

# Exam Winter Semester 2022

## Student Group

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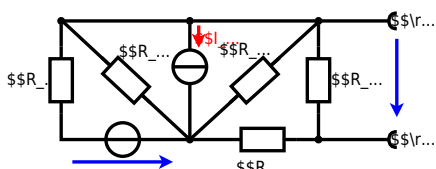
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**Exercise E5 Equivalent linear Source  
(written test, approx. 14 % of a 60-minute written test, WS2022)**

The circuit in the following has to be simplified.  
Result

$$U_{\text{rs}} = U_{\text{AB}} = 4.5 \text{ V}$$

$$R_{\text{i}} = R_{\text{AB}} = 6 \text{ } \Omega$$



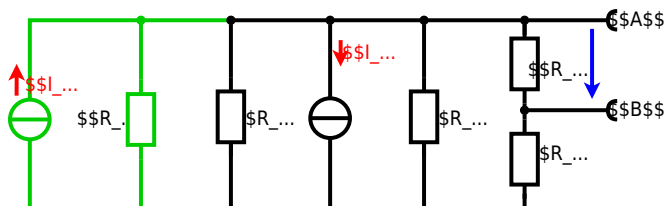
Calculated the internal resistance  $R_{\text{i}}$  and the source voltage  $U_{\text{rs}}$  of an equivalent linear voltage source on the connectors  $\text{A}$  and  $\text{B}$ . 
$$R_1=5.0 \text{ } \Omega, \quad U_2=6.0 \text{ V}, \quad R_3= 10 \text{ } \Omega, \quad I_4=4.2 \text{ A}, \quad R_5=10 \text{ } \Omega, \quad R_6=7.5 \text{ } \Omega, \quad R_7=15 \text{ } \Omega$$
 Use equivalent sources in order to simplify the circuit!

Solution

The best thing is to re-think the wiring like rubber bands and adjust them:



The linear voltage source of  $U_2$  and  $R_1$  can be transformed into a current source  $I_2 = \frac{U_2}{R_1}$  and  $R_1$ :



Now a lot of them can be combined. The resistors  $R_1$ ,  $R_3$ ,  $R_5$  are in parallel, like also  $I_2$  and  $I_4$ :

$$R_{135} = R_1 || R_3 || R_5$$

$$I_{24} = I_2 - I_4$$

The resulting circuit can again be transformed:



Here, the  $U_{24}$  is calculated by  $I_{24}$  as the following:

$$U_{24} = I_{24} \cdot R_{135} + I_2 \cdot R_4 + I_4 \cdot R_6 + I_5 \cdot R_7 + I_6 \cdot R_8$$

$$U_{24} = U_2 \cdot \frac{R_7}{R_6 + R_7 + R_1 \parallel R_3 \parallel R_5} - I_4 \cdot R_1 \parallel R_3 \parallel R_5$$

On the right side of the last circuit, there is a voltage divider given by  $R_{135}$ ,  $R_6$ , and  $R_7$ .

Therefore the voltage between  $A$  and  $B$  is given as:

$$U_{AB} = U_{24} \cdot \frac{R_7}{R_6 + R_7 + R_1 \parallel R_3 \parallel R_5} - \left( \frac{U_2}{R_1} - I_4 \right) \cdot \frac{R_7 \cdot R_1 \parallel R_3 \parallel R_5}{R_6 + R_7 + R_1 \parallel R_3 \parallel R_5}$$

For the internal resistance  $R_i$  the ideal voltage source is substituted by its resistance ( $=0\Omega$ , so a short-circuit):

$$R_{AB} = R_7 \parallel (R_6 + R_1 \parallel R_3 \parallel R_5)$$

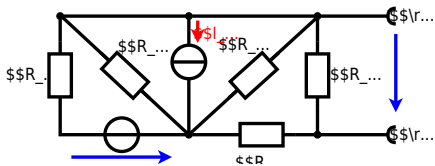
with  $R_1 \parallel R_3 \parallel R_5 = 5\Omega \parallel 10\Omega \parallel 10\Omega = 5\Omega \parallel 5\Omega = 2.5\Omega$ :

$$U_{AB} = \frac{6.0\text{V}}{5.0\Omega} - 4.2\Omega \cdot \frac{15\Omega \cdot 2.5\Omega}{7.5\Omega + 15\Omega + 2.5\Omega} \parallel R_{AB} = 15\Omega \parallel (7.5\Omega + 2.5\Omega)$$

### Exercise E6 Equivalent linear Source (written test, approx. 14 % of a 60-minute written test, WS2022)

The circuit in the following has to be simplified.  
Result

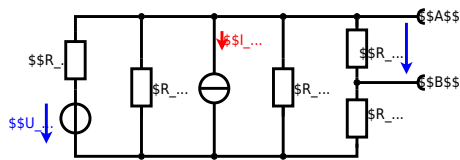
$$U_s = U_{AB} = 4.5\text{V} \parallel R_i = R_{AB} = 6\Omega$$



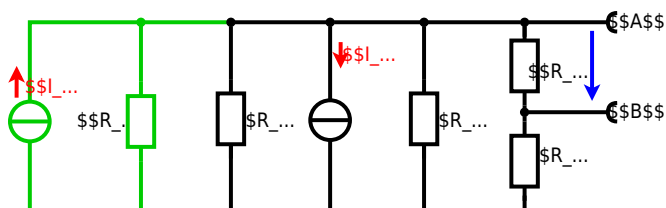
Calculate the internal resistance  $R_{in}$  and the source voltage  $U_{s}$  of an equivalent linear voltage source on the connectors  $A$  and  $B$ .  $R_1=5.0 \Omega$ ,  $U_2=6.0 \text{ V}$ ,  $R_3=10 \Omega$ ,  $I_4=4.2 \text{ A}$ ,  $R_5=10 \Omega$ ,  $R_6=7.5 \Omega$ ,  $R_7=15 \Omega$ . Use equivalent sources in order to simplify the circuit!

Solution

The best thing is to re-think the wiring like rubber bands and adjust them:



The linear voltage source of  $U_2$  and  $R_1$  can be transformed into a current source  $I_2 = \frac{U_2}{R_1}$  and  $R_1$ :



Now a lot of them can be combined. The resistors  $R_1$ ,  $R_3$ ,  $R_5$  are in parallel, like also  $I_2$  and  $I_4$ :

$$R_{135} = R_1 || R_3 || R_5$$

$$I_{24} = I_2 - I_4$$

The resulting circuit can again be transformed:



Here, the  $U_{24}$  is calculated by  $I_{24}$  as the following:

$$U_{24} = I_{24} \cdot R_{135} || R_6 || R_7$$





Solution

$$R_1 \&= 1.00 \sim \Omega$$

$$R_2 \&= 70.0 \sim \Omega$$

$$C_1 = 40 \sim \text{nF}$$

$$C_2 = 4.7 \sim \mu\text{F}$$

$$f = 4 \sim \text{MHz}$$

A series circuit means that the current is constant on every component.  
 The equivalent impedance for  $R_2$  and  $C_1$  combined is given by  

$$Z_{21} = R_2 + \frac{1}{j\omega C_1}$$
 Since  $\frac{1}{j\omega C_1}$  is perpendicular to  $R_2$ , this can be simplified to  

$$|Z_{21}| = \sqrt{R_2^2 + \left(\frac{1}{\omega C_1}\right)^2}$$
 So it gets clear that  $Z_{21}$  is perpendicular to  $Z_3$  (It has to, since  $R_3$  is perpendicular to  $\frac{1}{j\omega C_1}$ , too).  
 Therefore the resulting current of the parallel circuit is given as:  

$$I_{3R} = \sqrt{I_{21}^2 + I_{3C}^2}$$

$$I_{21} = \frac{U}{|Z_{21}|} = \frac{160 \text{ mA}}{\sqrt{70^2 + \left(\frac{1}{4 \cdot 10^6 \cdot 40 \cdot 10^{-9}}\right)^2}}$$

$$I_{3C} = \frac{U}{|Z_3|} = \frac{160 \text{ mA}}{\sqrt{100^2 + \left(\frac{1}{4 \cdot 10^6 \cdot 40 \cdot 10^{-9}}\right)^2}}$$

Back to the first formula:  

$$R_3 \cdot I_{3R} = |Z_3| \cdot I_{3R} \cdot \frac{|Z_3|}{|Z_3|} = |Z_3| \cdot I_{3R} \cdot \frac{1}{\sqrt{100^2 + \left(\frac{1}{4 \cdot 10^6 \cdot 40 \cdot 10^{-9}}\right)^2}}$$

**Exercise E12 Impedances at different Frequencies**  
 (written test, approx. 18 % of a 60-minute written test, WS2022)

A series circuit means that the current is constant on every component.  
 The equivalent impedance for  $R_2$  and  $C_1$  combined is given by  

$$Z_{21} = R_2 + \frac{1}{j\omega C_1}$$
 Since  $\frac{1}{j\omega C_1}$  is perpendicular to  $R_2$ , this can be simplified to  

$$|Z_{21}| = \sqrt{R_2^2 + \left(\frac{1}{\omega C_1}\right)^2}$$
 So it gets clear that  $Z_{21}$  is perpendicular to  $Z_3$  (It has to, since  $R_3$  is perpendicular to  $\frac{1}{j\omega C_1}$ , too).  
 Therefore the resulting current of the parallel circuit is given as:  

$$I_{3R} = \sqrt{I_{21}^2 + I_{3C}^2}$$

$$I_{21} = \frac{U}{|Z_{21}|} = \frac{160 \text{ mA}}{\sqrt{70^2 + \left(\frac{1}{4 \cdot 10^6 \cdot 40 \cdot 10^{-9}}\right)^2}}$$

$$I_{3C} = \frac{U}{|Z_3|} = \frac{160 \text{ mA}}{\sqrt{100^2 + \left(\frac{1}{4 \cdot 10^6 \cdot 40 \cdot 10^{-9}}\right)^2}}$$

Solution

$$R_1 \&= 1.00 \sim \Omega$$

$$R_2 \&= 70.0 \sim \Omega$$

$$C_1 = 40 \sim \text{nF}$$

$$C_2 = 4.7 \sim \mu\text{F}$$

$$f = 4 \sim \text{MHz}$$

A series circuit means that the current is constant on every component.  
 The equivalent impedance for  $R_2$  and  $C_1$  combined is given by  

$$Z_{21} = R_2 + \frac{1}{j\omega C_1}$$
 Since  $\frac{1}{j\omega C_1}$  is perpendicular to  $R_2$ , this can be simplified to  

$$|Z_{21}| = \sqrt{R_2^2 + \left(\frac{1}{\omega C_1}\right)^2}$$
 So it gets clear that  $Z_{21}$  is perpendicular to  $Z_3$  (It has to, since  $R_3$  is perpendicular to  $\frac{1}{j\omega C_1}$ , too).  
 Therefore the resulting current of the parallel circuit is given as:  

$$I_{3R} = \sqrt{I_{21}^2 + I_{3C}^2}$$

$$I_{21} = \frac{U}{|Z_{21}|} = \frac{160 \text{ mA}}{\sqrt{70^2 + \left(\frac{1}{4 \cdot 10^6 \cdot 40 \cdot 10^{-9}}\right)^2}}$$

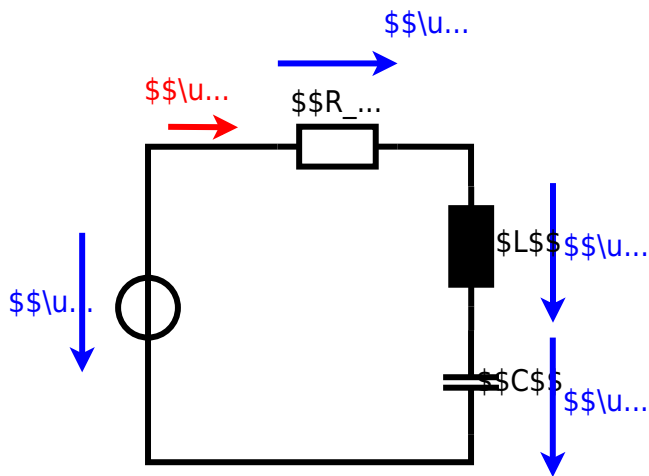
$$I_{3C} = \frac{U}{|Z_3|} = \frac{160 \text{ mA}}{\sqrt{100^2 + \left(\frac{1}{4 \cdot 10^6 \cdot 40 \cdot 10^{-9}}\right)^2}}$$

Back to the first formula:  

$$R_3 \cdot I_{3R} = |Z_3| \cdot I_{3R} \cdot \frac{|Z_3|}{|Z_3|} = |Z_3| \cdot I_{3R} \cdot \frac{1}{\sqrt{100^2 + \left(\frac{1}{4 \cdot 10^6 \cdot 40 \cdot 10^{-9}}\right)^2}}$$







**Exercise E14 Complex Impedance Circuit**  
**(written test, approx. 15 % of a 60-minute written test, WS2022)**

1. Calculate the current  $i(t)$  in the circuit shown in Fig. 1. The voltage source  $u(t) = 3.0 \sin(2\pi \cdot 15 \cdot t)$  V is connected in series with an inductor of  $330 \mu\text{H}$  and a capacitor of  $0.22 \mu\text{F}$ .

Result:  $Z = 19.8 - j48.2 \Omega$

Draw the circuit diagram of the given circuit and label all components, voltages, and currents.

$$Z = \frac{\hat{U}}{\hat{I}} \quad \hat{I} = \frac{\hat{U}}{Z} \quad Z_C = \frac{1}{j\omega C} = \frac{1}{j \cdot 2\pi \cdot 15 \cdot 0.22 \cdot 10^{-6}}$$

$$\hat{I} = \frac{3.0}{19.8 - j48.2} = 0.59 \cdot e^{j\phi} \text{ A}$$

$$i(t) = 0.59 \sin(2\pi \cdot 15 \cdot t + \phi) \text{ A}$$

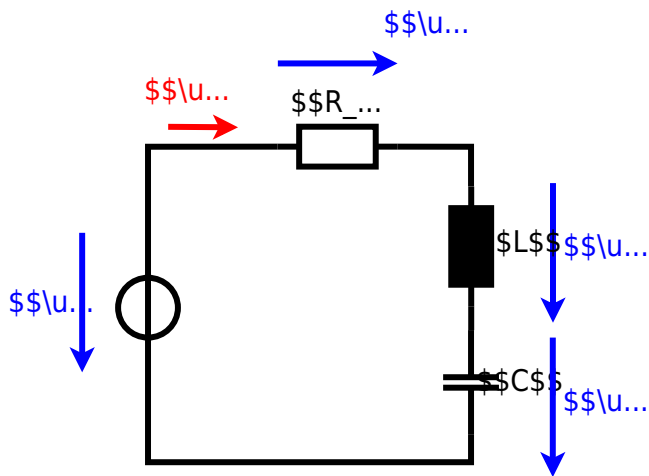
$$\underline{Z} = R + j\omega L - j\omega C = 330 \cdot 10^{-6} + j \cdot 2\pi \cdot 15 \cdot 330 \cdot 10^{-6} - j \cdot 2\pi \cdot 15 \cdot 0.22 \cdot 10^{-6}$$

$$\underline{Z} = 330 \cdot 10^{-6} + j \cdot 3.14 \cdot 10^{-4} - j \cdot 2.2 \cdot 10^{-4} = 330 \cdot 10^{-6} + j \cdot 9.2 \cdot 10^{-5} \Omega$$

$$|\underline{Z}| = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{(330 \cdot 10^{-6})^2 + (9.2 \cdot 10^{-5})^2} = 330 \cdot 10^{-6} \Omega$$







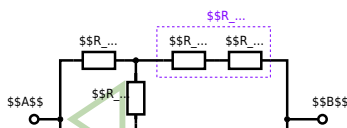
**Exercise E3 Pure Resistor Network Simplification**  
**(written test, approx. 13 % of a 60-minute written test, WS2022)**

The following shall be solved at once,  $R_2 = R_3 = 100 \Omega$  and the switch shall be given.  $R_1 = 400 \Omega$ . Calculate the equivalent resistance  $R_{eq}$  between  $A$  and  $B$ .

Solution

$$R_{eq} = 133.8 \Omega$$

Now a wye-delta transformation is necessary.



Since  $R_2 = R_3$  and based on the equations for the transformation, the transformed  $R_Y$  is given as:

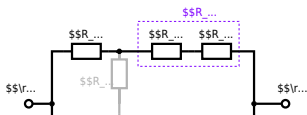
$$R_Y = \frac{R_2 \cdot R_2}{R_2 + R_2 + R_2} = \frac{(100 \Omega)^2}{3 \cdot 100 \Omega} = \frac{1}{3} \cdot 100 \Omega = 33.33 \Omega$$

The equivalent resistor is given by a parallel configuration of resistors in series:

$$R_{eq} = R_Y + (R_Y + R_1 + R_1) \parallel (R_Y + R_2) \parallel (R_Y + R_2) \parallel R_3$$

The switch shall now be open. Calculate the equivalent resistance  $R_{eq}$  between  $A$  and  $B$ .

Solution



The equivalent resistor is given by a parallel configuration of resistors in series:

$$R_{\text{eq}} = (R_2 + R_1 + R_1) \parallel (R_2 + R_2) \parallel R_{\text{eq}} = (100 \sim \Omega + 200 \sim \Omega + 200 \sim \Omega) \parallel (100 \sim \Omega + 100 \sim \Omega) \parallel R_{\text{eq}} = (500 \sim \Omega) \parallel (200 \sim \Omega) \parallel R_{\text{eq}} = \frac{\{500 \sim \Omega \cdot 200 \sim \Omega\}}{500 \sim \Omega + 200 \sim \Omega}$$

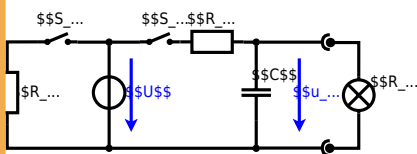
**Exercise E7 Charging Capacitors**  
 (written test, approx. 16 % of a 60-minute written test, WS2022)

The circuit below consists of a DC voltage source  $U$ , a resistor  $R_1$ , a resistor  $R_2$ , and a capacitor  $C$ . The switch  $S_1$  is initially open. The voltage across the capacitor is again  $U$  at the moment  $t_0 = 0 \text{ s}$  when the switch  $S_1$  is closed. Calculate the voltage  $u_c(t_2)$  across the capacitor at  $t_2 = 1 \text{ ms}$  after closing the switch.

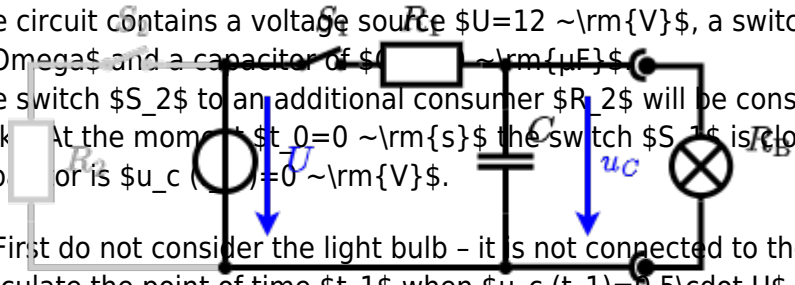
**Result:** To solve this, first create an equivalent linear voltage source from  $U$ ,  $R_1$ , and  $R_2$ .

$$U_{\text{eq}} = \frac{U \cdot R_2}{R_1 + R_2} \quad R_{\text{eq}} = R_1 \parallel R_2 = \frac{R_1 \cdot R_2}{R_1 + R_2}$$

On an alternative view, one can try to create an equivalent linear voltage source again. Then, the internal resistance is given by substituting the ideal voltage source is again short-circuiting  $R_2$ .

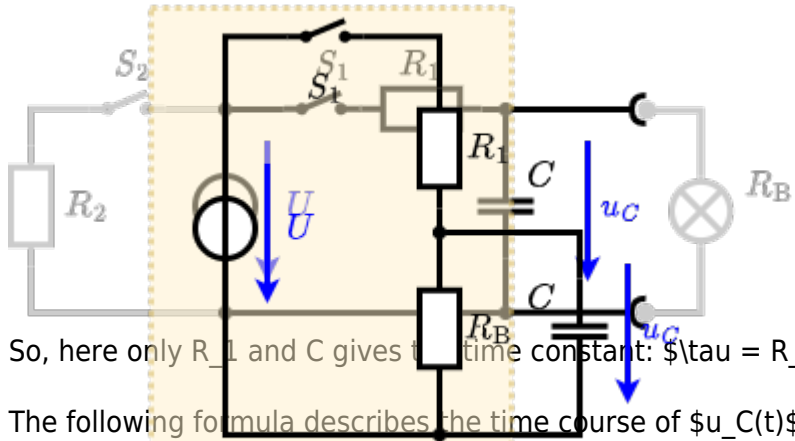


The circuit contains a voltage source  $U=12\text{ V}$ , a switch  $S_1$ , a resistor of  $R_1=20\text{ }\Omega$  and a capacitor of  $C=100\text{ }\mu\text{F}$ . The switch  $S_2$  to an additional consumer  $R_2$  will be considered to be open for the first task. At the moment  $t_0=0\text{ s}$  the switch  $S_1$  is closed, the voltage across the capacitor is  $u_c(t_0)=0\text{ V}$ .



First do not consider the light bulb - it is not connected to the RC circuit. Calculate the point of time  $t_1$  when  $u_c(t_1)=0.5 \cdot U$ .

Solution



So, here only  $R_1$  and  $C$  gives the time constant:  $\tau = R_1 \cdot C$

The following formula describes the time course of  $u_c(t)$  which has to be  $u_c(t_1)=0.5 \cdot U$ :  

$$u_c(t) = U \cdot (1 - e^{-t/\tau}) = 0.5 \cdot U$$
 It has to be rearranged to  $(1 - e^{-t/\tau}) = 0.5$ .  
 An equivalent linear voltage source can be given with  $U_s$ ,  $R_1$  and  $R_B$  as seen in yellow:  

$$\tau = R_1 \cdot C \cdot \ln(0.5)$$

Therefore, the voltage of the equivalent linear voltage source is:  $U_s = U \cdot \frac{R_B}{R_1 + R_B} = 1/2 \cdot U$ . The internal resistance is given by substituting the ideal voltage source with its resistance ( $r=0\text{ }\Omega$ , short-circuit).  

$$R_i = R_1 \parallel R_B = 10\text{ }\Omega$$

$$u_c(t_2) = U_s \cdot (1 - e^{-t_2/(R_i \cdot C)}) = \frac{1}{2} \cdot U \cdot (1 - e^{-1\text{ ms}/(10\text{ }\Omega \cdot 100\text{ }\mu\text{F})})$$

**Exercise E8 Charging Capacitors**  
 (written test, approx. 16 % of a 60-minute written test, WS2022)

The circuit (as shown in the figure) consists of a  $12\text{ V}$  DC voltage source, a  $20\text{ }\Omega$  resistor, a  $100\text{ }\mu\text{F}$  capacitor, a  $20\text{ }\Omega$  resistor, and a light bulb. The voltage across the capacitor is again  $0\text{ V}$  at the moment  $t_0=0\text{ s}$  when the switch  $S_1$  is closed. Calculate the voltage  $u_c(t_2)$  across the capacitor at  $t_2=1\text{ ms}$  after closing the switch.

**Solution** To solve this, first create an equivalent linear voltage source from  $U$ ,  $R_1$ , and  $R_B$ .  

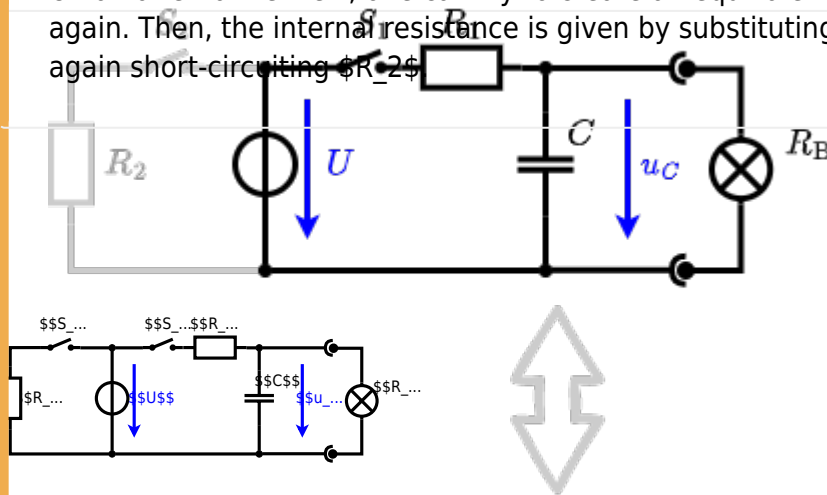
$$U_s = U \cdot \frac{R_B}{R_1 + R_B} = 6\text{ V}$$

$$R_i = R_1 \parallel R_B = 10\text{ }\Omega$$

Solution

The ideal voltage source  $U$  is in series with the internal resistance  $R_1$ . The voltage across the capacitor is  $u_C$ . The voltage across the light bulb is  $u_B$ . The voltage across the resistor  $R_2$  is  $u_{R_2}$ . The voltage across the capacitor is  $u_C$ . The voltage across the light bulb is  $u_B$ . The voltage across the resistor  $R_2$  is  $u_{R_2}$ .

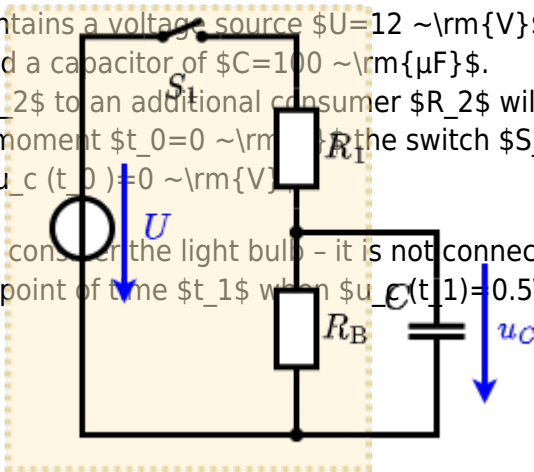
On an alternative view, one can try to create an equivalent linear voltage source again. Then, the internal resistance is given by substituting the ideal voltage source is again short-circuiting  $R_2$ .



The circuit contains a voltage source  $U=12 \text{ V}$ , a switch  $S_1$ , a resistor of  $R_1=20 \text{ }\Omega$  and a capacitor of  $C=100 \text{ }\mu\text{F}$ .

The switch  $S_2$  to an additional consumer  $R_2$  will be considered to be open for the first asks. At the moment  $t_0=0$  the switch  $S_1$  is closed, the voltage across the capacitor is  $u_C(t_0)=0$ .

First do not consider the light bulb - it is not connected to the RC circuit. Calculate the point of time  $t_1$  when  $u_C(t_1)=0.5 \cdot U$ .



Solution

An equivalent linear voltage source can be given with  $U$ ,  $R_1$ , and  $R_B$  as seen in yellow.

Therefore, the voltage of the equivalent linear voltage source is:  $U_s = U \cdot \frac{R_B}{R_1 + R_B} = \frac{1}{2} \cdot U$ . The internal resistance is given by substituting the ideal voltage source with its resistance ( $R=0 \text{ }\Omega$ , short-circuit).  $R_i = R_1 \parallel R_B = 10 \text{ }\Omega$ .

$$u_C(t_2) = U_s \cdot (1 - e^{-t_2/(R_i \cdot C)}) = \frac{1}{2} \cdot U \cdot (1 - e^{-t_2/(10 \text{ }\Omega \cdot 100 \text{ }\mu\text{F})})$$

So, here only  $R_1$  and  $C$  gives the time constant:  $\tau = R_1 \cdot C$

The following formula describes the time course of  $u_C(t)$  which has to be  $u_C(t_1)=0.5 \cdot U$ :  $u_C(t) = U \cdot (1 - e^{-t/\tau}) = 0.5 \cdot U$ . It has to be rearranged to  $(1 - e^{-t/\tau}) = 0.5 \implies e^{-t/\tau} = 0.5 \implies t/\tau = \ln(0.5) \implies t = \tau \cdot \ln(0.5) = R_1 \cdot C \cdot \ln(0.5)$

**Exercise E2 Temperature-dependent Resistance**  
**(written test, approx. 6 % of a 60-minute written test, WS2022)**

2. A refrigerator, explained in the effect course, is in a refrigeration system. The interior of the refrigerator has a temperature of  $25^\circ\text{C}$  and the exterior is at  $25^\circ\text{C}$ . The refrigerator has a power consumption of  $P = 10 \text{ W}$ .

Its temperature coefficients are:  $\alpha = 0.01 \text{ K}^{-1}$  and  $\beta = 71 \cdot 10^{-6} \text{ K}^{-2}$ .

Result: The temperature inside the refrigeration system can reach down to  $-40^\circ\text{C}$ .

Calculate the resistance of the thermistor at  $-40^\circ\text{C}$ .

The power transfer is  $P = U \cdot I$  and  $P = \frac{U^2}{R}$ . Therefore, a solution is to increase the resistance  $R$  of the thermistor. Therefore, with constant  $U$  and increasing  $R$  the power decreases. Ten times more resistance decreases the heat flow to one-tenth.

$$R = R_0 \cdot (1 + \alpha \cdot \Delta T + \beta \cdot \Delta T^2)$$
$$R = 10 \text{ } \Omega \cdot (1 + 0.01 \text{ K}^{-1} \cdot (-40^\circ\text{C} - 25^\circ\text{C}) + 71 \cdot 10^{-6} \text{ K}^{-2} \cdot (-40^\circ\text{C} - 25^\circ\text{C})^2)$$

**Exercise E2 Temperature-dependent Resistance**  
**(written test, approx. 6 % of a 60-minute written test, WS2022)**

2. A refrigerator, explained in the effect course, is in a refrigeration system. The interior of the refrigerator has a temperature of  $25^\circ\text{C}$  and the exterior is at  $25^\circ\text{C}$ . The refrigerator has a power consumption of  $P = 10 \text{ W}$ .

Its temperature coefficients are:  $\alpha = 0.01 \text{ K}^{-1}$  and  $\beta = 71 \cdot 10^{-6} \text{ K}^{-2}$ .

Result: The temperature inside the refrigeration system can reach down to  $-40^\circ\text{C}$ .

Calculate the resistance of the thermistor at  $-40^\circ\text{C}$ .

The power transfer is  $P = U \cdot I$  and  $P = \frac{U^2}{R}$ . Therefore, a solution is to increase the resistance  $R$  of the thermistor. Therefore, with constant  $U$  and increasing  $R$  the power decreases. Ten times more resistance decreases the heat flow to one-tenth.

$$R = R_0 \cdot (1 + \alpha \cdot \Delta T + \beta \cdot \Delta T^2)$$
$$R = 10 \text{ } \Omega \cdot (1 + 0.01 \text{ K}^{-1} \cdot (-40^\circ\text{C} - 25^\circ\text{C}) + 71 \cdot 10^{-6} \text{ K}^{-2} \cdot (-40^\circ\text{C} - 25^\circ\text{C})^2)$$

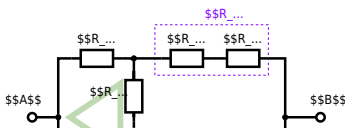
**Exercise E4 Pure Resistor Network Simplification**  
**(written test, approx. 13 % of a 60-minute written test, WS2022)**

The following shall be solved at once, the result is given.  $R_{AB}$ .

Solution

$$R_{eq} = 132.8 \Omega$$

Now a wye-delta transformation is necessary.



Since  $R_2=R_3$  and based on the equations for the transformation, the transformed  $R_Y$  is given as:

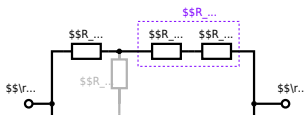
$$R_Y = \frac{R_2 \cdot R_2}{R_2 + R_2 + R_2} = \frac{(100 \Omega)^2}{3 \cdot 100 \Omega} = \frac{1}{3} \cdot 100 \Omega = 33.33 \Omega$$

The equivalent resistor is given by a parallel configuration of resistors in series:

$$R_{eq} = R_Y + (R_Y + R_1 + R_1) \parallel (R_Y + R_2) \parallel (R_Y + R_2)$$

.. The switch shall now be open. Calculate the equivalent resistance  $R_{eq}$  between  $A$  and  $B$ .

Solution



The equivalent resistor is given by a parallel configuration of resistors in series:

$$R_{\text{eq}} = (R_2 + R_1 + R_1) \parallel (R_2 + R_2) \parallel R_{\text{eq}} = (100 \sim\Omega + 200 \sim\Omega + 200 \sim\Omega) \parallel (100 \sim\Omega + 100 \sim\Omega) \parallel R_{\text{eq}} = (500 \sim\Omega) \parallel (200 \sim\Omega) \parallel R_{\text{eq}} = \frac{500 \sim\Omega \cdot 200 \sim\Omega}{500 \sim\Omega + 200 \sim\Omega}$$

**Exercise E1 Resistance of a Wire by Resistivity**  
**(written test, approx. 6 % of a 60-minute written test, WS2022)**

2. The heating element is used to heat the wire with a temperature of  $180 \sim\text{C}$ . The electric power dissipation (= heat flow) of  $P=40 \sim\text{W}$  is necessary. Determine the current  $I$  needed to operate it for heating elements. The Nichrome wire has a resistivity of  $1.10 \cdot 10^{-6} \sim\Omega \cdot \text{m}$ .

The heating element is  $3 \sim\text{m}$  long and has a diameter of  $3.57 \sim\text{mm}$ .  
 Solution: Calculate the resistance  $R$  of the heating element.

Solution

$$P = U \cdot I = R \cdot I^2 \quad \rightarrow \quad I = \sqrt{\frac{P}{R}} = \sqrt{\frac{40 \sim\text{W}}{0.33 \sim\Omega}}$$

$$R = \rho \cdot \frac{l}{A} \quad | \quad \text{with } A = r^2 \cdot \pi = \frac{1}{4} d^2 \cdot \pi \quad \parallel \quad R = \rho \cdot \frac{4 \cdot l}{d^2 \cdot \pi} \quad \parallel \quad R = 1.10 \cdot 10^{-6} \sim\Omega \cdot \text{m} \cdot \frac{4 \cdot 3 \sim\text{m}}{(3.57 \cdot 10^{-3} \sim\text{m})^2 \cdot \pi}$$

## Exercise E1 Resistance of a Wire by Resistivity (written test, approx. 6 % of a 60-minute written test, WS2022)

2. Heating element made of solid nichrome wire with a temperature coefficient of  $1.80 \cdot 10^{-4} \text{ } ^\circ\text{C}^{-1}$ . Electric power dissipation (= heat flow) of  $P=40 \text{ W}$  is necessary.

Calculate the current  $I$  needed to operate it.

The Nichrome wire has a resistivity of  $1.10 \cdot 10^{-6} \text{ } \Omega \cdot \text{m}$ .

The heating element is  $3 \text{ m}$  long and has a diameter of  $3.57 \text{ mm}$ .

∴ Calculate the resistance  $R$  of the heating element.

Solution

$$\begin{aligned} P &= U \cdot I = R \cdot I^2 \quad \rightarrow \quad I = \\ &= \sqrt{\frac{P}{R}} = \sqrt{\frac{40 \text{ W}}{0.33 \text{ } \Omega}} \end{aligned}$$

$$\begin{aligned} R &= \rho \cdot \frac{l}{A} \quad \text{with } A = r^2 \cdot \pi = \\ &= \frac{1}{4} d^2 \cdot \pi \quad R = \rho \cdot \frac{4 \cdot l}{d^2 \cdot \pi} \quad R = \\ &= 1.10 \cdot 10^{-6} \text{ } \Omega \cdot \text{m} \cdot \frac{4 \cdot 3 \text{ m}}{(3.57 \cdot 10^{-3} \text{ m})^2 \cdot \pi} \end{aligned}$$

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