

# Exam Winter Semester 2022

## Student Group

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# Exam Summer Semester 2021

## Additional permitted Aids

- non-programmable calculator,
- formulary (4 one-sided DIN A4 pages)

## Hits

- The duration of the exam is 120 min.
- Attempts to cheat will lead to exclusion and failure of the exam.
- Withdrawal is no longer possible after these exam has been handed out.
- Please write down intermediate calculations and results on the assignment sheet. (when more space is needed also on the reverse side. In this case: Mark it clearly).
- Always use units in the calculation.
- Use a document-proof, non-red pen.
- Sub-tasks, which are independently solvable are marked with: (independent)
- Sub-tasks, which are hard are marked with: (hard)

## Tasks

### Exercise E8 Charging Capacitors

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

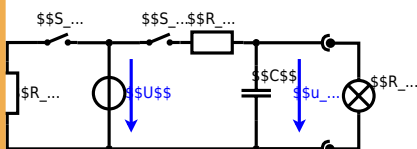
The circuit (with the realisation) is in the picture. For  $t < 0$  the switch  $S_1$  is open and the voltage across the capacitor is again  $0 \text{ V}$  at the moment  $t_0 = 0 \text{ s}$  when the switch  $S_1$  is closed. Calculate the voltage  $u_c(t_2)$  across the capacitor at  $t_2 = 1 \text{ ms}$  after closing the switch.

#### Resolution

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

Solution: The internal resistance is given by substituting the ideal voltage source is again short-circuiting  $R_2$ .

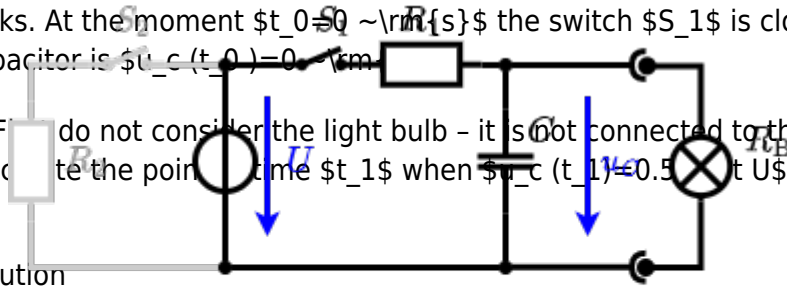
On an alternative view, one can try to create an equivalent linear voltage source again. Then, the internal resistance is given by substituting the ideal voltage source is again short-circuiting  $R_2$ .



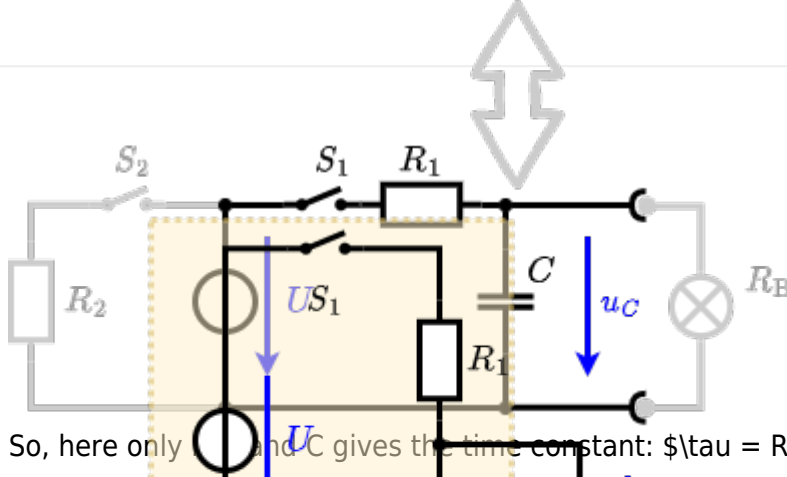
The circuit contains a voltage source  $U = 12 \text{ V}$ , a switch  $S_1$ , a resistor of  $R_1 = 20 \text{ }\Omega$  and a capacitor of  $C = 100 \text{ }\mu\text{F}$ . The switch  $S_2$  to an additional consumer  $R_2$  will be considered to be open for the first

asks. At the moment  $t_0 = 0 \text{ s}$  the switch  $S_1$  is closed, the voltage across the capacitor is  $u_c(t_0) = 0 \text{ V}$ .

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



Solution



So, here only  $U$  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 
$$(1 - e^{-t/\tau}) = 0.5 \implies e^{-t/\tau} = 0.5 \implies -t/\tau = \ln(0.5) \implies t = \tau \cdot \ln(0.5)$$

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 ( $R_i = 0 \Omega$ , short-circuit). 
$$R_i = R_1 \parallel R_B = 10 \Omega$$

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

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

2. A RC circuit with resistor values  $R_1 = 1 \text{ k}\Omega$  and  $R_2 = 10 \text{ k}\Omega$  is shown in the following circuit (of 3S)  $U = 10 \text{ V}$ .  
 Result:  $f_1 = 200 \text{ kHz}$  (high-pass filter)  $Z_1 = 10 \text{ }\Omega$  through  $R_1$ .  
 $Z_C = 40 \text{ nF}$  at  $f_1 = 4 \text{ MHz}$ .

Solution

$$R_1 = 1.00 \text{ }\Omega$$

**Solution**

A series circuit means that the current is constant on every component. Parallel circuit means that the voltage is the same on  $R_3$  and  $C_3$ .

$$\underline{U} = \underline{U}_3 + \underline{U}_C$$

$$\underline{U} = \underline{I} \cdot R_3 + \underline{I} \cdot X_C$$

So it gets clear that perpendicular components can be summed like  $\sqrt{a^2 + b^2}$  instead of  $a + b$ , since  $R_3$  is  $\sqrt{a^2 + b^2}$ .

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

$$I_3 = \sqrt{I_{R_3}^2 + I_{C_3}^2}$$

$$I_3 = \sqrt{0.3^2 + 0.4^2} = 0.5 \text{ A}$$

This can be rearranged to get  $R_3$ :

$$R_3 = \frac{U}{I_3} = \frac{50 \text{ V}}{0.5 \text{ A}} = 100 \text{ } \Omega$$

Back to the first formula:

$$I_3 = \frac{U}{R_3} = \frac{50 \text{ V}}{100 \text{ } \Omega} = 0.5 \text{ A}$$

**Exercise E10 Analyzing complex Impedances (written test, approx. 14 % of a 60-minute written test, WS2022)**

2. Calculate the phase angle and the effective value of the current through the components ( $R$  and  $X_L$ ) shall be given.

After analysis, the following complex impedance can be extracted and written in phase form:

**Solution**

.. Calculation of the physical values of the components.

$$Z = R + j\omega L = 10 \text{ } \Omega + j20 \text{ } \Omega = 10 + j20 \text{ } \Omega$$

**Solution**

$$I = \frac{U}{Z} = \frac{50 \text{ V}}{10 + j20 \text{ } \Omega}$$

The current and voltage are in phase since the  $Z$  is purely real resulting in  $\varphi = 0^\circ$ .

Therefore, the component  $R$  is in phase with the  $\omega$  and  $X_L$  is  $90^\circ$  ahead.

$$I = \frac{50 \text{ V}}{10 + j20 \text{ } \Omega} = \frac{50 \text{ V}}{\sqrt{10^2 + 20^2} \angle \arctan\left(\frac{20}{10}\right)} = \frac{50 \text{ V}}{22.36 \angle 63.4^\circ} = 2.24 \angle -63.4^\circ \text{ A}$$

The phase angle  $\varphi$  can be calculated as:

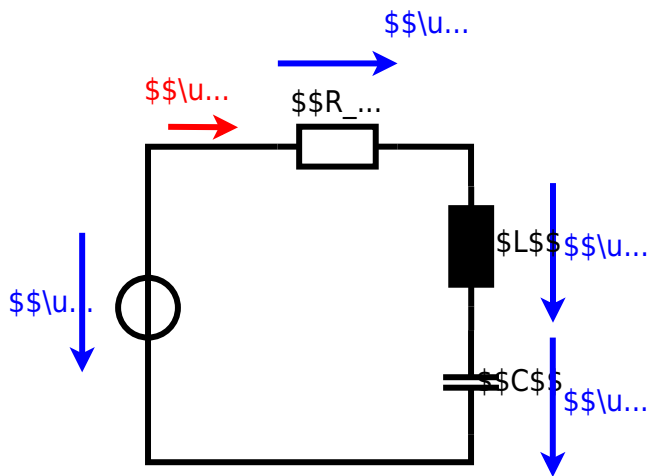
$$\varphi = \arctan\left(\frac{\text{Im}(Z)}{\text{Re}(Z)}\right) = \arctan\left(\frac{20}{10}\right) = 63.4^\circ$$

With the complex part comes the complex value:

$$I = \frac{50 \text{ V}}{22.36 \angle 63.4^\circ} = 2.24 \angle -63.4^\circ \text{ A}$$







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