INSA INSTITUT NATIONAL DES SCIENCES APPLIQUÉES LYON

FIMI
SCAN 1st
2022-2023

Physics exam 3 – Semester 1
February 23rd, 2023. Duration: 1 h

No document allowed. No mobile phone. Non-programmable calculator allowed. The proposed grading scale is only indicative.
The marks will account not only for the results, but also for the justifications, and the way you analyze the results. Moreover, any result must be given in its literal form involving only the data given in the text. It is also reminded that the general clarity and cleanness of your paper may also be taken into account.

Transient regime of an RC circuit

A dipole AB is composed of a resistance R in series with a capacitor of capacitance C. This dipole is connected to the terminals of a DC voltage source (Low Frequency Generator - LFG) with an electromotive force $E > 0$ and internal resistance R_g using a switch K, as shown in Figure 1. At initial time the circuit is open and the capacitor is discharged.
K is closed at $t = 0$, the voltage across the capacitor is denoted $u_c(t)$.
Numerical values: $R = 100\,\mathrm{k\Omega}$, $C = 1\,\mu\mathrm{F}$

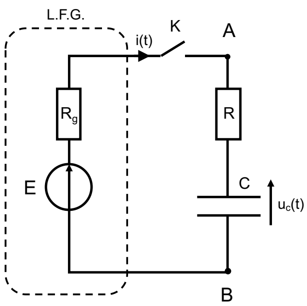

Figure 1

Part 1 : Theoretical study

1. The LFG is similar to the one you've been using during the labworks. Based on your experimental knowledge and available data, justify that the internal resistance of the LFG (R_g) can be neglected in front of R (*i.e.* $R \gg R_g$).

2. Give the differential equation governing $u_c(t)$ for $t > 0$ under the form $u_c(t) + \tau \frac{du_c(t)}{dt} = E$ expressing τ using the electrical quantities defined in Fig. 1. Give the numerical value of τ.

3. Obtain the expression of $u_c(t)$ and $i(t)$ for $t > 0$.

In the following questions, we consider the circuit after a lapse of time $t_1 > 0$.

4. Obtain E_R the energy dissipated by resistor R in the time interval $[0; t_1]$.

5. Obtain E_C the energy stored in the capacitor in the time interval $[0; t_1]$.

6. Determine the energy delivered by the e.m.f. E_E in the time interval $[0; t_1]$ and check the energy balance.

Part 2: experimental study

We now wish to observe $u_c(t)$ using an oscilloscope. To this aim, we connect the terminals of the capacitor to one of the channel of the oscilloscope as sechematized in Figure 2. However, connecting the oscilloscope through coaxial cables introduces parasitic elements which are modelled as a parallel association of a resistor (R_x) and a capacitor (C_x). From the oscillocope manufacter's manual we read $16\,\mathrm{pF} \leq C_x \leq 47\,\mathrm{pF}$.
The capacitor being initially discharged, K is again closed at $t = 0$.
In this part, we will consider $R_g = 0$

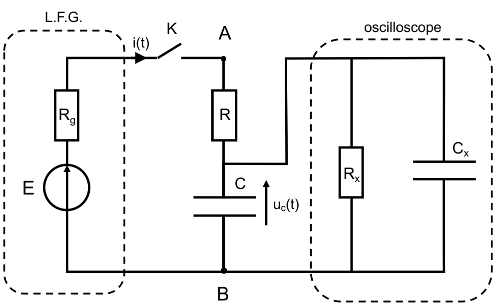

Figure 2

1. From a quick steady-state DC analysis, find the limit value of $u_c(t = +\infty)$
2. Show that the parallel association of 2 capacitors (capacitances C_1 and C_2) is equivalent to a single capacitor (capacitance $C_1 + C_2$).
3. Using an annotated equivalent electric scheme at $t > 0$ obtain the differential equation governing $u_c(t)$. This equation will be written $u_c(t) + \tau' \frac{du_c(t)}{dt} = \frac{E}{\alpha}$ with τ' and α expressed using the electrical quantities defined in Fig. 2.
4. Upon measuring $u_c(t)$, we obtain the oscillogram shown in Fig. 3. Exploit this graph to determine both R_x and E (we will not consider uncertainties).

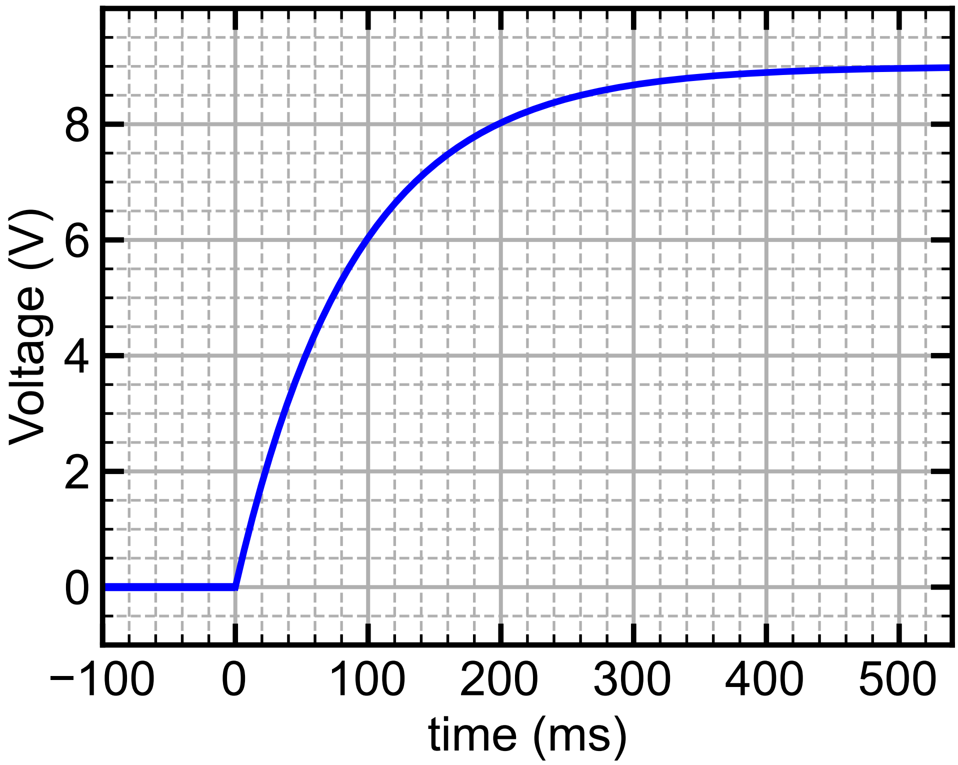

Figure 3

5.