

task_tb6pi8dgh0m2e2pw_with_calculation

Student Group

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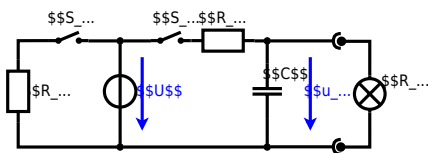
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Charging Capacitors, exam WS2022

Exercise 1 : Charge Capacitors

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

The circuit shown in the following is used to control the brightness when turning on a small light bulb.

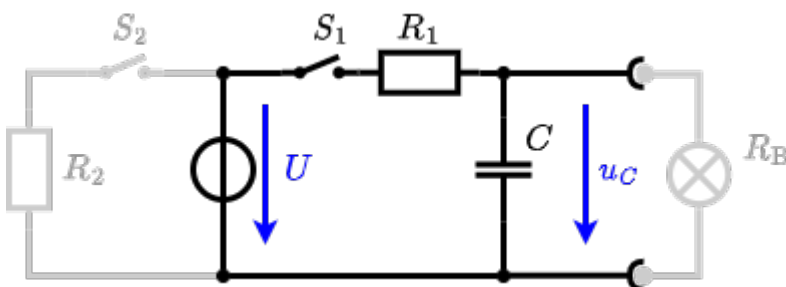


The circuit contains a voltage source $U=12\text{ V}$, a switch S_1 , a resistor of $R_1=20\ \Omega$ and a capacitor of $C=100\ \mu\text{F}$.

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

1. 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



The following formula describes the time course of $u_C(t)$
$$u_C(t) = U \cdot (1 - e^{-t/\tau})$$
 The resulting circuit can again be transformed:



Here, the U_{24} is calculated by I_{24} as the following:
$$U_{24} = R_{135} \cdot I_{24} = \left(\frac{U_2}{R_1} - I_4 \right) \cdot R_1 \parallel R_3 \parallel R_5$$

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

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

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

Final result

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

2. Calculate the overall energy dissipated by R_1 while charging the capacitor 0 V to 12 V .

3. Now, consider the light bulb as a resistor of $R_B = 20 \Omega$, and ignore again the left side (S_2 is open). 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_B .

4. Explain (without calculation) how the situation in 3. would change once also \$S_2\$ is closed from the beginning on.

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