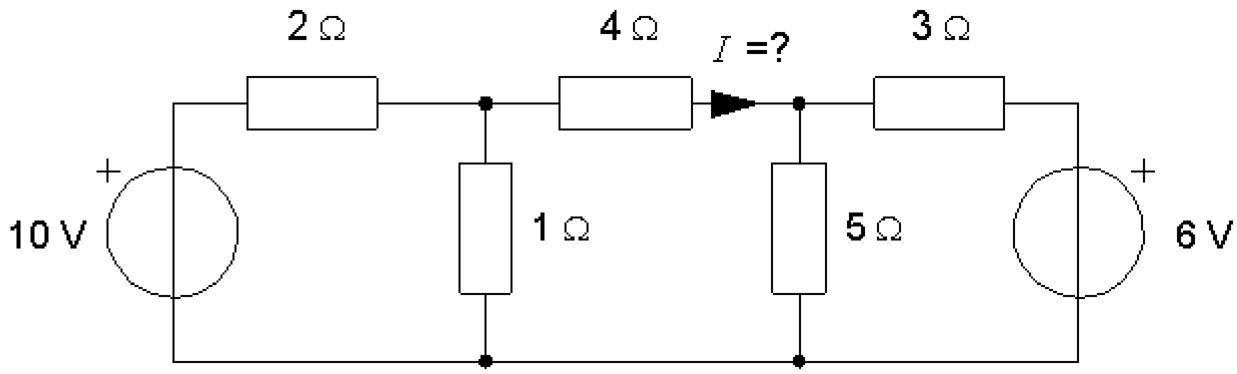


Equivalent circuits (instead of mesh analysis)!



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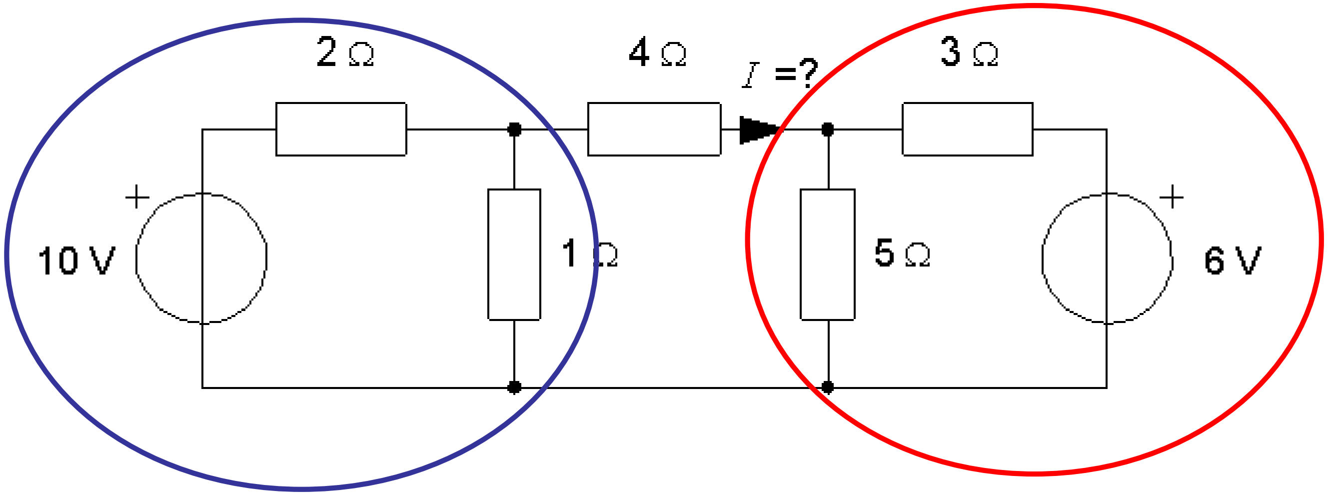

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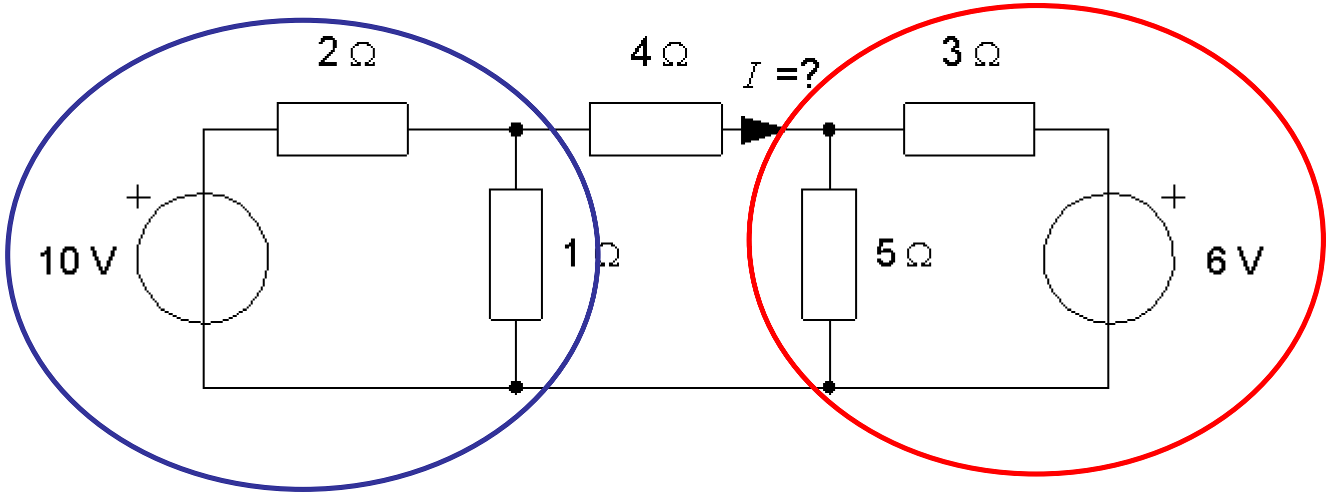
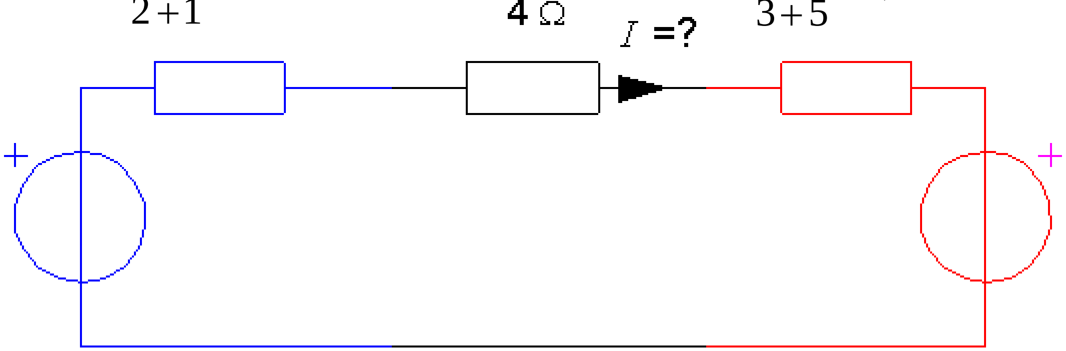


$$\frac{1\cdot 2}{2+1}=0{,}67 \qquad \frac{3\cdot 5}{3+5}=1{,}88$$



$$10\frac{1}{1+2}=3{,}33 \qquad 6\frac{5}{5+3}=3{,}75$$

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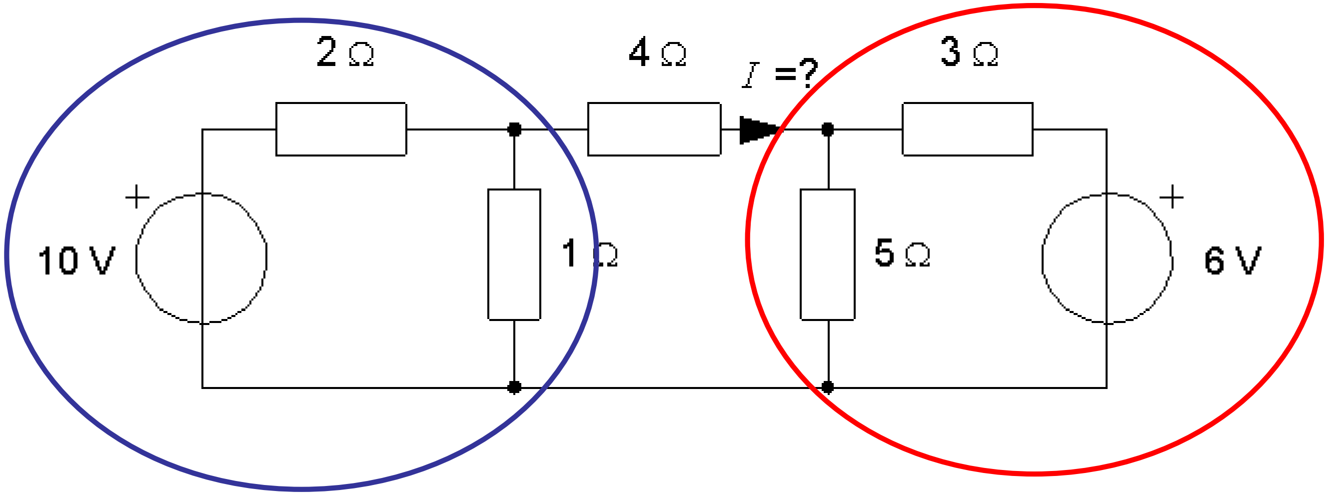
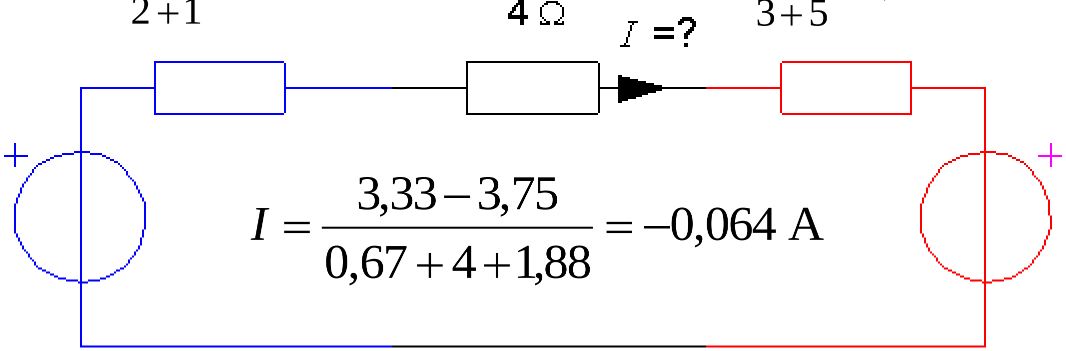
Equivalent circuits (instead of mesh analysis)!



$$\frac{1 \cdot 2}{2+1} = 0,67$$

$$\frac{3 \cdot 5}{3+5} = 1,88$$



$$10\frac{1}{1+2} = 3,33$$

$$I = \frac{3,33 - 3,75}{0,67 + 4 + 1,88} = -0,064 \text{ A}$$

$$6\frac{5}{5+3} = 3,75$$

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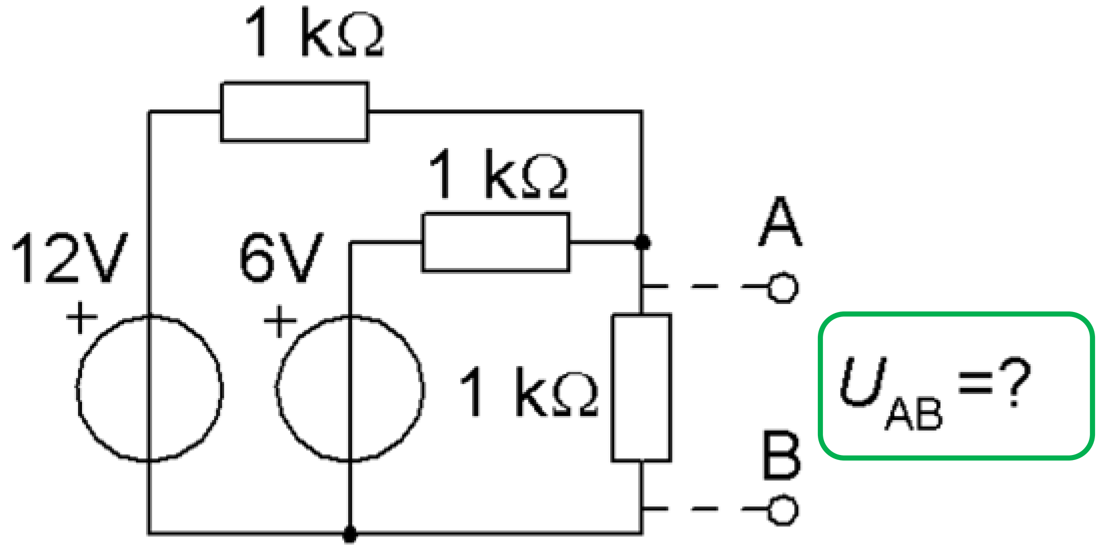
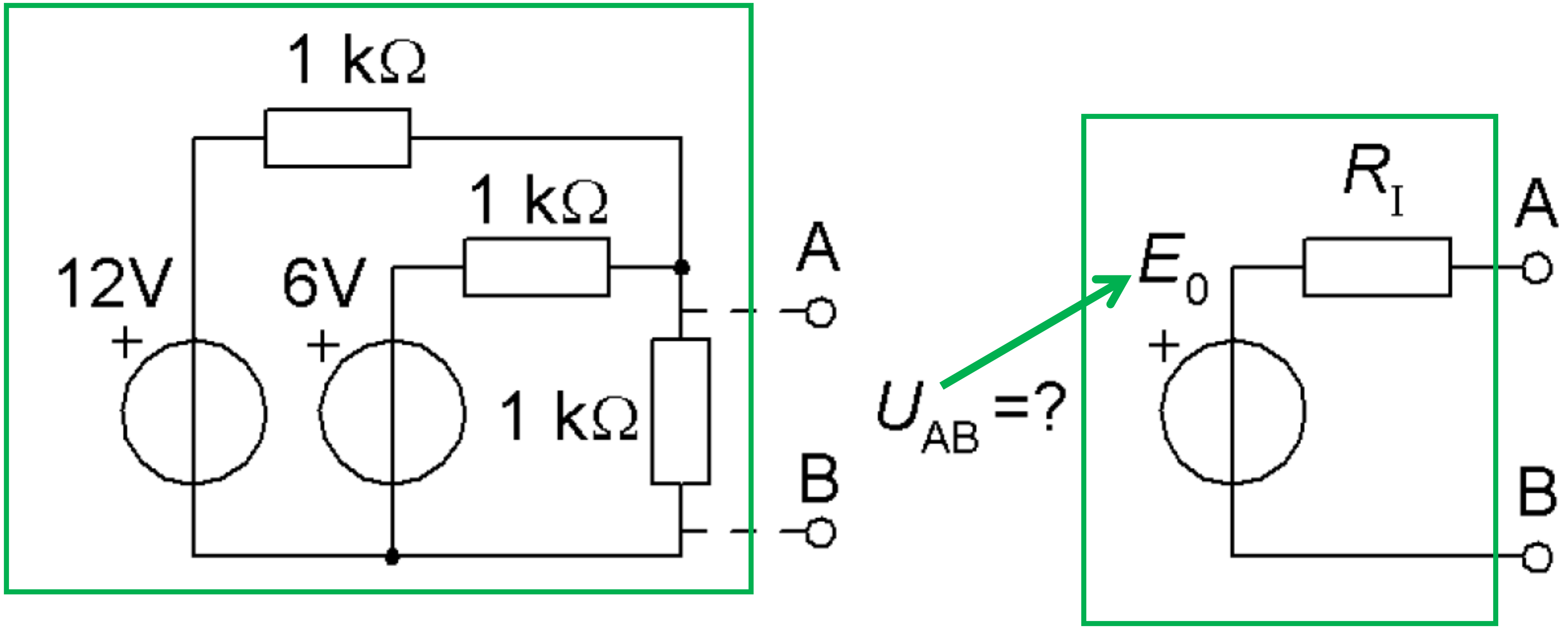
Example (8.10)



What value has the voltage U_{AB} ?

- Use Thevenine equivalent to at ”same time” get value of U_{AB} !

Example (8.10)

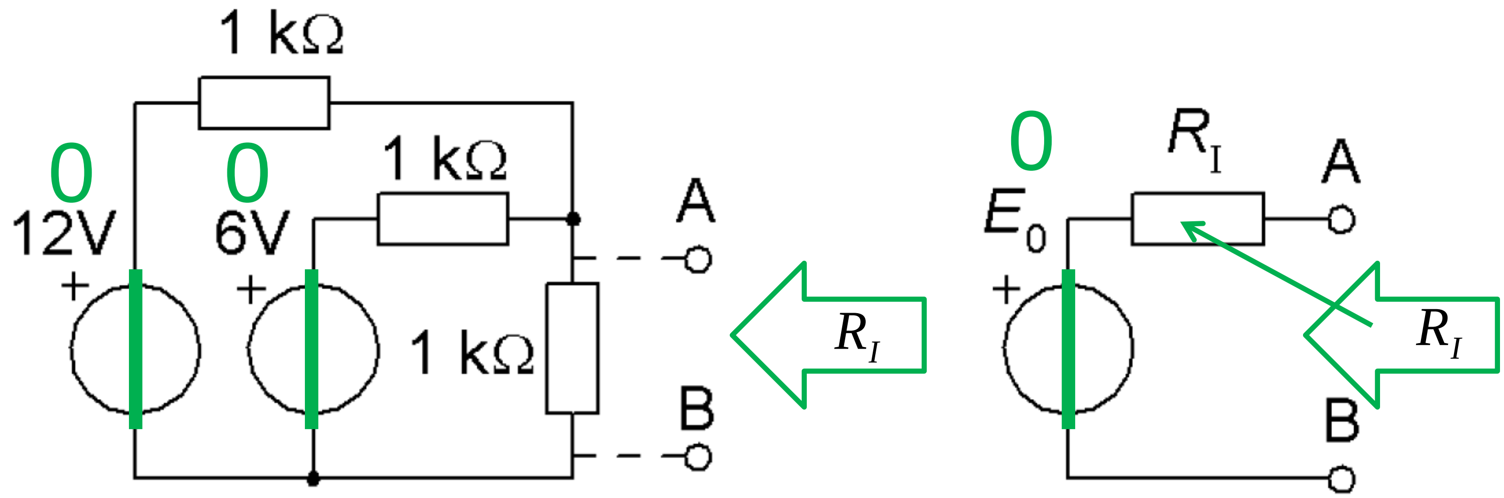


a) Derive a Thevenin's equivalent, E_0 R_I, to the circuit with the two voltage sources and the three resistors.

b) How big is the voltage drop U_{AB} over 1 kΩ resistor in the original circuit?

Example (8.10)

Let's calculate the voltage drop U_{AB} over the 1 kΩ resistor in the circuit, from the Thevenin's equivalent, as then U_{AB} will be the same as the E_0!

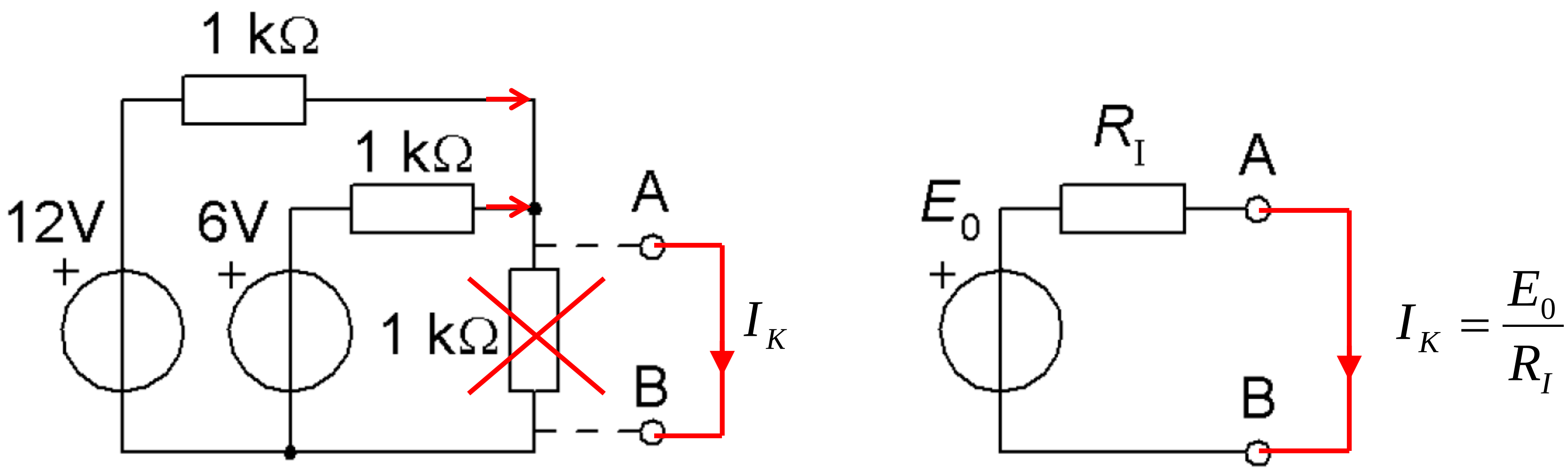


- R_I is the equivalent resistance when the both voltage sources are turned down to zero:

$$R_I = \frac{1}{\frac{1}{1\text{k}\Omega} + \frac{1}{1\text{k}\Omega} + \frac{1}{1\text{k}\Omega}} = \frac{1}{3}\text{k}\Omega$$

Example (8.10)

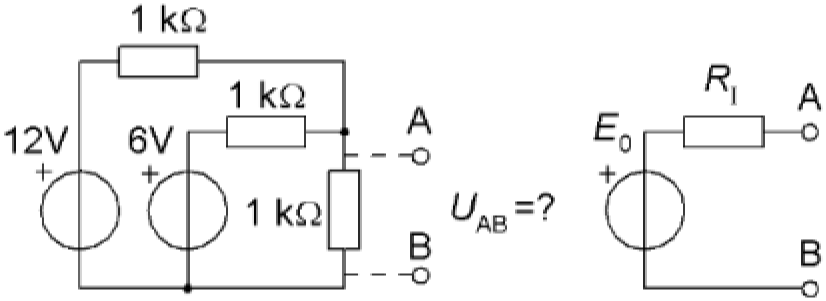
- I_K short circuit current.



Suppose A and B are directly connected to each other. The third 1 kΩ resistor will be short circuit and get no current and can therefore be ignored. The short circuit current will come from the two voltage sources through their 1k Ω resistors:

$$I_K = \frac{12\text{V}}{1\text{k}\Omega} + \frac{6\text{V}}{1\text{k}\Omega} = 18\,\text{mA}$$

Example (8.10)



The Thevenin equivalent will have the same short circuit current I_K = 18 mA. This makes it easy to calculate E_0:

$$I_K = \frac{E_0}{R_I} \quad \Rightarrow \quad E_0 = I_K \cdot R_I = 18 \cdot \frac{1}{3} = 6 \text{ V}$$

And the voltage drop U_{AB} is the same $E_{0.}$ U_{AB} = 6 V.

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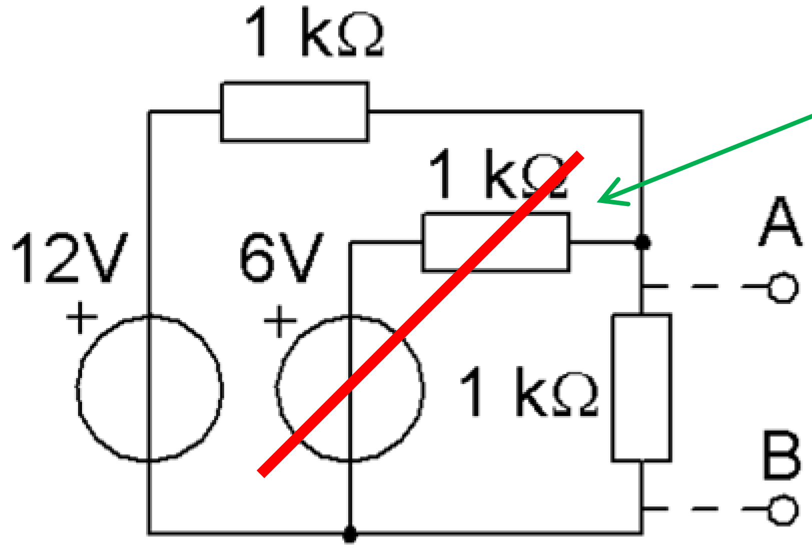
Example (8.10)

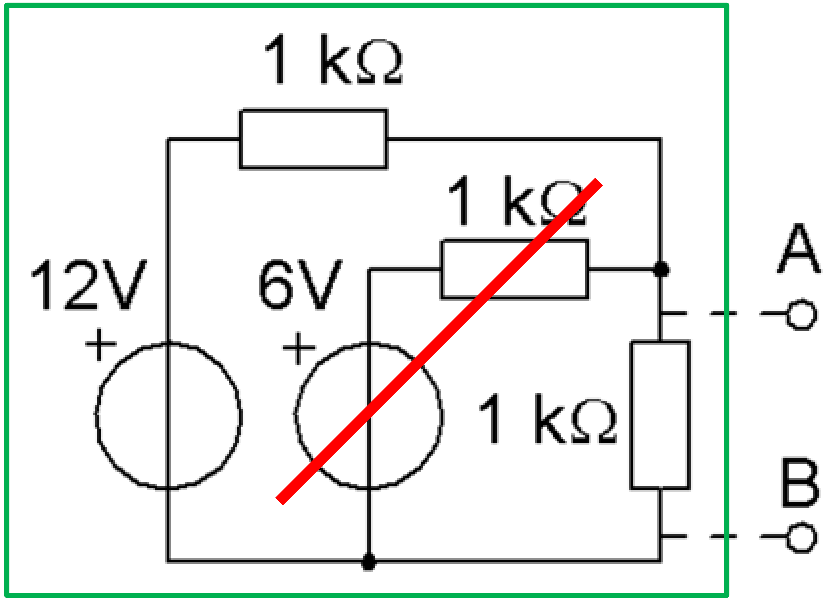


No current!

$U_{AB} = 6$ V

- What would happen if one removed the 6V battery?

Example (8.10)



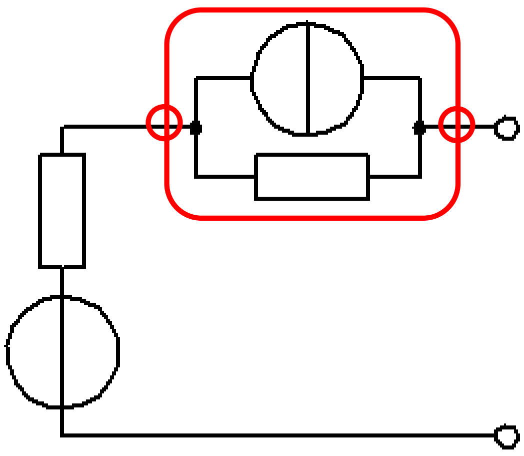
$U_{AB} = 6\text{ V}$

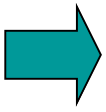
- What would happen if one removed the 6V battery?

This is now another two terminal circuit.
U_{AB} is unchanged U_{AB} = **6V**, but R_I increases to R_I = **0,5 kΩ**.
($I_K = 6/0{,}5 =$ **12 mA**).

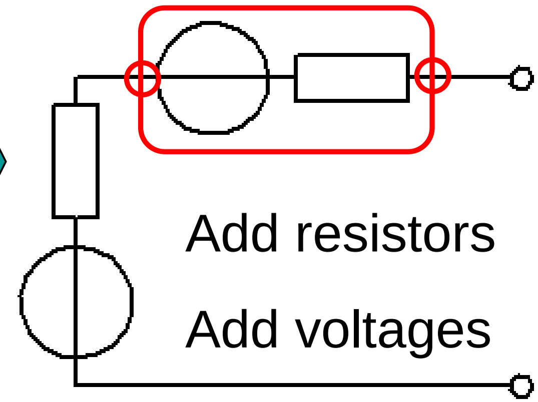
Tips & Tricks

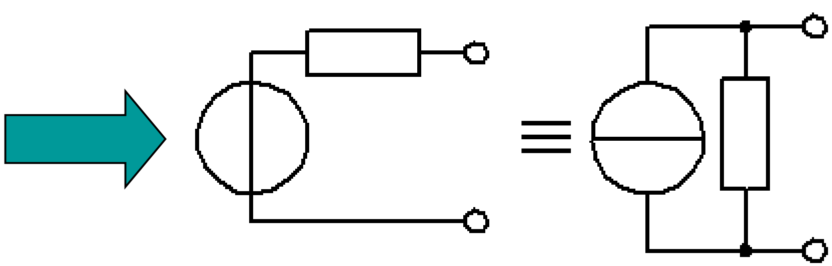
- *U*, *I* Series connected





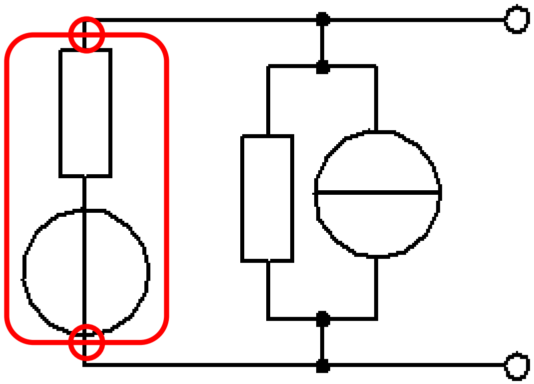
Transform to voltage source!



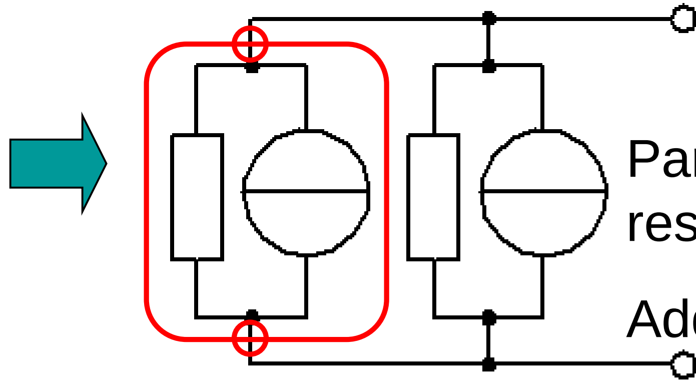


Tips & Tricks

- *U*, *I* Parallel connected

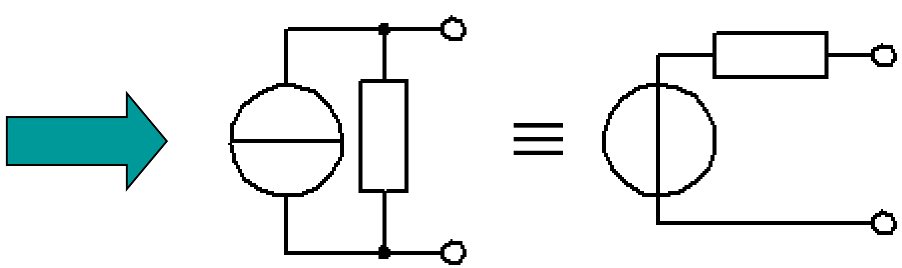


Transform to current source!

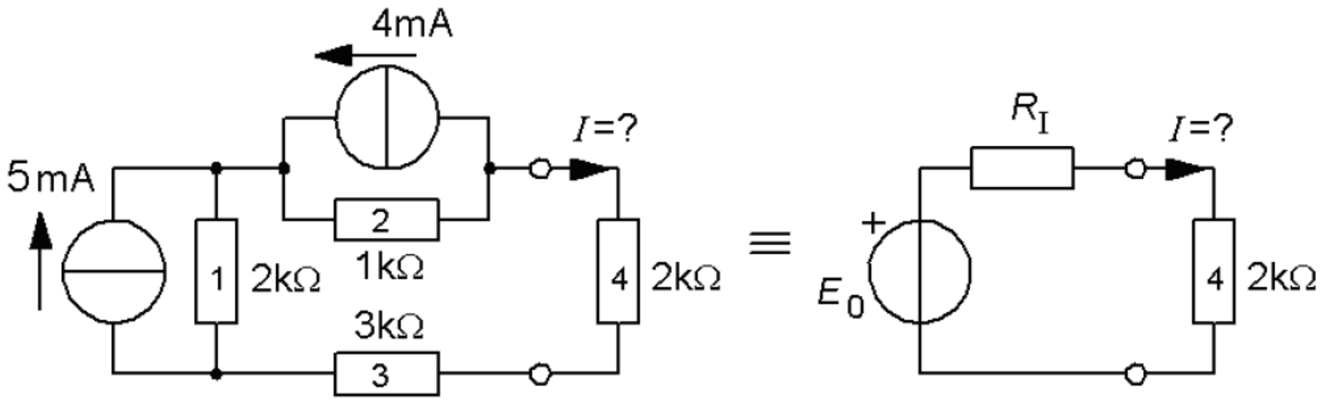


Parallel resistors

Add currents



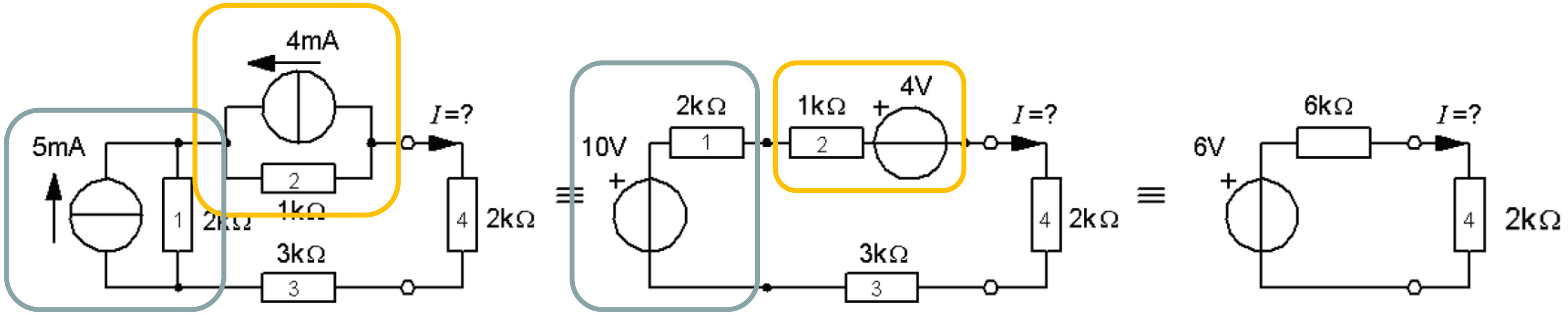
Example (8.9)



a) Derive a Thevenin's equivalent, E_0 R_I, to the circuit with the two current sources.

b) Calculate how big the current I would be if you connected a resistor R_4 = 2 kΩ to the circuit (or it's equivalent).

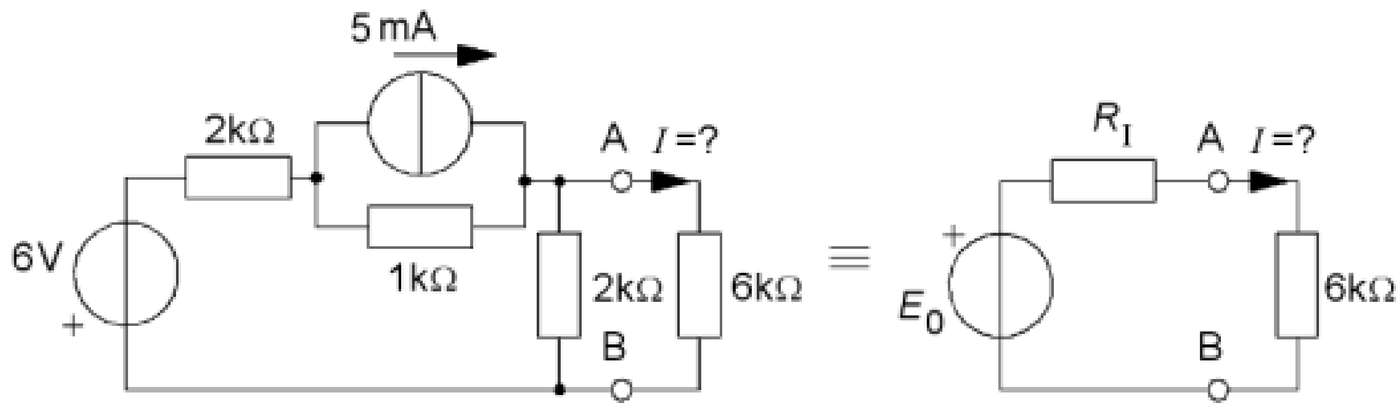
Example (8.9)



$$5\text{mA}||2\text{k}\Omega \Leftrightarrow 10\text{V}+2\text{k}\Omega,\ 4\text{mA}||1\text{k}\Omega \Leftrightarrow 4\text{V}+1\text{k}\Omega \Rightarrow 6\text{V}+6\text{k}\Omega$$

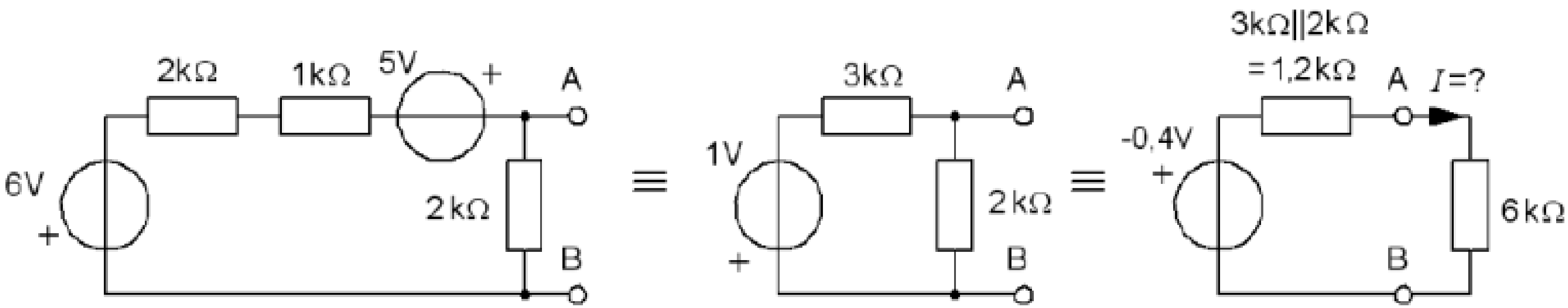
$$I = \frac{E_0}{R_I + R_L} = \frac{6}{6+2} = 0{,}75 \text{ mA}$$

Example (8.11)



a) Derive a Thevenin's equivalent, E_0 R_I, to the circuit with the voltage source and the current source and the three resistors. (The 6 kΩ resistor is not includes in the circuit).
b) Calculate how big current I would flow in a resistor R = 6 kΩ connected to A-B? What direction will the current have?

Example (8.11)



The current source with the 1 kΩ resistor can be transformed to a voltage source. The circuit then becomes a 1 V voltage source with a voltage divider.

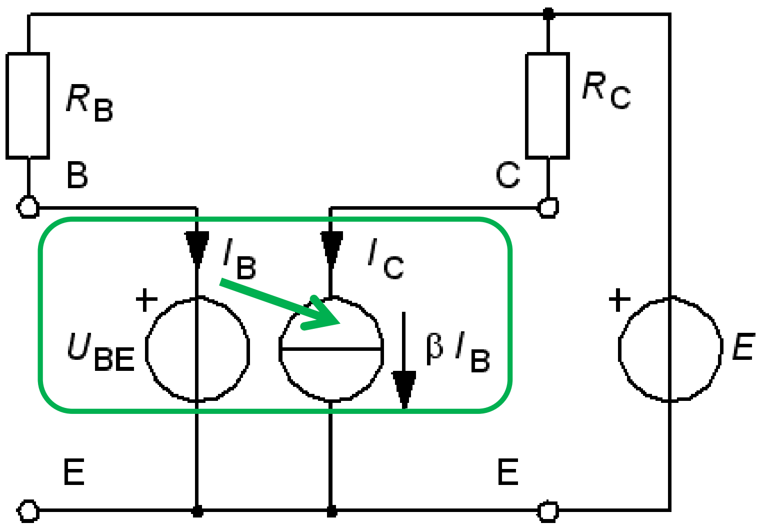
$$E_0 = 1\frac{2}{3+2} = 0{,}4 \text{ V} \quad R_I = \frac{3 \cdot 2}{3+2} = 1{,}2 \text{ k}\Omega$$

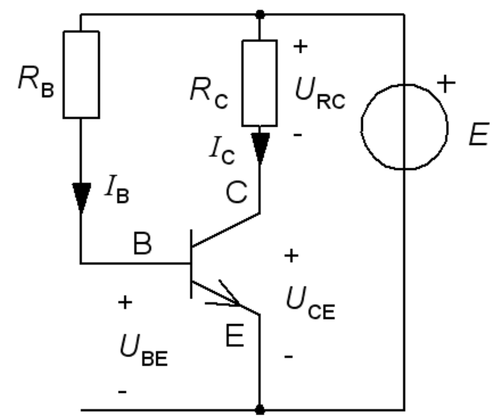
The open circuit voltage is 0,4 V, and the internal resistance 3kΩ||2k Ω = 1,2 k Ω. Note. The voltage source 0,4V is opposite to the definition of the figure (-0,4V).

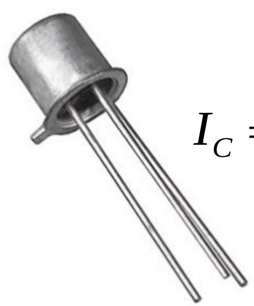
(Dependent sources)

Electronics semiconductor components must be described by dependent sources. Such source has an entity E or I that is decided by some other current or voltage in the circuit.

(Eg. Transistor).







$I_C = \beta \cdot I_B$

Ethis example could be an transistor, and the calculation of its operating point ...

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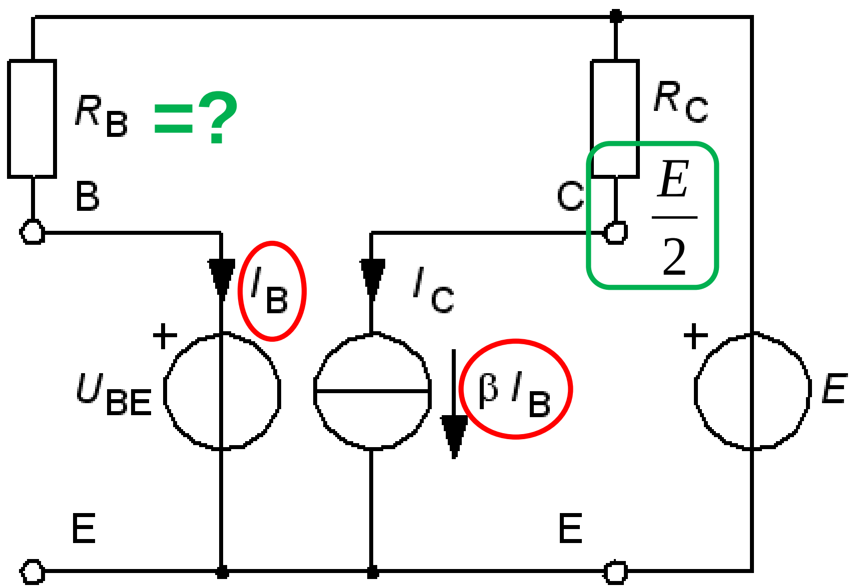
(Eg. Transistor).

- Derive the value of resistor R_B so the voltage drop over resistor R_C will be the **half** of E ?

The current source I_C is depending on current I_B by the equation: $I_C = \boldsymbol{\beta} \cdot I_B$.



We do not introduce any new special symbols dependent sources.

(Eg. Transistor).

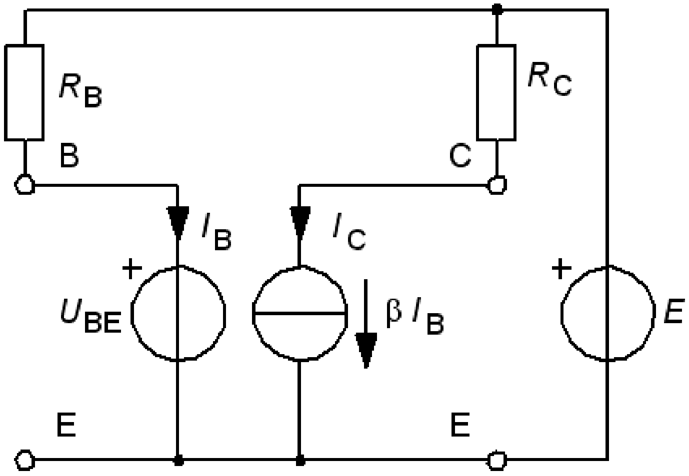
Derive the value of R_B so the voltage drop over R_C will be the **half** of E ?

$$E = 10\ \text{V} \quad U_{BE} = 0{,}5\ \text{V} \quad \beta = 40 \quad R_C = 10\ \text{k}\Omega$$

$$U_{RC} = R_C \cdot I_{RC} = \frac{E}{2} \quad \Rightarrow \quad I_{RC} = \frac{5}{10 \cdot 10^{3}} = 0{,}5 \cdot 10^{-3}$$

$$I_{RC} = \beta \cdot I_B + \frac{E}{2R_O} \quad \Rightarrow \quad I_B = \frac{0{,}5 \cdot 10^{-3} - 0{,}1 \cdot 10^{-3}}{40} = 10 \cdot 10^{-6}$$

$$I_B = \frac{E - U_{BE}}{R_B} \quad \Rightarrow \quad R_B = \frac{10 - 0{,}5}{10 \cdot 10^{-6}} = 950\ k\Omega$$



Calculations with depending sources can thus take place in a similar way as with independent sources, ***but beware …***

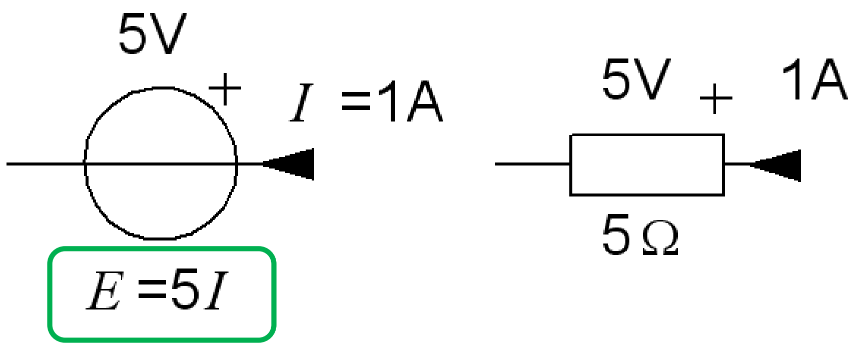
Avoid …

Do not use the superposition principle whith dependent generators. To ***reset*** a source can break the dependence with the the rest of the circuit.

Do not reset dependent sources to find the internal resistance of a two terminal circuit. To ***reset*** a source can break the dependence with the the rest of the circuit.

However, it will always work to use calculations on *open* and *shorted* two terminal circuits.

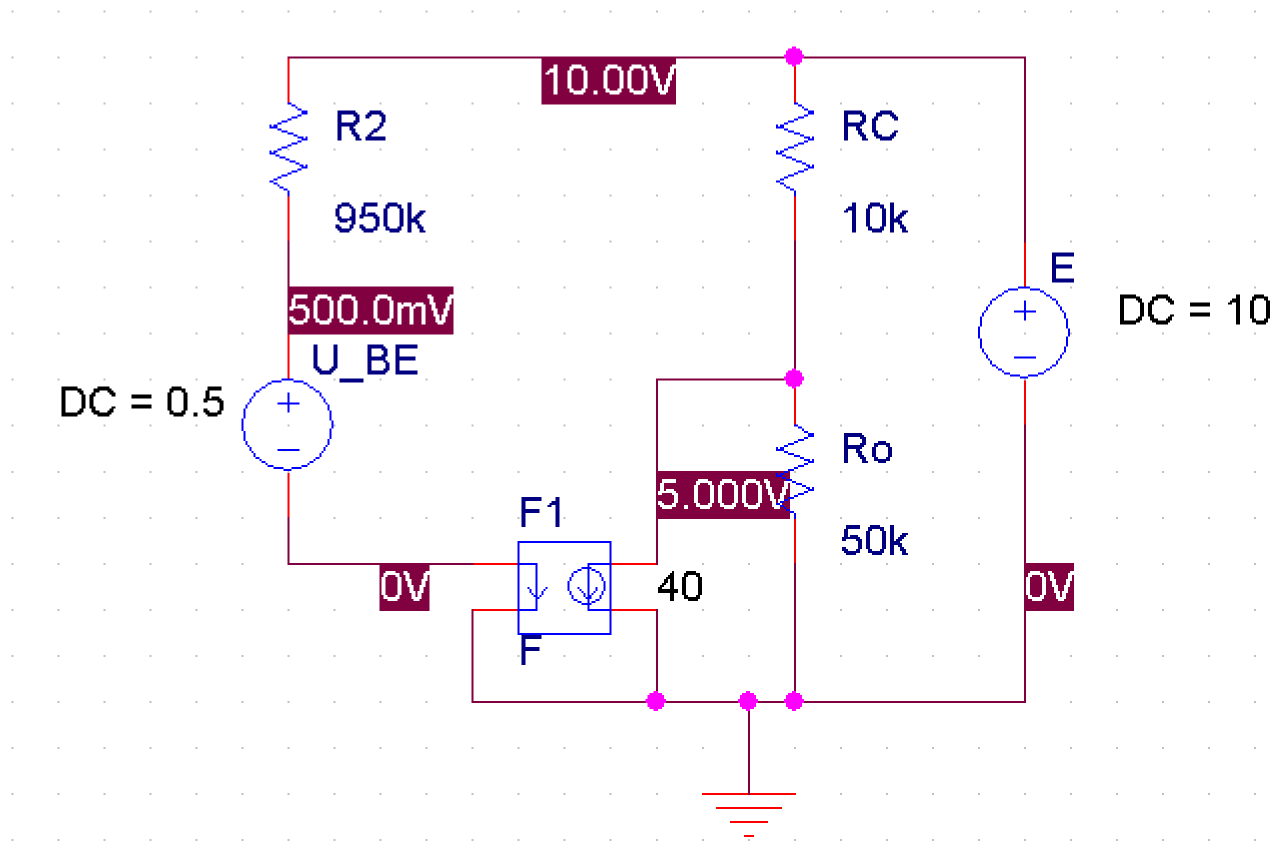
Eg. current depending voltage source …



Suppose we got an emf E that in some way is dependent of its own current I, eg. $E = 5 \cdot I$. It will then act as an resistor with the value 5Ω!

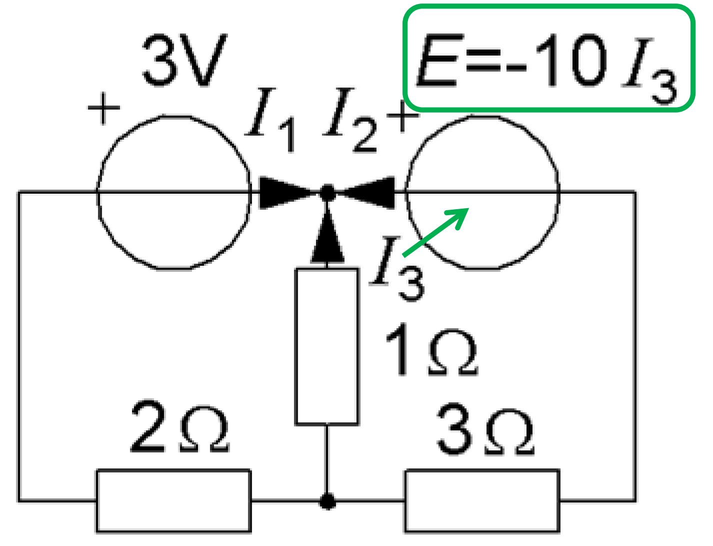
If you reset all sources in such a circuit, you will no longer se all resistors that exists in the circuit.

A Spice-simulation

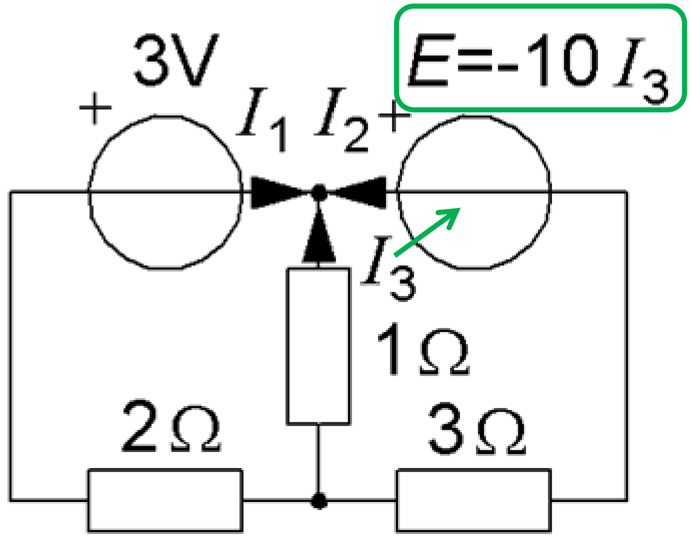


It is possible to simulate circuits with dependent generators.

7.4 Depending source



7.4 Depending source



Kirchhoff current law: $I_1 + I_2 + I_3 = 0$

Kirchhoffs voltage law (the mesh with the *not depending emf*):

$-2I_1 - 3 + 1I_1 = 0 \Leftrightarrow -2I_1 + 0I_2 + 1I_3 = 3$

Kirchhoffs voltage law (the mesh with the *depending emf*):

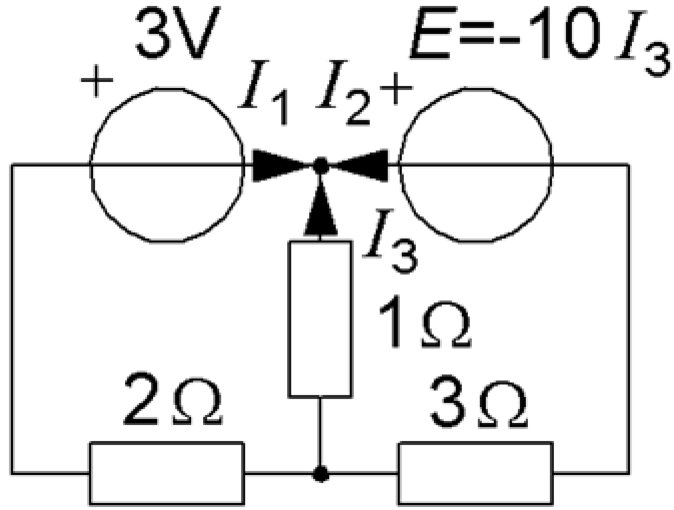
$-1I_3 - (-10I_3) + 3I_2 = 0 \Leftrightarrow 0I_1 + 3I_2 + 9I_3 = 0$

7.4 Depending source

$$I_1 + I_2 + I_3 = 0$$

$$-2I_1 + 0I_2 + 1I_3 = 3$$

$$0I_1 + 3I_2 + 9I_3 = 0$$



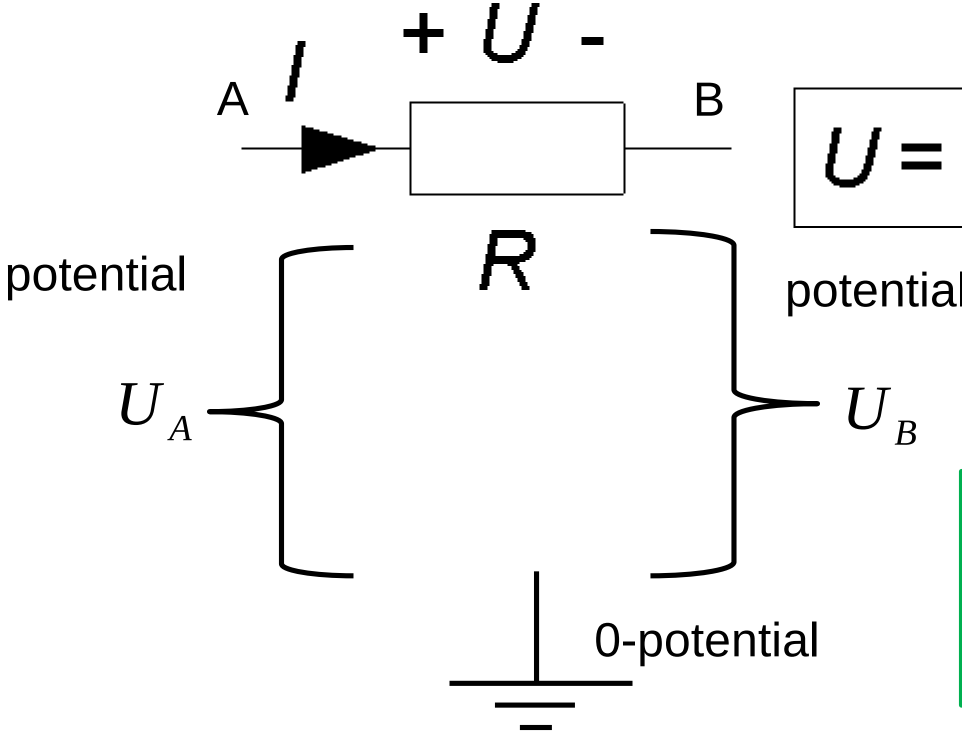
The values are the same as used throughout the course example.

$$\begin{pmatrix} 1 & 1 & 1 \\ -2 & 0 & 1 \\ 0 & 3 & 9 \end{pmatrix} \bullet \begin{pmatrix} I_1 \\ I_2 \\ I_3 \end{pmatrix} = \begin{pmatrix} 0 \\ 3 \\ 0 \end{pmatrix} \qquad I_1 = -2 \quad I_2 = 3 \quad I_3 = -1$$

It is possible to calculate circuits with dependent generators.

Node analysis

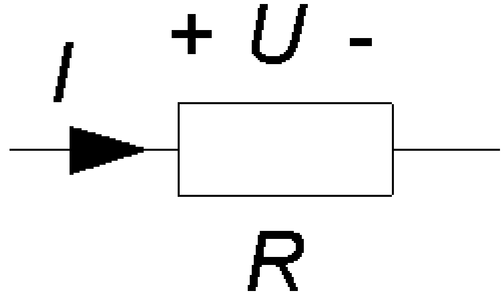
$$U_{AB} = U_A - U_B$$



$$U = IR$$

$$I = \frac{U_{AB}}{R} = \frac{U_A - U_B}{R}$$

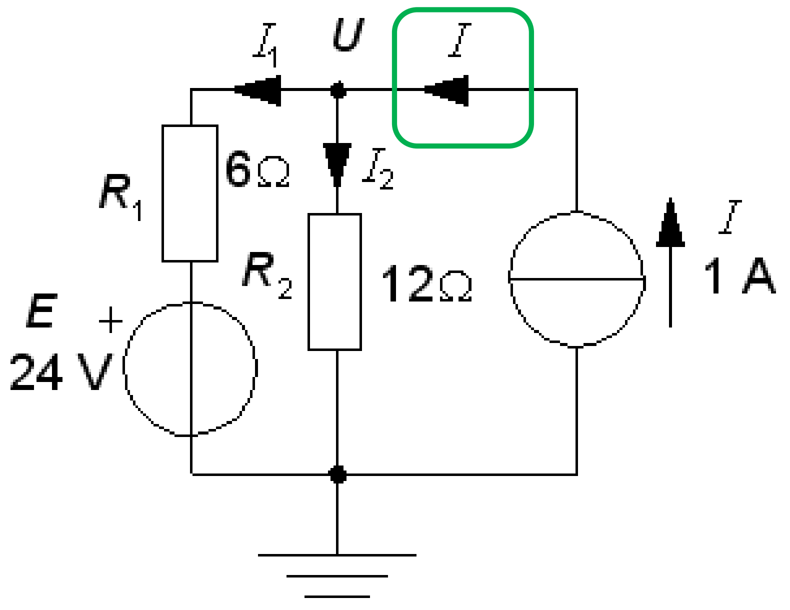
Node analysis



$$U = IR$$

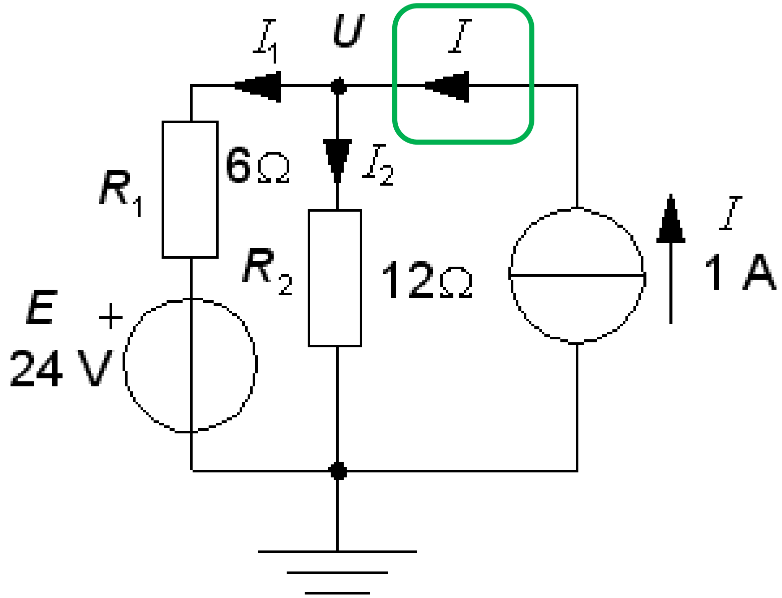
OHM's law

(Current source at node analysis)



$$I = ?$$

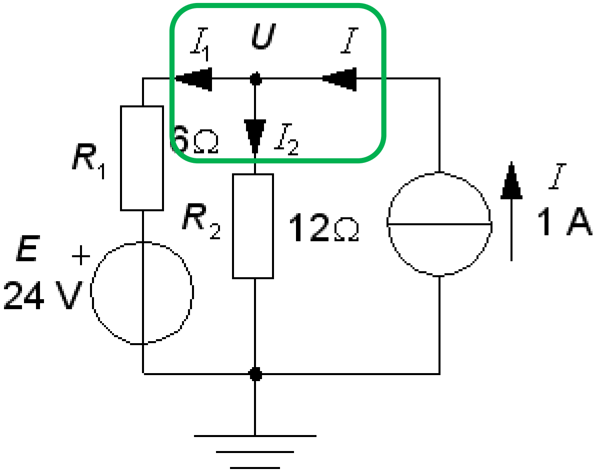
(Current source at node analysis)



$$I = ? \qquad I = 1\,\text{A}$$

(Current source at node analysis)

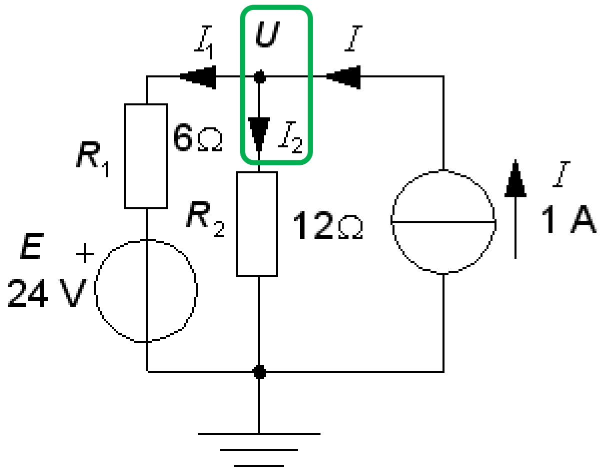
$$-I_1 - I_2 + 1 = 0 \quad I_1 + I_2 = 1$$



(Current source at node analysis)

$$-I_1 - I_2 + 1 = 0 \quad I_1 + I_2 = 1$$

$$I_2 = \frac{U-0}{R_2} = \frac{U}{12}$$

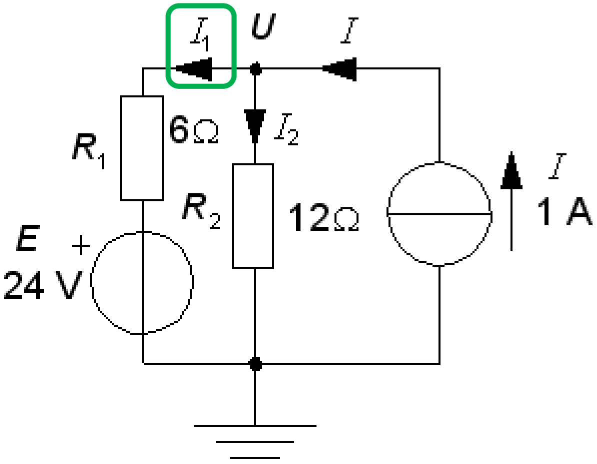


(Current source at node analysis)

$$-I_1 - I_2 + 1 = 0 \quad I_1 + I_2 = 1$$

$$I_2 = \frac{U - 0}{R_2} = \frac{U}{12}$$

$$I_1 = \frac{U - E}{R_1} = \frac{U - 24}{6}$$



(Current source at node analysis)

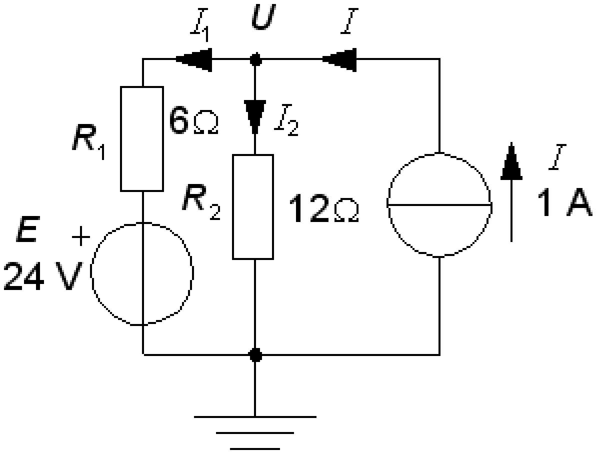
$$-I_1 - I_2 + 1 = 0 \quad I_1 + I_2 = 1$$

$$I_2 = \frac{U - 0}{R_2} = \frac{U}{12}$$

$$I_1 = \frac{U - E}{R_1} = \frac{U - 24}{6}$$

$$1 = \frac{U}{12} + \frac{U - 24}{6} = \frac{2 \cdot U - 48 + U}{12} \quad \Leftrightarrow \quad 12 = 3 \cdot U - 48$$

$$\boxed{U = 20 \text{ V}}$$



(Node analyses – currents)

$$I_2 = \frac{20}{12} = \boxed{1{,}67}$$

$$I_1 = \frac{20-24}{6} = \boxed{-0{,}67}$$

Check: $I_1 + I_2 = 1 \quad \Rightarrow \quad -0{,}67 + 1{,}67 = \boxed{1}$