SCAN 1st - Year: 2013-2014

PHYSICS EXAM

ELECTRODYNAMICS

Duration: 2h

Indicative grading scale: Section A: 6 pts, Section B: 7 pts, Section C: 7 pts.
No documents allowed. The use of not-programmable calculator is allowed.
The marks will account for the justifications, the writing and the general clarity and cleanness of your papers.

A. Active or passive dipole?

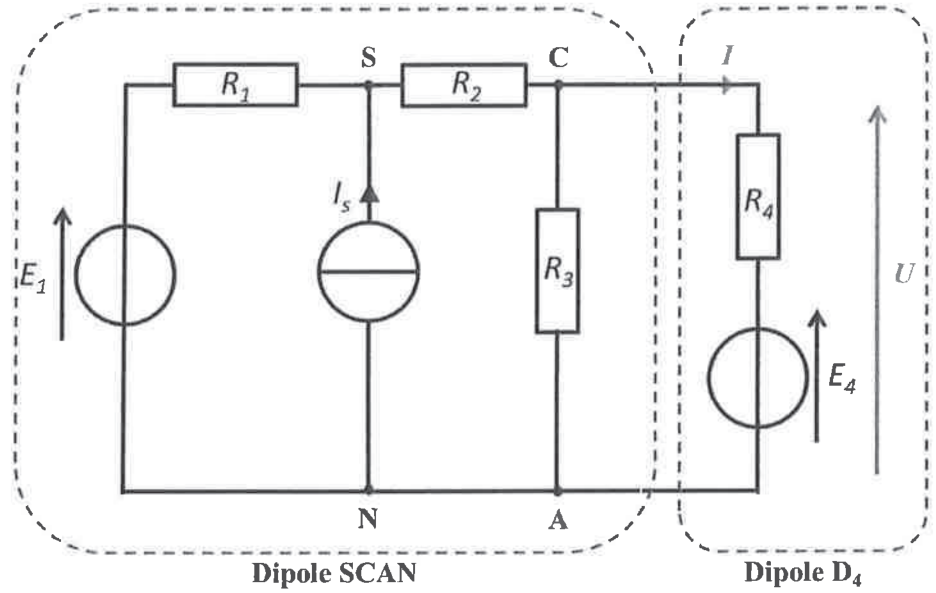

Figure A.1

A.1. Find out the equivalent generator of Thévenin of the dipole "SCAN" (left dipole in the dashed line). Give the expressions of E_{Th} and R_{Th}.

A.2. Give the equation of the current-voltage characteristic of the dipole "SCAN" $I = f(U)$.

A.3. Using the graph paper, plot the current-voltage characteristic of the dipole "SCAN" for U ranging from 0 to 40V.
Data: $R_1 = 40\Omega$, $R_2 = 60\Omega$, $R_3 = 100\Omega$, $I_s = 50$ mA, $E_1 = 18$V.

A.4. The dipole SCAN is connected with the dipole "D_4" as shown Figure A.1. Explaining your method, determine the values of U and I in the circuit.
Data: $R_4 = 200\Omega$; $E_4 = 100$V

A.5. In this case, justify if the dipole "D_4" is an active or a passive dipole.

B. Building an AC source

In this part, we will focus on the use of a capacitor to build an AC voltage source starting from a DC one.
To do so, the capacitor (C =20 μF) will be connected as shown in Figure B.1 with an ideal DC voltage source of electromotive force U_e. A resistor (R = 100 Ω) is connected in series with the source.

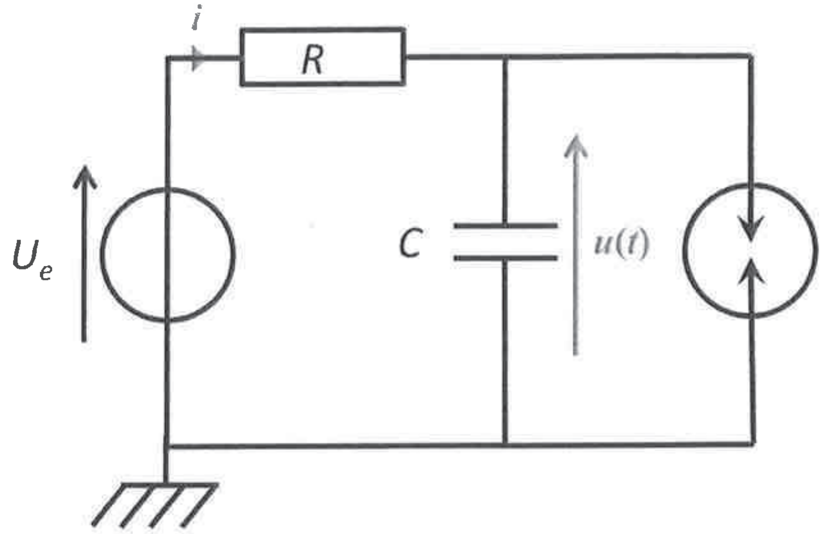

Figure B.1

At $t = 0$, the capacitor is discharged.

While $u(t) < V_0$, the dipole which is in parallel with the capacitor can be considered as an open switch.

When $u(t)$ reaches a threshold value denoted V_0, (V_0 is positive and adjustable), the dipole which is in parallel with the capacitor creates a spark which short-circuits the capacitor: this latter discharges itself within such a small duration that we will consider the discharging as instantaneous. The voltage $u(t)$ is hence decreased back to 0 V. Then, the capacitor can recharge itself and $u(t)$ begins a new cycle.

B.1. Give the expression of $u(t)$ for the first cycle and while $u(t) < V_0$.

B.2. Determine the time t_1 when the spark triggers itself. You will express it as a function of U_e, R, C and V_0. Calculate t_1 in the case where $V_0 = U_e/2$.

B.3. Justify that the signal is periodic. What is its period T?

B.4. Plot a graphical representation of $u(t)$ for t ranging from 0 to $3T$. Indicate on your plot the notable values of $u(t)$.

B.5. Determine the expression of the intensity $i(t)$ during the first cycle and plot $i(t)$ for t ranging from 0 to $3T$. Indicate on your plot the notable values of $i(t)$.

B.6. Explain with the help of a scheme how you would proceed to visualize both $u(t)$ and $i(t)$ with an oscilloscope.

Bonus question. Starting from the expression of the period T, and based on the adjustable value of V_0, identify two possible behaviors. Explain how the network behaves in both cases.

C. Circuits in Alternating Current

We model the input of an oscilloscope via a resistor R_0 with a parallel capacitor C_0 (Figure C.1).
We want to measure, with the oscilloscope, the electromotive force of a sinusoidal AC voltage source $e(t)$, of angular frequency ω, amplitude E and phase angle $\varphi_e = 0$. The internal resistance of the source is r.

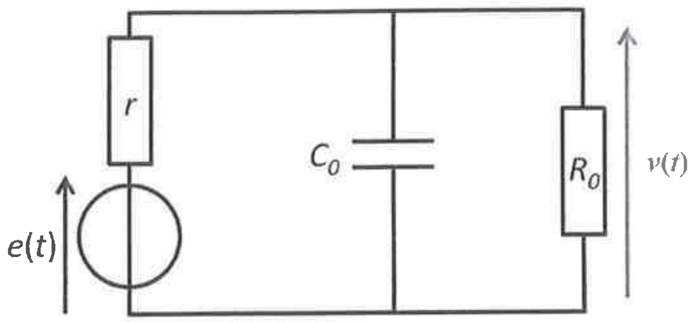

Figure C.1

C.1. What is the impedance of the dipole constituted by R_0 and C_0?

C.2. Express $\frac{\underline{v}}{\underline{e}}$ as a function of ω, R_0, C_0 and r. Deduce the amplitude V of $v(t)$ and the phase shift φ between the output $v(t)$ and the input $e(t)$.

C.3. Let us now connect a probe of resistance R' and capacitance C' between the source and the oscilloscope (Figure C.2).

Determine the ratio $\underline{H} = \frac{\underline{v}_2}{\underline{v}_1}$, and its gain $|\underline{H}| = \frac{|\underline{v}_2|}{|\underline{v}_1|}$.

What is the gain $|\underline{H}|$ at very low and very high frequencies?

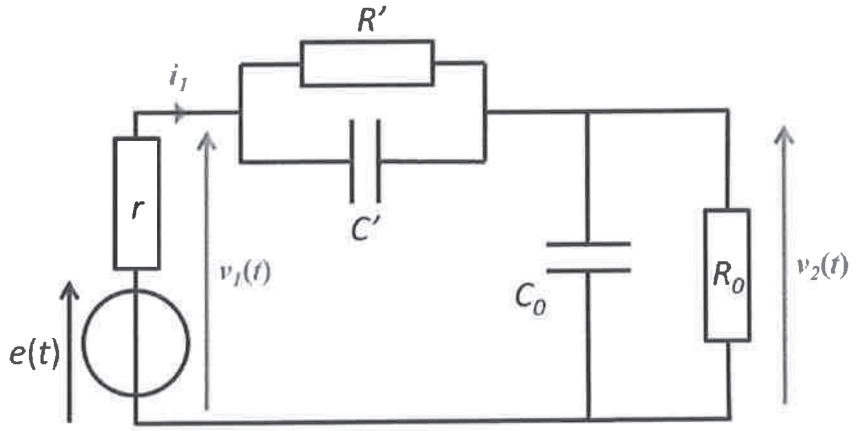

Figure C.2

C.4. How to simplify the circuit at very low and high frequencies? You will illustrate your answer thanks to schemes.

C.5. We now have $R' = 9\,R_0$ and $C' = C_0/9$. Give the expression of the input impedance $\underline{Z}_i = \frac{\underline{v}_1}{\underline{i}_1}$ of the group (probe+oscilloscope) as a function of R_0, C_0 and ω. Compare this impedance to the impedance $\underline{Z}_0$ obtained without the probe. Conclude.