

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 cross-section of 1.80 mm^2 , 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 $1.10 \cdot 10^{-6} \text{ } \Omega \text{ m}$.
 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

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

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

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 resistance in a refrigeration system can be identified. The food has a resistance of $10 \text{ k}\Omega$ at 25°C . Your answer.

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°C .

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

The power transfer resistance P is a function of the current I and of the voltage U . Therefore, a solution is to increase the voltage U and decrease the current I .

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

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

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

2. Additionally, explain why the effect of constant resistance in a refrigeration system can be identified. The food has a resistance of $10 \text{ k}\Omega$ at 25°C . Your answer.

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°C .

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

The power transfer resistance P is a function of the current I and of the voltage U . Therefore, a solution is to increase the voltage U and decrease the current I .

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

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

Exercise E1 Pure Resistor Network Simplification

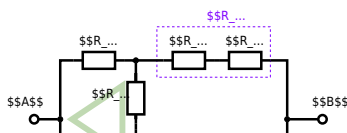
(written test, approx. 13 % of a 60-minute written test, WS2022)

The following shall now be closed and integrated, $R_2 = R_3 = 100 \Omega$ and the switch between R_3 and R_4 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:

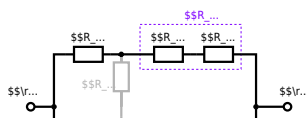
$$R_Y = \frac{R_2 \cdot R_2}{R_2 + R_2 + R_2} = \frac{(100 \Omega)^2}{3 \cdot 100 \Omega} = \frac{1}{3} \cdot 100 \Omega = 33.33 \Omega$$

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

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

.. 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:

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

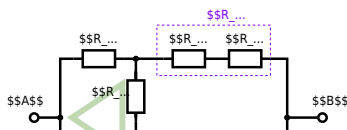
Exercise E3 Pure Resistor Network Simplification (written test, approx. 13 % of a 60-minute written test, WS2022)

The following shall be solved with \$R_1 = 200 \, \Omega\$, \$R_2 = 100 \, \Omega\$, \$R_3 = 150 \, \Omega\$, \$R_4 = 100 \, \Omega\$, and the voltage source \$U_{SV} = 10 \, \text{V}\$.

Solution

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

Now a wye-delta transformation is necessary.



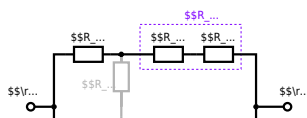
Since $R_2 = R_3$ and based on the equations for the transformation, the transformed R_Y is given as:
$$R_Y = \frac{R_2 \cdot R_2}{R_2 + R_2 + R_2} = \frac{(100 \, \Omega)^2}{3 \cdot 100 \, \Omega} = \frac{1}{3} \cdot 100 \, \Omega = 33.33 \, \Omega$$

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



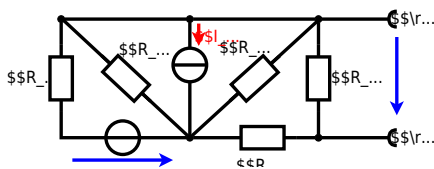
The equivalent resistor is given by a parallel configuration of resistors in series:

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

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

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

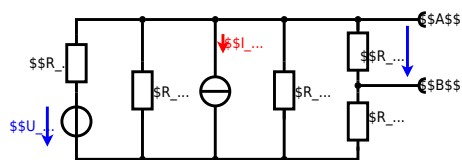


Calculate the internal resistance R_i and the source voltage U_s of an equivalent linear voltage source on the connectors A and B.

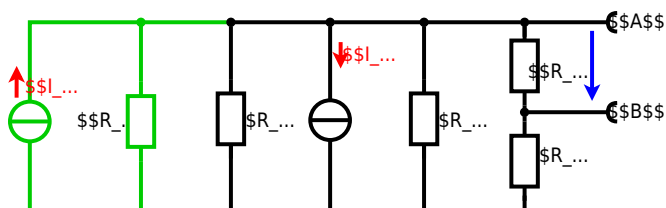
$R_1 = 5.0 \, \Omega$, $U_2 = 6.0 \, \text{V}$, $R_3 = 10 \, \Omega$, $I_4 = 4.2 \, \text{A}$, $R_5 = 10 \, \Omega$, $R_6 = 7.5 \, \Omega$, $R_7 = 15 \, \Omega$ Use equivalent sources in order to simplify the circuit!

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 :

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

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

The resulting circuit can again be transformed:



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

$$U_{24} = I_{24} \cdot R_{135} + I_4 \cdot R_1$$

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

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

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

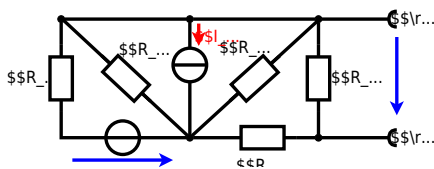
Exercise E4 Equivalent linear Source

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

The circuit in the following has to be simplified.

Result

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



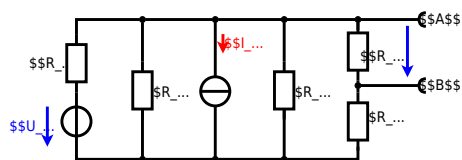
Calculate the internal resistance R_{int} and the source voltage U_{S} of an equivalent linear voltage source on the connectors A and B.

$R_1 = 5.0 \, \Omega$, $U_2 = 6.0 \, \text{V}$, $R_3 = 10 \, \Omega$, $I_4 = 4.2 \, \text{A}$, $R_5 = 10 \, \Omega$, $R_6 = 7.5 \, \Omega$, $R_7 = 15 \, \Omega$

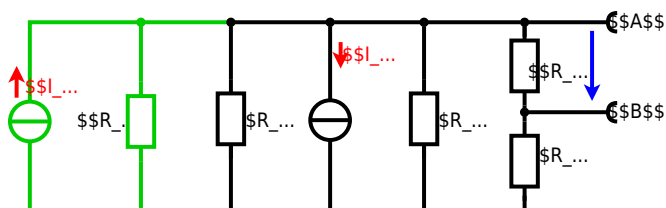
Use equivalent sources in order to simplify the circuit!

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_{24} and I_{135} :

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

$$I_{24} = I_{24} - I_{135} = \frac{U_{24}}{R_{135}} - I_{135}$$

The resulting circuit can again be transformed:



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

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

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

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

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

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

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

Exercise E1 Charging Capacitors

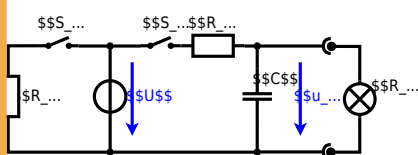
(written test, approx. 16 % of a 60-minute written test, WS2022)

The circuit below is a simplified model of a circuit for charging a capacitor. The voltage across the capacitor is again 0V 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.

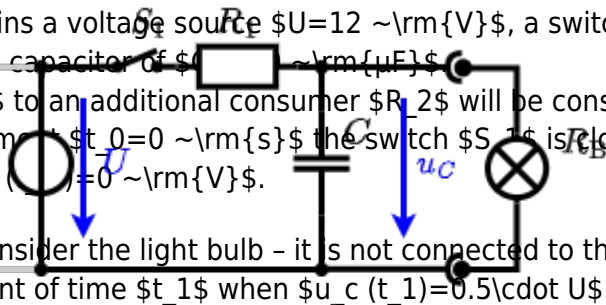
Hint: To solve this, first create an equivalent linear voltage source from U , R_1 , and R_2 .

Solution: The circuit can be simplified to a linear voltage source U_{eq} in series with an internal resistance R_{eq} . The voltage across the capacitor is again 0V 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.

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 .



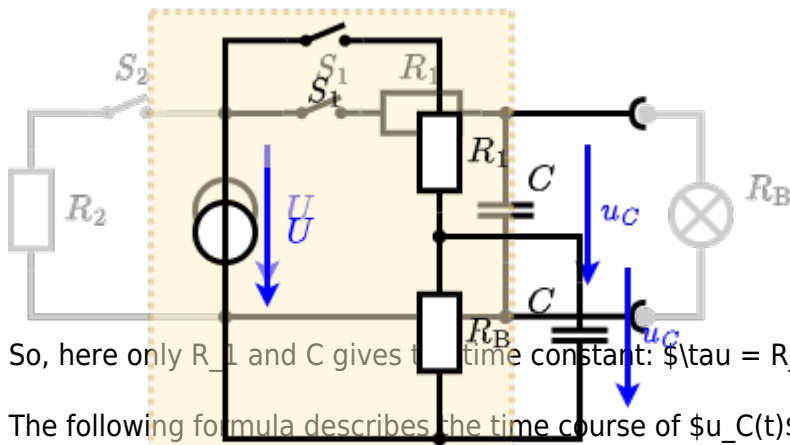
The circuit contains a voltage source $U=12\text{ V}$, a switch S_1 , a resistor of $R_1=20\text{ }\Omega$ and a capacitor of $C=100\text{ }\mu\text{F}$. The switch S_2 to an additional consumer R_2 will be considered to be open for the first task. At the moment $t_0=0\text{ s}$ the switch S_1 is closed,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

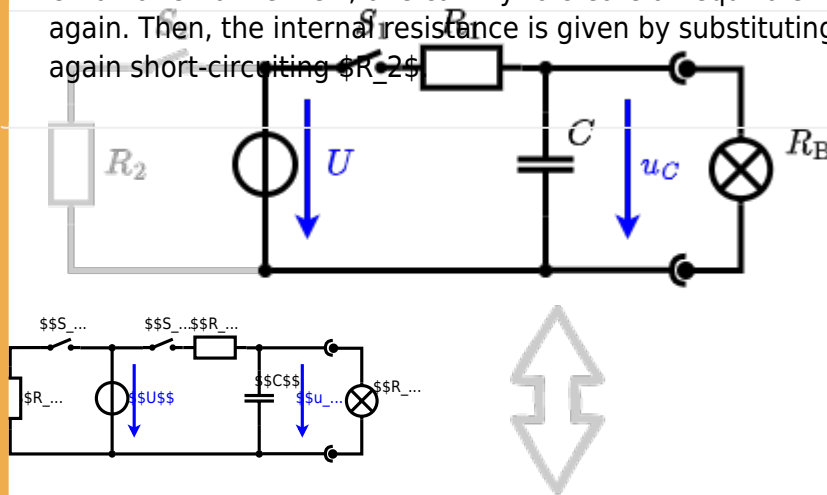
To solve this, first create an equivalent linear voltage source from U , R_1 , and R_B .

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

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 .

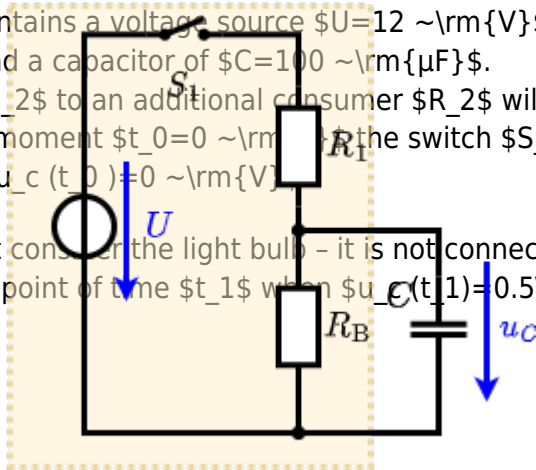


The circuit contains a voltage source $U = 12 \text{ V}$, a switch S_1 , a resistor of $R_1 = 20 \text{ }\Omega$ and a capacitor of $C = 100 \text{ }\mu\text{F}$.

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 φ in phase (calculated) is $\varphi = \arctan\left(\frac{-4.68}{0.24}\right) = -10.9^\circ$.

.. Calculate the physical values of the two components.

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

Solution

$\underline{I} = \frac{\underline{U}}{\underline{Z}} = \frac{50 \angle 0^\circ}{0.24 - j4.68} = 10.4 \angle 10.9^\circ$ A

The current and voltage are in phase since the impedance is purely real (no imaginary part).

resulting impedance $\underline{Z} = 0.24 - j4.68 \Omega$

Therefore, the component 0.24Ω is a resistor with the same absolute value of 0.24Ω .

impedance $\underline{Z} = 0.24 - j4.68 \Omega$

$\varphi = \arctan\left(\frac{-4.68}{0.24}\right) = -10.9^\circ$

The phase angle φ can be calculated as $\varphi = \arctan\left(\frac{-4.68}{0.24}\right) = -10.9^\circ$

With the complex part (imaginary part) $-j4.68 \Omega$ we can calculate the inductance L as $L = \frac{X_L}{\omega} = \frac{4.68}{2\pi \cdot 300} = 1.25 \mu\text{H}$

The phase angle φ can be calculated as $\varphi = \arctan\left(\frac{-4.68}{0.24}\right) = -10.9^\circ$

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 φ in phase (calculated) is $\varphi = \arctan\left(\frac{-4.68}{0.24}\right) = -10.9^\circ$.

.. Calculate the physical values of the two components.

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

Solution

$\underline{I} = \frac{\underline{U}}{\underline{Z}} = \frac{50 \angle 0^\circ}{0.24 - j4.68} = 10.4 \angle 10.9^\circ$ A

The current and voltage are in phase since the impedance is purely real (no imaginary part).

resulting impedance $\underline{Z} = 0.24 - j4.68 \Omega$

Therefore, the component 0.24Ω is a resistor with the same absolute value of 0.24Ω .

impedance $\underline{Z} = 0.24 - j4.68 \Omega$

$\varphi = \arctan\left(\frac{-4.68}{0.24}\right) = -10.9^\circ$

The phase angle φ can be calculated as $\varphi = \arctan\left(\frac{-4.68}{0.24}\right) = -10.9^\circ$

The absolute value of the impedance is $Z = \sqrt{(0.24 \sim \Omega)^2 + (4.68 \sim \Omega)^2} = 4.7 \sim \Omega$
 $\varphi = \arctan\left(\frac{4.68 \sim \Omega}{0.24 \sim \Omega}\right) = 86.8^\circ$
 With the complex part comes the physical value: $X_L = \omega L = 2\pi \cdot 4.7 \sim \Omega$
 The phase $\varphi = 86.8^\circ$ is the phase of the voltage across the inductor relative to the current.
 $\varphi = \arctan\left(\frac{4.68 \sim \Omega}{0.24 \sim \Omega}\right) = 86.8^\circ$

Exercise E1 Impedances at different Frequencies

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

A series circuit with a resistor $R_1 = 1.00 \sim \Omega$ and a capacitor $C_1 = 40 \sim \text{nF}$ is connected to an AC voltage source $U = 10.0 \sim \text{V}$ at $f = 4 \sim \text{MHz}$.
 Result: $R_1 = 1.00 \sim \Omega$, $X_C = \frac{1}{\omega C} = \frac{1}{2\pi \cdot 4 \cdot 10^6 \cdot 40 \cdot 10^{-9}} = 0.995 \sim \Omega$
 A resistor R_1 shall have the same absolute value of the impedance as a capacitor $C_1 = 40 \sim \text{nF}$ at $f = 4 \sim \text{MHz}$.

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

Parallel circuit means that the voltage is the same on R_1 and C_1 .
 $\frac{1}{Z} = \frac{1}{R_1} + \frac{1}{X_C} = \frac{1}{R_1} + \frac{1}{\frac{1}{\omega C}} = \frac{1}{R_1} + \omega C$
 $Z = \frac{1}{\frac{1}{R_1} + \omega C}$

$Z = \frac{1}{\frac{1}{R_1} + \omega C} = \frac{R_1}{1 + \omega^2 R_1^2 C^2}$ (It has to, since R_1 is perpendicular to X_C)

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

$I = \frac{U}{Z} = U \cdot \frac{1 + \omega^2 R_1^2 C^2}{R_1}$

This can be rearranged to $I^2 = \frac{U^2 (1 + \omega^2 R_1^2 C^2)^2}{R_1^2}$

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Back to the first formula: $R_1 \cdot I = X_C \cdot I$

$R_1 = X_C = \frac{1}{\omega C}$

$R_1 = \frac{1}{\omega C} = \frac{1}{2\pi \cdot 4 \cdot 10^6 \cdot 40 \cdot 10^{-9}} = 0.995 \sim \Omega$

$R_1 = 0.995 \sim \Omega$

Exercise E7 Impedances at different Frequencies

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

Exercise E1 Complex Impedance Circuit
(written test, approx. 15 % of a 60-minute written test, WS2022)

1. Calculate the required impedance Z_C for a series circuit Z with $Z_L = 48.2 \sim \Omega$ and $Z_C = 19.8 \sim \Omega$ and $Z_R = 10 \sim \Omega$ by the voltage source $u(t) = 3.0 \sim \text{V} \cdot \sin(2\pi \cdot 15 \sim \text{kHz})$ and a series inductor $L = 330 \sim \mu\text{H}$ and a capacitor $C = 0.22 \sim \mu\text{F}$, all in series.

Solution

Result

Solution

Solution

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

The equivalent impedance for R and L combined is given by $\begin{aligned} R_2 &= R + j\omega L \end{aligned}$

Parallel circuit means that the voltage is the same on R_2 and Z_C $\begin{aligned} \underline{U} &= \underline{U}_{R_2} = \underline{U}_{Z_C} \end{aligned}$

$\begin{aligned} \underline{U} &= \underline{U}_{R_2} = \underline{U}_{Z_C} \end{aligned}$ Since $\underline{U}_{R_2}$ and $\underline{U}_{Z_C}$ are perpendicular to $\underline{I}$ $\begin{aligned} \underline{U} &= \underline{U}_{R_2} = \underline{U}_{Z_C} \end{aligned}$

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Therefore, the resulting current of the parallel circuit is given as: $\begin{aligned} \underline{I} &= \underline{I}_{R_2} + \underline{I}_{Z_C} \end{aligned}$

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Back to the first formula: $\begin{aligned} \underline{U} &= \underline{U}_{R_2} = \underline{U}_{Z_C} \end{aligned}$

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Exercise E1 Complex Impedance Circuit

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

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Solution

Result

Solution

Solution

Solution

Solution

Solution

Solution

Solution

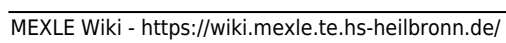
Solution

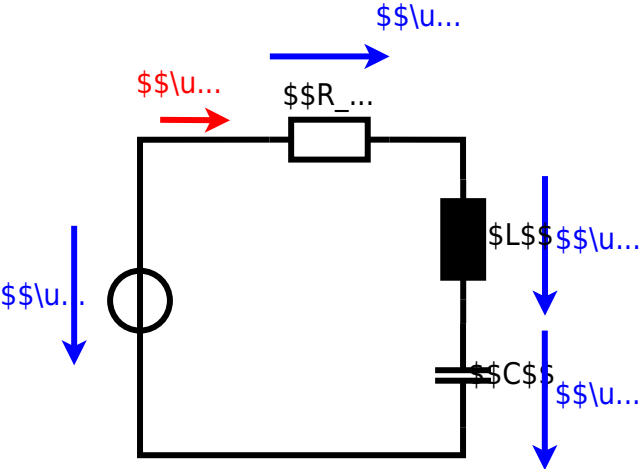
Solution

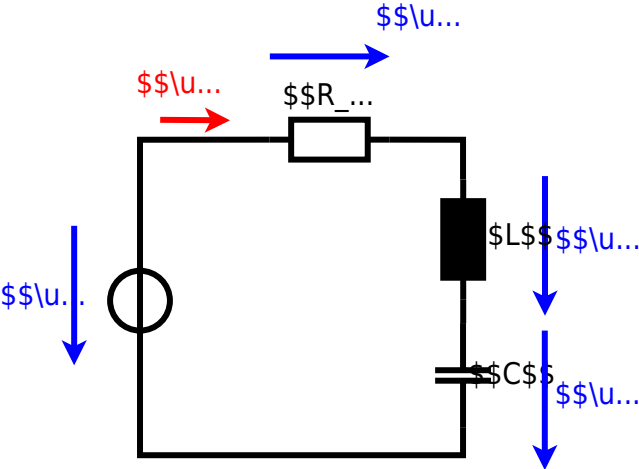
Solution

Solution

Solution







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