MAGNIER Zoé 62 -

INSA INSTITUT NATIONAL DES SCIENCES APPLIQUÉES LYON

SCAN 1st - Year: 2017-2018

PHYSICS EXAM - ELECTRODYNAMICS

Friday, December, the 15th - Duration: 1h30

- No documents allowed. Only the use of a calculator is allowed.
- The marks will account for the justifications, the critical analysis of your results, as well as for the writing and the general clarity and cleanness of your documents.
- Every non homogeneous result presented without any comment will lead to a penalty on your final grade.

Lecture questions: (≈ *2 pts*) ok

1) Give the complex impedance in passive sign convention of an ideal coil of inductance L and of an ideal capacitor of capacitance C.
2) A sine-signal (dimensionless) is defined as follows:
   $s_1(t) = 4\sqrt{2}\cos(100\pi t + \frac{\pi}{4})$ with t the time in s
   Give the peak-to-peak amplitude and the frequency of signal $s_1(t)$.

Assignment I: "Zener diode" (≈ *9 pts*)

Indication: the Zener diode is a passive dipole that has not been studied in physics class but no specific knowledge on this dipole is required for solving this exercise.

We consider the circuit depicted in Figure 1.a, corresponding to a voltage source of e.m.f E and internal resistance R, connected in series with a Zener diode. This voltage source is actually an equivalent Thévenin's source corresponding to two real voltage sources (with respective e.m.f $E_1>0$ and $E_2>0$ and internal resistances R_1 and R_2) associated in parallel (see Figure 1.b).

1) Determine the e.m.f E and the internal resistance R of the equivalent Thévenin's source as functions of E_1, E_2, R_1 and R_2.

The current-voltage characteristic of the Zener diode in passive sign convention (convention fixed in Figure 1.a) is represented in Appendix 1.

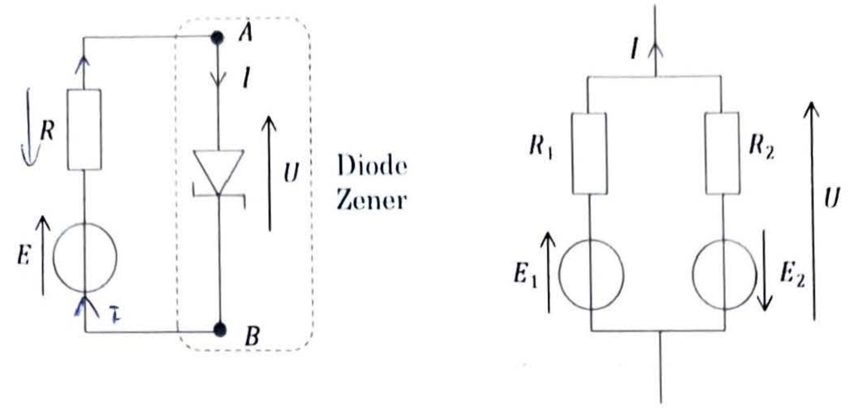
2) Determine graphically on Appendix 1 the operating point of the circuit of Figure 1.a. *Numerical values: $E = 1.5V$ and $R = 50\Omega$.*

3) The terminals of the Zener diode are switched. Using Appendix 2, determine graphically the new operating point of the circuit.

The Zener diode and the equivalent Thévenin's source (e.m.f E and internal resistance R) studied previously are used in the circuit depicted in Figure 2.

4) **The switch K is open.** Give the expression of the current intensities noted I, I_1, I_2 and I_K.

5) **The switch K is closed.** Give the new expressions of the current intensities I, I_1, I_2 and I_K.



a) b)

Figure 1

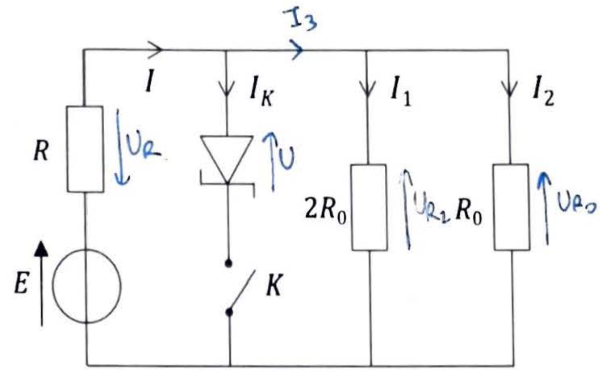


Figure 2

Assignment 2: Free oscillations in a RLC circuit *(≈ 9pts)*

Let's consider a circuit containing a voltage source (of e.m.f. E and internal resistance R), a capacitor of capacitance $C = (10 \pm 1)\,nF$, an ideal coil of inductance L, a resistor of resistance R_0 and a double-throw switch (i.e. it can operate in two different positions) called K. The circuit is depicted in Figure 3.

When $t < 0$, the capacitor is connected to the voltage source (switch K in position (1)): it charges until the steady state is reached. Then, at time $t = 0$, the switch K is flipped to position (2).

1) Write the Kirchhoff's voltage law as well as all the relations that are needed to formulate the differential equation describing the voltage $v(t)$ across the capacitor (equation valid for $t > 0$).

2) Show that this differential equation can be written as:

$$\frac{d^2v(t)}{dt^2} + 2\delta\frac{dv(t)}{dt} + \omega_0^2 v(t) = 0 \qquad \text{(I)}$$

And **give the expressions** of the two constants δ and ω_0.

3) At $t = 0^+$, determine the expressions for the voltage $v(t = 0^+)$ across the capacitor, the current intensity $i(t = 0^+)$, the voltage $u_{R_0}(t = 0^+)$ across the resistor R_0 and the voltage $u_L(t = 0^+)$ across the ideal coil.

For this set-up, we will consider that the general solution of the equation (I) has the following form: $v(t) = Ae^{-\delta t} \cos(\omega t + \varphi)$
with: A and φ two real constants; ω is the angular frequency of the voltage $v(t)$.

The evolution of the voltage $v(t)$ versus time is plotted in Appendix 3.

4) Using a graphical method, determine the pseudo-period T of the signal $v(t)$, together with its uncertainty.

5) Using a graphical method, determine the numerical values of the two constants A and φ **(for this question, you are not expected to give the uncertainties)**.

For a low damping coefficient δ, one can show that the pseudo-period of $v(t)$ reads:

$$T = \frac{2\pi}{\sqrt{\omega_0^2 - \delta^2}} \approx \frac{2\pi}{\omega_0}$$

6) Compute the numerical value of L, as well as its absolute uncertainty.

7) We would like to visualize both the evolution of the voltage $v(t)$ across the capacitor and the current intensity $i(t)$ flowing through the circuit. How would you connect and set-up the two channels 1 and 2 of the oscilloscope to perform these measurements?

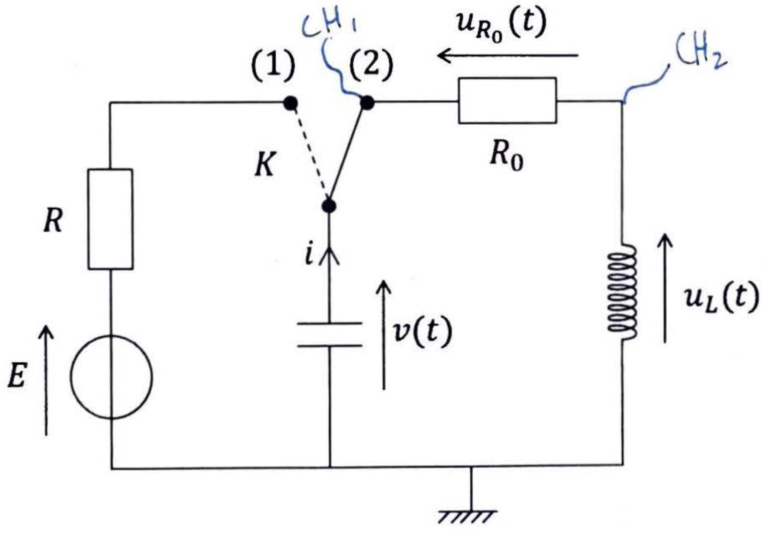


Figure 3 : *Scheme of the RLC circuit for t>0*