INSA INSTITUT NATIONAL DES SCIENCES APPLIQUÉES LYON

FIMI
SCAN 1st
Year 2018-2019

Exam 3 - Physics

December, 21st 2018, duration : 1h30

No document allowed. The use of a non-programmable calculator is allowed. The marks will account not only for the results, but also for the justifications, and the way you analyze the results. It is also reminded that presentation, clarity and spelling will be taken into account through a +/-1 bonus-penalty. The proposed grading scale is only indicative. Any result provided without units will be consider as false.

Figures 5 and 6 have to be returned back with your paper exam

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Exercise 1 : Straigthforward application of lectures and practicals (5.5 points)

Consider a circuit consisting in a sinusoidal voltage source $e(t)$ of period T and peak amplitude E. The source supplies a circuit containing a resistance $R = 10\,\mathrm{k}\Omega$ and a dipole whose impedance Z is unknown. Let $u_R(t)$ be the voltage difference across R and $u_Z(t)$ the voltage difference across impendance Z. The scheme of the circuit is depicted in Figure 1.

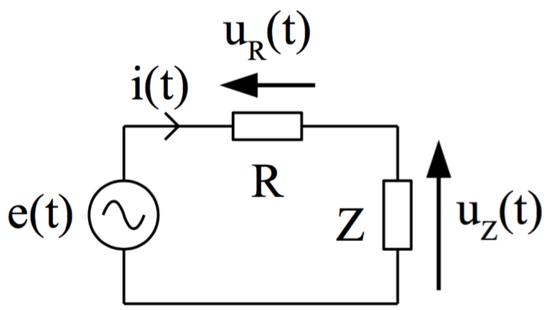

FIGURE 1 – Circuit in AC regime

Justify your answers for all of the following questions. You can annotate Fig. 5 (given in appendix) and return it back with your exam paper.

1. From Fig. 5, determine the following quantities together with their uncertainties :
   a) The period T of the source signal $e(t)$ and the time shift τ between $u_R(t)$ and $u_Z(t)$.
   b) Peak amplitudes of $u_R(t)$ and $u_Z(t)$.

2. State whether if $u_R(t)$ is ahead or lagging behind $u_Z(t)$. Is the current $i(t)$ ahead or lagging behind $u_Z(t)$?

3. Give the expression of the phase shift φ between $i(t)$ and $u_Z(t)$ as function of T and τ.

4. Compute the numerical value of φ and its absolute uncertainty $\Delta\varphi$. Provide the result as : $\varphi = (\ldots \pm \Delta\varphi)$.

5. Let U_R and U_Z be the peak amplitude of the voltage difference across R and the unknown impedance Z respectively. Determine the expression of the modulus of the impedance Z (data can be taken among R, U_R, U_Z and E).

6. Compute the numerical value of the modulus of impedance Z.

7. Which elementary dipole is Z ? justify your answer.

Exercise 2 : Nonlinear characteristic and operating point (5 points)

1. Preliminary study : circuit simplification (independant question)

Let's consider the circuit depicted in FIG. 2-a. Using a method of you choice, show that the circuit between nodes A and B is equivalent to a real voltage source (E,R) as shown in Fig. 2-b. Provide the expression of E and R as function of E_1, E_2, R_1 and R_2.

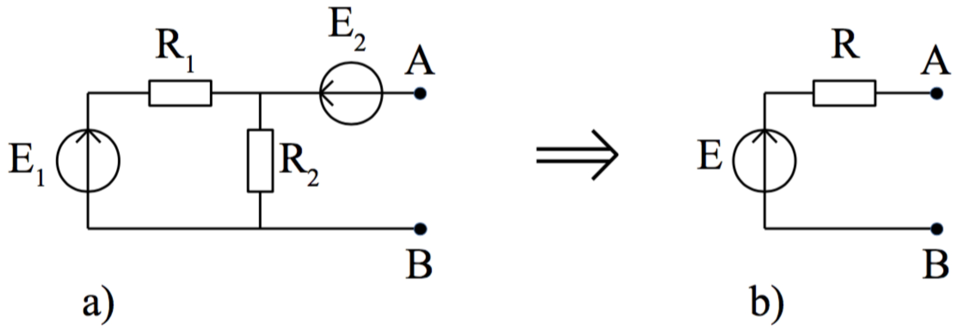

FIGURE 2 – Circuit simplification

2. Operating point

Let's consider a diode whose real characteristics is given in Fig. 6 (*i.e.* passive sign convention). Note that the scales are different depending on the sign of V_D. As $V_D < 0$ current I is negative and very small. The diode is put into series within the circuit presented in Fig. 3. We will assume that $E > 0$.

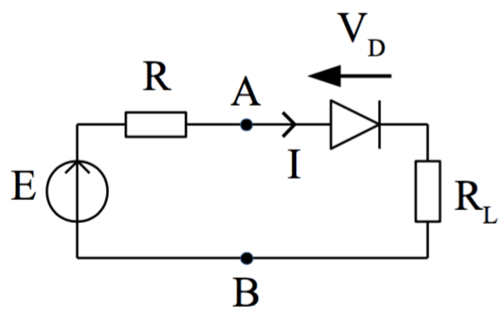

FIGURE 3 – Circuit with a diode

a) Using Kirchhoff's circuit law, demonstrate that $V_D > 0$.

b) Let $E = 1.5\,\text{V}$ and $R + R_L = 30\,\Omega$. Complete Fig. 6 to graphically determine the operating point of the circuit (do not forget to return it back with your exam paper !).

Bonus : Estimate and compute the uncertainties on this operating point.

Exercise 3 : Circuit in transient regime (9.5 points)

We study the circuit depicted in Fig. 4 containing an ideal voltage source E, 3 resistors R_1, R_2 and R_3, a coil of inductance L and a switch K. We will consider that K has been closed for a very long time before being suddenly opened at time $t = 0$.
Notice : Make use of schemes to indicate - as clearly as possible - the different electrical quantities you will

study together with their orientation. You may use nodes A, B, C and D to label the different currents and voltages (*e.g.* : u_{CD}, i_{CB},...).

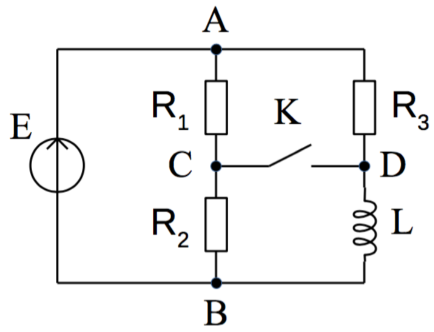

FIGURE 4 – Circuit in transient state

1. Just before K was opened, what could be said about the currents and voltages across the different branches of the circuit ? Give and justify the literal expression for each current and voltage.
Give their numerical values using $E = 24\,\text{V}$, $R_1 = 12\,\Omega$, $R_2 = 6\,\Omega$, $R_3 = 8\,\Omega$ and $L = 1\,\text{H}$.

2. Once K is open, establish the differential equation describing the evolution of u_{CD} (<u>the voltage difference across K</u>).

3. What is the limit value reached by u_{CD} as t tends to infinity ? Provide the literal expression and the numerical value.

4. Solve the differential equation and plot the evolution of u_{CD} as a function of time.

Document 1 :

NAME and GROUP :

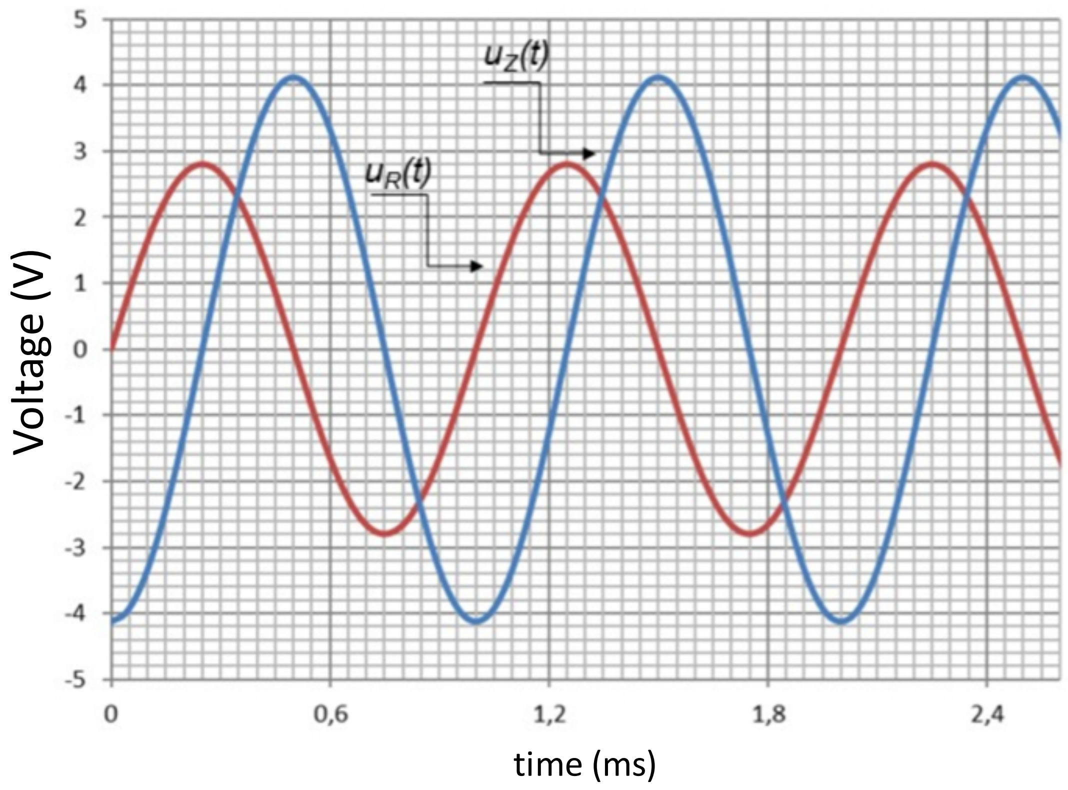

FIGURE 5 – Oscillogram showing the evolution of the voltage differences $u_R(t)$ across resistance R and $u_Z(t)$ across the dipole of unknown impendance Z

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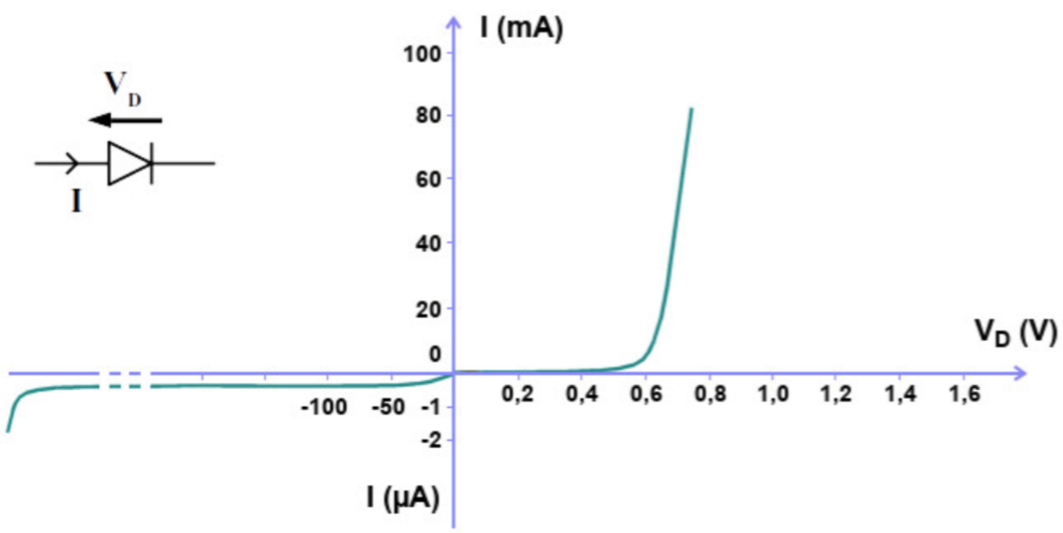

FIGURE 6 – I-V characteristic of a real diode

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