

Exam Winter Semester 2022

Student Group

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

2. For heating elements made of nichrome wire with a temperature coefficient of $1.80 \times 10^{-3} \text{ K}^{-1}$, an electric power dissipation (= heat flow) of $P = 40 \text{ W}$ is necessary.
 a) Calculate the current I needed for heating elements.
 The Nichrome wire has a resistivity of $1.10 \times 10^{-6} \text{ } \Omega \text{ m}$.
 The heating element is 3 m long and has a diameter of 3.57 mm .
 b) Calculate the resistance R of the heating element.

Solution

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

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

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

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Exercise E1 Temperature-dependent Resistance (written test, approx. 6 % of a 60-minute written test, WS2022)

2. Additionally, explain why the effect of constant temperature inside the refrigeration system can reach down to -40°C . The thermistor has a resistance of $10\text{ k}\Omega$ at 25°C . Your answer.

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

Result
The temperature inside the refrigeration system can reach down to -40°C .

Calculate the resistance of the thermistor at -40°C .

The power transfer resistor P is a part of the circuit and generates heat. Therefore, a solution is to use a float up the refrigeration system.
Therefore, with constant U and increasing R the power decreases. Ten times more resistance decreases the heat flow to one-tenth.

$$R = R_0 \cdot (1 + \alpha \cdot \Delta T + \beta \cdot \Delta T^2) \quad | \quad \Delta T = T_{\text{end}} - T_{\text{start}} \\ R = 10 \text{ k}\Omega \cdot \left(1 + 0.01 \cdot 10^{-6} \cdot (-40 - 25) + 71 \cdot 10^{-6} \cdot (-40 - 25)^2 \right)$$

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

2. Additionally, explain why the effect of constant temperature inside the refrigeration system can reach down to -40°C . The thermistor has a resistance of $10\text{ k}\Omega$ at 25°C . Your answer.

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

Result
The temperature inside the refrigeration system can reach down to -40°C .

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Therefore, with constant U and increasing R the power decreases. Ten times more resistance decreases the heat flow to one-tenth.

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Exercise E1 Pure Resistor Network Simplification

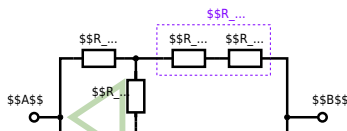
(written test, approx. 13 % of a 60-minute written test, WS2022)

The following shall now be closed and integrated, $R_2 = R_3 = 100 \Omega$ and the switch between R_2 and R_3 shall be open. Calculate the equivalent resistance R_{eq} between A and B .

Solution

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

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:

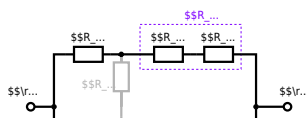
$$R_Y = \frac{R_2 \cdot R_3}{R_2 + R_3} = \frac{100 \cdot 100}{100 + 100} = 50 \Omega$$

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

$$R_{\text{eq}} = R_Y + (R_Y + R_1 + R_1) \parallel (R_Y + R_2) = 50 + (50 + 100 + 100) \parallel (50 + 100)$$

.. 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:

$$R_{eq} = (R_2 + R_1 + R_1) \parallel (R_2 + R_2) \parallel (100 \, \Omega + 200 \, \Omega + 200 \, \Omega) \parallel (100 \, \Omega + 100 \, \Omega) \parallel (500 \, \Omega) \parallel (200 \, \Omega) \parallel (500 \, \Omega \cdot 200 \, \Omega) / (500 \, \Omega + 200 \, \Omega)$$

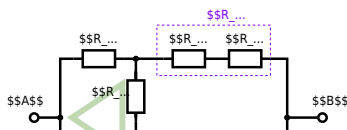
Exercise E3 Pure Resistor Network Simplification (written test, approx. 13 % of a 60-minute written test, WS2022)

The following shall be solved with \$R_1=200 \, \Omega\$, \$R_2=100 \, \Omega\$, \$R_3=150 \, \Omega\$, \$R_4=100 \, \Omega\$, and \$R_5=200 \, \Omega\$.
Result given: \$R_{eq} = 132.8 \, \Omega\$.

Solution

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

Now a wye-delta transformation is necessary.



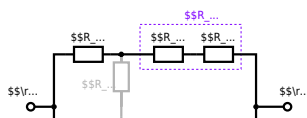
Since $R_2 = R_3$ and based on the equations for the transformation, the transformed R_Y is given as:
$$R_Y = \frac{R_2 \cdot R_2}{R_2 + R_2 + R_2} = \frac{(100 \, \Omega)^2}{3 \cdot 100 \, \Omega} = \frac{1}{3} \cdot 100 \, \Omega = 33.33 \, \Omega$$

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

$$R_{\text{eq}} = R_Y + (R_Y + R_1 + R_1) \parallel (R_Y + R_2) \parallel R_{\text{eq}} = 33.33 \, \Omega + (33.33 \, \Omega + 400 \, \Omega) \parallel (33.33 \, \Omega + 100 \, \Omega)$$

1. 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:

$$\begin{aligned} R_{\text{eq}} &= (R_2 + R_1 + R_3) \parallel (R_4 + R_5) \\ R_{\text{eq}} &= (100 \, \Omega + 200 \, \Omega + 200 \, \Omega) \parallel (100 \, \Omega + 100 \, \Omega) \\ R_{\text{eq}} &= (500 \, \Omega) \parallel (200 \, \Omega) \\ R_{\text{eq}} &= \frac{500 \, \Omega \cdot 200 \, \Omega}{500 \, \Omega + 200 \, \Omega} \end{aligned}$$

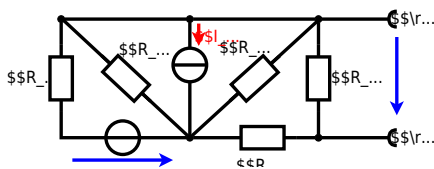
Exercise E1 Equivalent linear Source

(written test, approx. 14 % of a 60-minute written test, WS2022)

The circuit in the following has to be simplified.

Result

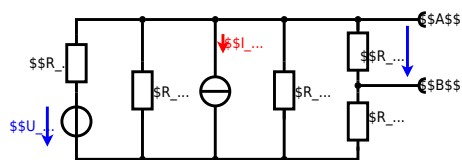
$$\begin{aligned} U_s &= U_{\text{AB}} = 4.5 \, \text{V} \\ R_i &= R_{\text{AB}} = 6 \, \Omega \end{aligned}$$



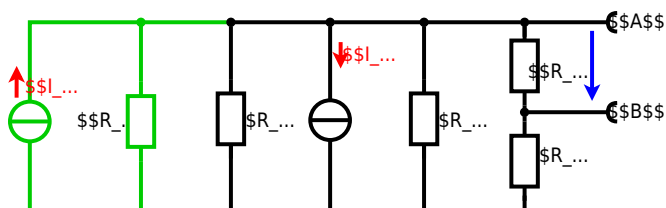
Calculate the internal resistance R_{int} and the source voltage U_{S} of an equivalent linear voltage source on the connectors A and B. $\begin{aligned} R_1 &= 5.0 \, \Omega, \quad U_2 = 6.0 \, \text{V}, \quad R_3 = 10 \, \Omega, \quad I_4 = 4.2 \, \text{A}, \\ R_5 &= 10 \, \Omega, \quad R_6 = 7.5 \, \Omega, \quad R_7 = 15 \, \Omega \end{aligned}$ 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 :

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

$$I_{24} = I_2 - I_4 = \frac{U_2}{R_1} - I_4$$

The resulting circuit can again be transformed:



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

$$U_{24} = I_{24} \cdot R_{135}$$

$$U_{24} = U_2 \cdot \frac{R_7}{R_6 + R_7 + R_1 || R_3 || R_5} = (U_2 - U_4) \cdot \frac{R_1 || R_3 || R_5}{R_6 + R_7 + R_1 || R_3 || R_5}$$

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:

$$U_{AB} = U_{24} \cdot \frac{R_7}{R_6 + R_7 + R_1 || R_3 || R_5} = (U_2 - U_4) \cdot \frac{R_7 \cdot R_1 || R_3 || R_5}{R_6 + R_7 + R_1 || R_3 || R_5}$$

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

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

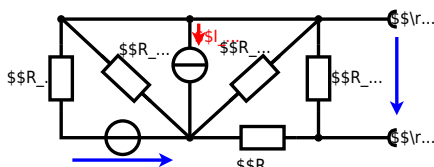
with $R_1 || R_3 || R_5 = 5\Omega || 10\Omega || 10\Omega = 5\Omega || 5\Omega = 2.5\Omega$:

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

Exercise E4 Equivalent linear Source (written test, approx. 14 % of a 60-minute written test, WS2022)

The circuit in the following has to be simplified.
Result

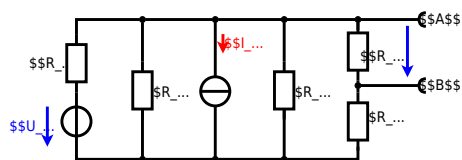
$$U_s = U_{AB} = 4.5\text{V} \quad R_i = R_{AB} = 6\Omega$$



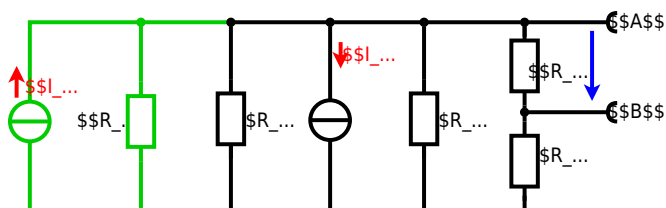
Calculate the internal resistance R_{int} and the source voltage U_s of an equivalent linear voltage source on the connectors A and B. $\begin{aligned} R_1 &= 5.0 \, \Omega, \quad U_2 = 6.0 \, \text{V}, \quad R_3 = 10 \, \Omega, \quad I_4 = 4.2 \, \text{A}, \\ R_5 &= 10 \, \Omega, \quad R_6 = 7.5 \, \Omega, \quad R_7 = 15 \, \Omega \end{aligned}$ 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 :

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

$$I_{24} = I_2 - I_4 = \frac{U_2}{R_1} - I_4$$

The resulting circuit can again be transformed:



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

$$U_{24} = I_{24} \cdot R_4$$

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

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:

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

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

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

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

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

Exercise E1 Charging Capacitors

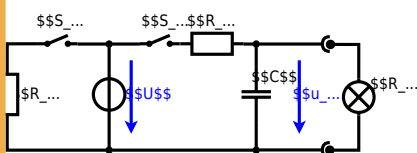
(written test, approx. 16 % of a 60-minute written test, WS2022)

The circuit below is a simplified model of a circuit for charging a capacitor. The circuit consists of a voltage source U , a switch S_1 , a resistor R_1 , a capacitor C , and a resistor R_2 . The voltage across the capacitor is again 0 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.

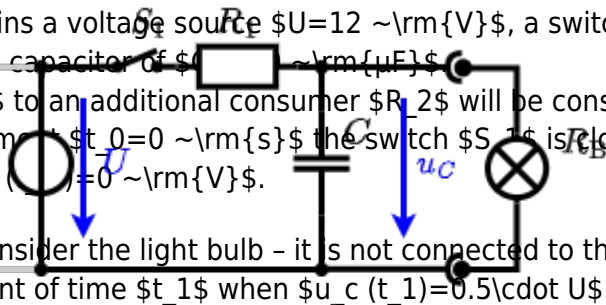
Hint: To solve this, first create an equivalent linear voltage source from U , R_1 , and R_2 .

Solution: The circuit can be simplified to a single loop circuit. The voltage source U is in series with R_1 and R_2 . The voltage across the capacitor is $u_c(t_2)$.

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 .



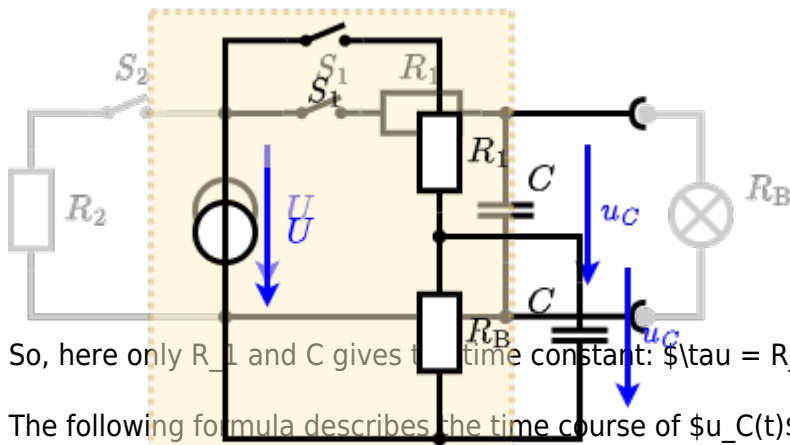
The circuit contains a voltage source $U=12\text{ V}$, a switch S_1 , a resistor of $R_1=20\text{ }\Omega$ and a capacitor of $C=100\text{ }\mu\text{F}$. The switch S_2 to an additional consumer R_2 will be considered to be open for the first task. At the moment $t_0=0\text{ s}$ the switch S_1 is closed,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

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 ($=0\text{ }\Omega$, 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 E5 Charging Capacitors

(written test, approx. 16 % of a 60-minute written test, WS2022)

The circuit (see the solution) consists of a 12 V DC voltage source U , a switch S_1 , a resistor $R_1=20\text{ }\Omega$, a capacitor $C=100\text{ }\mu\text{F}$, and a light bulb $R_B=20\text{ }\Omega$. The voltage across the capacitor is again 0 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

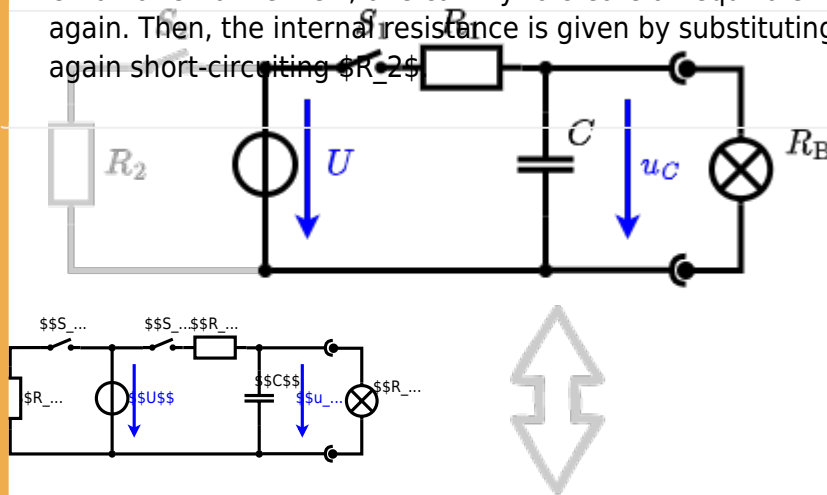
To solve this, first create an equivalent linear voltage source from U , R_1 , and R_B .

$$U_s = U \cdot \frac{R_B}{R_1 + R_B} = \frac{1}{2} \cdot U = 6\text{ V}$$

Solution

The ideal voltage source is given by $U_s = U \cdot \frac{R_1}{R_1 + R_B}$ and the internal resistance is given by $R_i = R_1 \parallel R_B$.

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 .

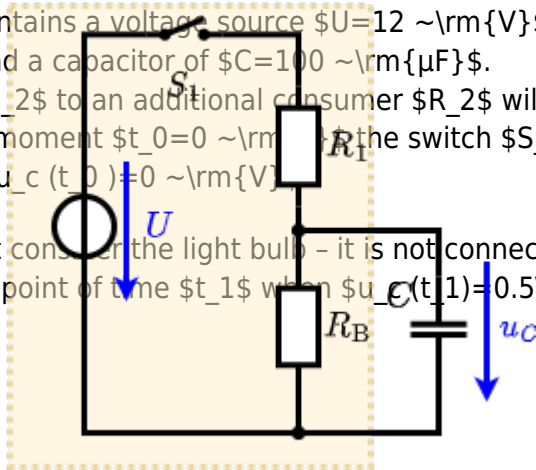


The circuit contains a voltage source $U = 12 \text{ V}$, a switch S_1 , a resistor of $R_1 = 20 \text{ }\Omega$ and a capacitor of $C = 100 \text{ }\mu\text{F}$.

The switch S_2 to an additional consumer R_2 will be considered to be open for the first tasks. At the moment $t_0 = 0$ 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

An equivalent linear voltage source can be given with U_s , 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 ($R_i = 0 \text{ }\Omega$, short-circuit).

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

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 E1 Analyzing complex Impedances**(written test, approx. 14 % of a 60-minute written test, WS2022)**

2. Calculate the phase angle of the solution $\underline{U} = 50 \angle 0^\circ$ mV and $\underline{Z} = 0.24 - j4.68 \Omega$ in both the components. ($\$R\$$ and $\$ \underline{X}_L \$$) shall be given.

After analysis, the full bridge dimensioned impedance can be extracted and the phase angle in phase with the voltage $\underline{U} = 50 \angle 0^\circ$ mV and $\underline{Z} = 0.24 - j4.68 \Omega$ in both the components.

.. Calculate the physical values of the two components.

Solution $\begin{aligned} R &= 0.24 \Omega \\ X_L &= 4.68 \Omega \end{aligned}$

Solution

$\underline{I} = \frac{\underline{U}}{\underline{Z}} = \frac{50 \angle 0^\circ}{0.24 - j4.68} = 10.42 \angle 87.96^\circ$ A

The current and voltage are in phase with the voltage $\underline{U} = 50 \angle 0^\circ$ mV and $\underline{Z} = 0.24 - j4.68 \Omega$ in both the components.

Therefore, the component 0.24Ω is a resistor with the same absolute value of 0.24Ω impedance. $\underline{X}_L = j4.68 \Omega$ is an inductor with the same absolute value of 4.68Ω impedance.

The phase angle φ can be calculated as $\varphi = \arctan\left(\frac{\text{Im}(\underline{I})}{\text{Re}(\underline{I})}\right) = \arctan\left(\frac{-4.68}{0.24}\right) = -87.96^\circ$

With the complex part $0.24 - j4.68 \Omega$ in both the components, $\underline{I} = 10.42 \angle 87.96^\circ$ A

The phase angle φ can be calculated as $\varphi = \arctan\left(\frac{\text{Im}(\underline{I})}{\text{Re}(\underline{I})}\right) = \arctan\left(\frac{-4.68}{0.24}\right) = -87.96^\circ$

Exercise E6 Analyzing complex Impedances**(written test, approx. 14 % of a 60-minute written test, WS2022)**

2. Calculate the phase angle of the solution $\underline{U} = 50 \angle 0^\circ$ mV and $\underline{Z} = 0.24 - j4.68 \Omega$ in both the components. ($\$R\$$ and $\$ \underline{X}_L \$$) shall be given.

After analysis, the full bridge dimensioned impedance can be extracted and the phase angle in phase with the voltage $\underline{U} = 50 \angle 0^\circ$ mV and $\underline{Z} = 0.24 - j4.68 \Omega$ in both the components.

.. Calculate the physical values of the two components.

Solution $\begin{aligned} R &= 0.24 \Omega \\ X_L &= 4.68 \Omega \end{aligned}$

Solution

$\underline{I} = \frac{\underline{U}}{\underline{Z}} = \frac{50 \angle 0^\circ}{0.24 - j4.68} = 10.42 \angle 87.96^\circ$ A

The current and voltage are in phase with the voltage $\underline{U} = 50 \angle 0^\circ$ mV and $\underline{Z} = 0.24 - j4.68 \Omega$ in both the components.

Therefore, the component 0.24Ω is a resistor with the same absolute value of 0.24Ω impedance. $\underline{X}_L = j4.68 \Omega$ is an inductor with the same absolute value of 4.68Ω impedance.

The phase angle φ can be calculated as $\varphi = \arctan\left(\frac{\text{Im}(\underline{I})}{\text{Re}(\underline{I})}\right) = \arctan\left(\frac{-4.68}{0.24}\right) = -87.96^\circ$

The absolute value of the impedance is $\sqrt{(0.24 \sim \Omega)^2 + (4.68 \sim \Omega)^2} = 4.7 \sim \Omega$.
 The phase φ is $\arctan\left(\frac{4.68}{0.24}\right) = 87.1^\circ$.
 With the complex part comes the physical value: $X_L = \omega L = 2\pi f L = 2\pi \cdot 4.7 \sim \Omega \cdot 10^{-6} \text{ s} = 29.4 \sim \mu\text{s}$.
 The phase φ is $\arctan\left(\frac{4.68}{0.24}\right) = 87.1^\circ$.
 The phase φ is $\arctan\left(\frac{4.68}{0.24}\right) = 87.1^\circ$.

Exercise E1 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 and L combined is given by $Z = \sqrt{R^2 + X_L^2}$.
 Parallel circuit means that the voltage is the same on R_3 and C_2 .
 The equivalent impedance for R_3 and C_2 combined is given by $Z = \frac{R_3 \cdot X_C}{R_3 + X_C}$.
 Back to the first formula: $R_3 \cdot X_C = Z^2 \cdot (R_3 + X_C)$.
 Result: $R_3 = 1.00 \sim \Omega$.
 Back to the first formula: $R_3 \cdot X_C = Z^2 \cdot (R_3 + X_C)$.
 Result: $R_3 = 1.00 \sim \Omega$.

Solution

$R_1 = 1.00 \sim \Omega$

$R_2 = 10.0 \sim \Omega$

A series circuit means that the current is constant on every component.

The equivalent impedance for R and L combined is given by $Z = \sqrt{R^2 + X_L^2}$.

Parallel circuit means that the voltage is the same on R_3 and C_2 .
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 Back to the first formula: $R_3 \cdot X_C = Z^2 \cdot (R_3 + X_C)$.
 Result: $R_3 = 1.00 \sim \Omega$.

The equivalent impedance for R_3 and C_2 combined is given by $Z = \frac{R_3 \cdot X_C}{R_3 + X_C}$.
 Back to the first formula: $R_3 \cdot X_C = Z^2 \cdot (R_3 + X_C)$.
 Result: $R_3 = 1.00 \sim \Omega$.

Therefore, the resulting current of the parallel circuit is given as: $I = \frac{U}{Z}$.

The equivalent impedance for R_3 and C_2 combined is given by $Z = \frac{R_3 \cdot X_C}{R_3 + X_C}$.

Back to the first formula: $R_3 \cdot X_C = Z^2 \cdot (R_3 + X_C)$.
 Result: $R_3 = 1.00 \sim \Omega$.

Back to the first formula: $R_3 \cdot X_C = Z^2 \cdot (R_3 + X_C)$.
 Result: $R_3 = 1.00 \sim \Omega$.

Back to the first formula: $R_3 \cdot X_C = Z^2 \cdot (R_3 + X_C)$.
 Result: $R_3 = 1.00 \sim \Omega$.

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 Result: $R_3 = 1.00 \sim \Omega$.

Back to the first formula: $R_3 \cdot X_C = Z^2 \cdot (R_3 + X_C)$.
 Result: $R_3 = 1.00 \sim \Omega$.

Back to the first formula: $R_3 \cdot X_C = Z^2 \cdot (R_3 + X_C)$.
 Result: $R_3 = 1.00 \sim \Omega$.

Exercise E7 Impedances at different Frequencies

(written test, approx. 18 % of a 60-minute written test, WS2022)

Reactive power is the real resistor value of $20 \pm 3 \text{ m}\Omega$ in parallel with a capacitor having impedance of $35 \pm 3 \text{ }\Omega$. B.0
 $\sim \text{m}\Omega$, $\text{fitB} = 200 \sim 450 \text{ kHz}$, Hz high gene test current $\text{fitB} = \$0 \{3R\} \sim 1 \text{ A}$ $\sim \text{m}\Omega$ A\$ through
 a resistor R_1 shall have the same absolute value of the impedance as a capacitor
 $C_1 = 40 \sim \text{nF}$ at $f_1 = 4 \sim \text{MHz}$.

$$\begin{aligned} \text{solution} \quad \begin{aligned} \text{begin}\{align*\} \quad R_1 &= 1.00 \sim \Omega \end{aligned} \\ \text{solution} \quad \begin{aligned} \text{begin}\{align*\} \quad R_2 &= 10.0 \sim \Omega \end{aligned} \\ \text{solution} \end{aligned}$$

A series circuit means that the current is constant on every component.

The equivalent impedance for R_S and L_S combined is given by $\begin{aligned} \text{Parallel circuit means that the voltage is the same on } R_S \text{ and } L_S \\ \text{Since } \underline{I}_S \text{ is perpendicular to } \underline{I}_L \text{, the resulting current } \underline{I}_S \text{ is perpendicular to } \underline{I}_L \text{, thus can be simplified to } \sqrt{I_{S_R}^2 + I_{S_L}^2} \end{aligned}$ (It has to, since R_S is perpendicular to $\sqrt{I_{S_R}^2 + I_{S_L}^2}$ too)

Therefore the resulting current of the parallel circuit is given as:

$$\underline{I}_S = \sqrt{I_{S_R}^2 + I_{S_L}^2}$$

This can be rearranged to give $\underline{I}_S = \sqrt{I_{S_R}^2 + I_{S_L}^2}$

Back to the first formula:

$$R_3 \cdot \underline{I}_S = X_{L3} \cdot \frac{\underline{I}_S}{\sqrt{I_{S_R}^2 + I_{S_L}^2}}$$
$$\underline{I}_S = \frac{X_{L3}}{R_3} \cdot \frac{\underline{I}_S}{\sqrt{I_{S_R}^2 + I_{S_L}^2}}$$
$$\sqrt{I_{S_R}^2 + I_{S_L}^2} = \frac{X_{L3}}{R_3}$$

Exercise E1 Complex Impedance Circuit

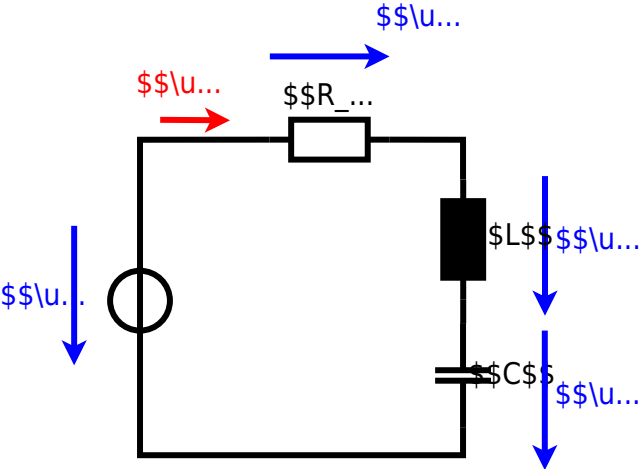
(written test, approx. 15 % of a 60-minute written test, WS2022)

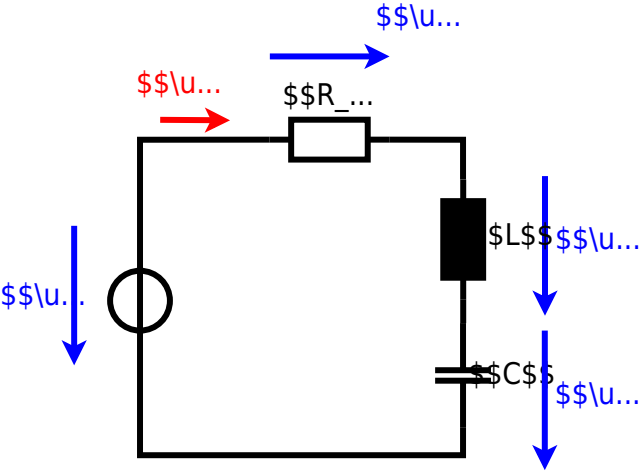
[illegible]

Solution
This linear source is connected with an inductor of $330 \sim \{\rm \mu H\}$ and a capacitor of $0.22 \sim \{\rm \mu F\}$, all in series.

$$\begin{aligned} Z &= 107.3 \, \Omega \parallel (48.2 \, \Omega + j19.8 \, \Omega) \\ Z &= 71.1 \, \Omega - j16.6 \, \Omega \end{aligned}$$
$$\begin{aligned} \text{With } \underline{Z} &= \sqrt{Z_L^2 + Z_C^2} \text{ and } \underline{\phi} = \tan^{-1} \left(\frac{Z_C}{Z_L} \right) \\ \underline{I} &= \frac{V}{\underline{Z}} = \frac{V}{\sqrt{Z_L^2 + Z_C^2}} \angle -\phi \\ \underline{I} &= \frac{V}{\sqrt{Z_L^2 + Z_C^2}} \angle -\phi \end{aligned}$$







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