

Exam Winter Semester 2022

Student Group

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Exam Winter Semester 2022

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 E1 Charging Capacitors

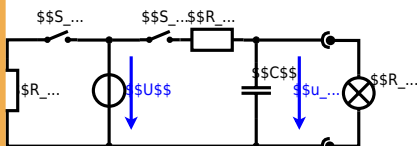
(written test, approx. 16 % of a 60-minute written test, WS2022)

The circuit (with the algebra) is in the slide of PR11 in the 2019 exam. The capacitor is initially uncharged. The voltage across the capacitor is again U_0 at the moment $t_0=0$ when the switch S_1 is closed. Calculate the voltage $u_c(t_2)$ across the capacitor at $t_2=1$ ms after closing the switch.

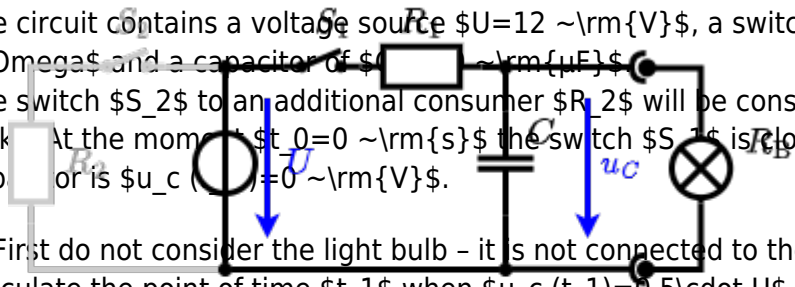
Solution
 To solve this, first create an equivalent linear voltage source from U_0 , R_1 , and R_2 .

The equivalent voltage source is $U_{eq} = U_0 \cdot \frac{R_2}{R_1 + R_2}$ and the internal resistance is $R_{int} = \frac{R_1 \cdot R_2}{R_1 + R_2}$.

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 .

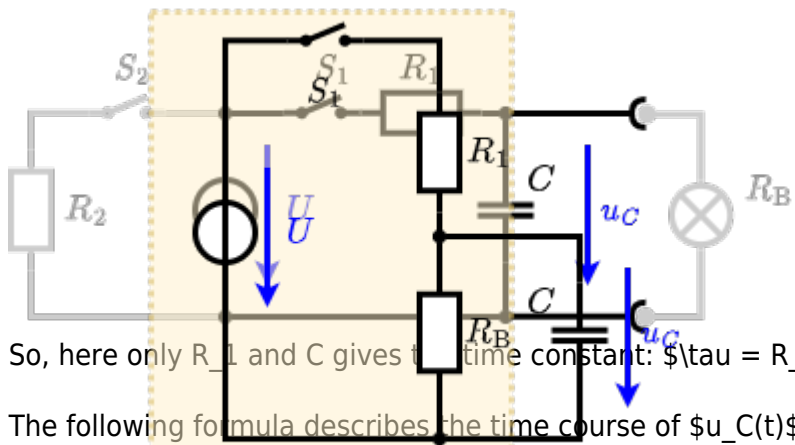


The circuit contains a voltage source $U=12\text{ V}$, a switch S_1 , a resistor of $R_1=20\text{ }\Omega$ and a capacitor of $C=100\text{ }\mu\text{F}$. The switch S_2 to an additional consumer R_2 will be considered to be open for the first task. At the moment $t_0=0\text{ s}$ the switch S_1 is closed,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

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

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 ($=0\text{ }\Omega$, 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 E9 Impedances at different Frequencies
 (written test, approx. 18 % of a 60-minute written test, WS2022)

2. A RC circuit has the resistor values $R_1=1\text{ }\Omega$ and $R_2=3\text{ }\Omega$ and a capacitor of $C=1\text{ }\mu\text{F}$. The voltage source is $U=10\text{ V}$.
 Result: $Z_B=20\text{ }\Omega$ ($Z_B=450\text{ }\Omega$ at $f=1\text{ kHz}$), $Z_C=100\text{ }\Omega$ ($Z_C=10\text{ }\Omega$ at $f=10\text{ MHz}$)
 3. A resistor R_1 shall have the same absolute value of the impedance as a capacitor $C_1=40\text{ nF}$ 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 .

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

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

So it gets clear that perpendicular components can be summed over $\sqrt{R_3^2 + X_C^2}$ instead, since R_3 is $\sqrt{R_3^2 + X_C^2} \sin(\phi)$ and X_C is $\sqrt{R_3^2 + X_C^2} \cos(\phi)$.

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

$$I = \frac{U}{\sqrt{R_3^2 + X_C^2}}$$

This can be rearranged to get R_3 :

$$R_3 = \frac{U}{I} \sqrt{1 - \left(\frac{X_C}{U/I}\right)^2}$$

Back to the first formula:

$$I = \frac{U}{\sqrt{R_3^2 + X_C^2}}$$

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

2. Calculate the phase angle and the current I if $U = 50 \text{ V}$, $R = 10 \text{ }\Omega$, $X_L = 20 \text{ }\Omega$, $X_C = 30 \text{ }\Omega$ and $f = 50 \text{ Hz}$. Both U and I are in the RMS domain. (R and X_L shall be given.)

After analysis, the full dimensional complex impedance has to be extracted and given in phase form $Z = |Z| \angle \phi = |Z| (\cos(\phi) + j \sin(\phi))$.

Solution

.. Calculation of physical values of the components.

$$X_L = 2\pi f L = 2\pi \cdot 50 \cdot 0.1 = 31.4 \text{ }\Omega$$

Solution

$$\underline{I} = \frac{\underline{U}}{\underline{Z}} = \frac{50 \angle 0^\circ}{10 + j31.4 - j30} = \frac{50 \angle 0^\circ}{10 + j1.4}$$

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

Therefore, the component $1.4 \text{ }\Omega$ can be neglected with the $10 \text{ }\Omega$ resistor.

$$I = \frac{50}{10} = 5 \text{ A}$$

The phase angle ϕ can be calculated as:

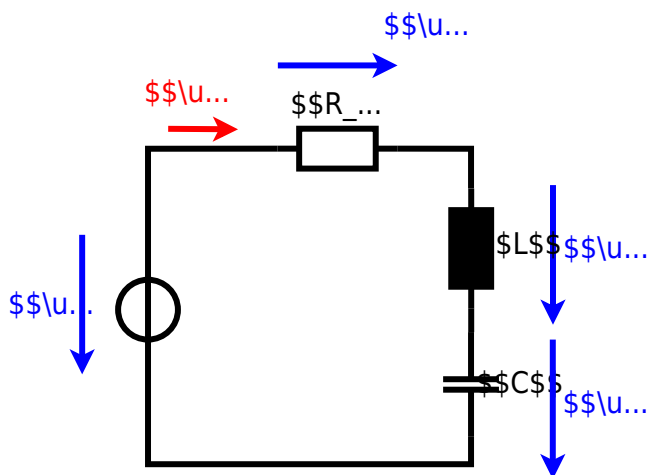
$$\phi = \arctan\left(\frac{\text{Im}(Z)}{\text{Re}(Z)}\right) = \arctan\left(\frac{1.4}{10}\right) = 8.1^\circ$$

With the complex part comes the complex value:

$$I = 5 \angle -8.1^\circ$$

The phase ϕ can be calculated as:

$$\phi = \arctan\left(\frac{\text{Im}(Z)}{\text{Re}(Z)}\right) = \arctan\left(\frac{-1.4}{10}\right) = -8.1^\circ$$



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