INSA INSTITUT NATIONAL DES SCIENCES APPLIQUÉES LYON

SCAN 1st - Year: 2014-2015

PHYSICS EXAM - **ELECTRODYNAMICS**

Duration: 1h30

Indicative grading scale: Assignment 1: 2pts, Assignment 2: 8 pts (+ bonus), Assignment 3: 10 pts (+ bonus).

- No documents allowed. The use of not-programmable 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.

- The conventions and the physical quantities of interest will always have to be defined and specified on your schemes.

Assignment 1: Complex impedance of a coil.

Assuming that an ideal coil is connected to an AC voltage source and that the intensity through the coil reads $i(t) = \sin(\omega t)$:

1. Give the complex expression of the intensity.
2. Compute the complex impedance of the ideal coil.

Assignment 2: Electric transmission loss.

A measurement device called M is fed by a DC voltage source with electromotive force equal to E. The source is assumed to be ideal for current intensities lower than I_{max}. The distance between the voltage source and the measurement device varies; both dipoles are connected together by a copper-made extension cord of length L and of total resistance R_f. The measurement device can be modeled by a resistor of resistance R_M. For this measurement device to work, the voltage across its terminals should be higher than U_{min} and lower than U_{max}. The scheme of the electric circuit is depicted in *Figure 1*. Numerical values of dipoles characteristics are listed below.

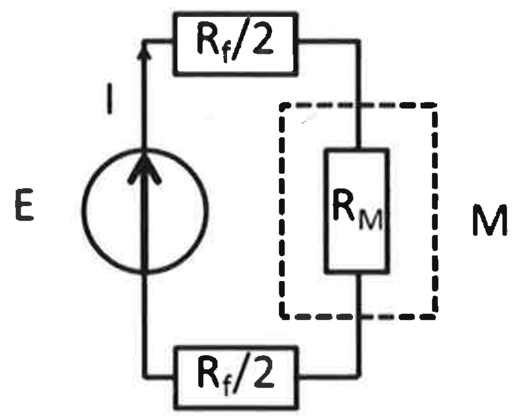

Figure 1: Electric circuit with evidence of extension-cables with non-negligible resistance.

Let's recall that the total resistance of a conducting component with constant cross-section S, length ℓ and electric resistivity ρ reads:

$$R = \rho \ell / S$$

1.1. Compute the current intensity I as a function of R_M, R_f and E. Justify your answer with special caution in defining the quantities you'll need.

1.2. Starting from the relation you established previously and from the expression of the R_f resistance, deduce the expression of the maximal length L_M of the cable so that the measurement device can work properly. Evaluate L_M.

1.3. (*BONUS*) Whatever the length of the extension cord $L < L_M$, can we assume the voltage source to be ideal?

During a series of test runs, one need two measurement devices similar to the one described in the first section. The used voltage source is the same as in the previous section and is connected to the measurement devices through only one extension cord of length L_M.

2.1. The two apparatus are first connected in series. Draw the electrical circuit corresponding to the described set-up. Will the measurement apparatus work properly? Justify your answer.

2.2. The two apparatus are then connected in parallel. Again, draw the electrical circuit corresponding to the described set-up. Will the measurement apparatus work properly? Justify your answer.

2.3. (BONUS) Suggest a solution for the devices to operate properly. Justify your answer.

Data: E=220V; I_{max} = 8.0 A; R_M = 44 Ω; U_{min} = 210 V; U_{max} = 230 V;
Cross-section of the extension cord: S = 2.0 mm²
Electric resistivity of the copper: $\rho = 17\text{x}10^{-9}$ Ω.m

Assignment 3: Study of a circuit containing a coil.

Let's study the circuit depicted in *Figure 2*, corresponding to an ideal voltage source of emf E, of an ideal coil of inductance L, a resistor of resistance R_L, of a lamp modeled by a resistance R_M, a switch K and a perfect diode of cut-in voltage equal to zero (see the I-V curve of *Figure 3*). The lamp will light on if the current intensity, which crosses it, is greater or equal to I_{min}. Numerical values of dipoles characteristics are listed below.

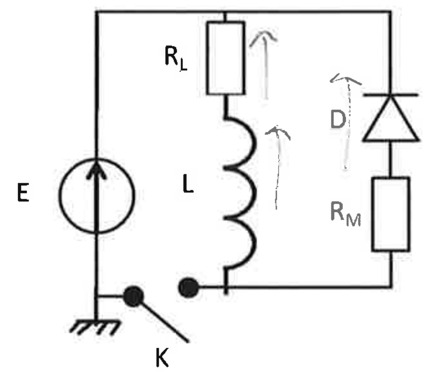

Figure 2a: electric circuit.

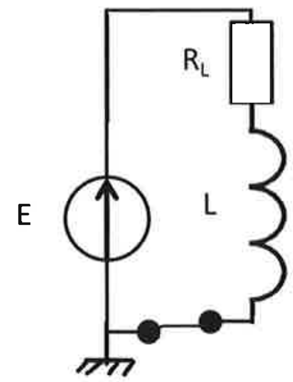

Figure 2b: equivalent circuit.

1. The aim of this first section (**which is independent from the next ones**) is to show that, when one closes the switch, the set-up depicted in *Figure 2a* is then equivalent to the one depicted in *Figure 2b*.

a. Assuming that the operating point of the diode belongs to the vertical part of its I-V curve, what does it imply for the u_D voltage and the i_D intensity? By which equivalent dipole could the diode be replaced?
b. Now, assuming that the operating point of the diode belongs to the horizontal part of its I-V curve, what does it imply for the u_D voltage and the i_D intensity? By which equivalent dipole could the diode be replaced?
c. Show that the circuit illustrated in *Figure 2a* is equivalent to the one depicted *Figure 2b* once the switch is closed.

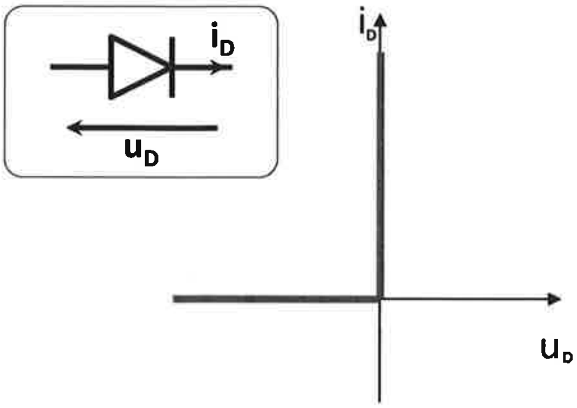

Figure 3: I-V curve of the perfect diode.

2. The switch is closed at time *t*, which will be taken as the time reference. Following the first section, the circuit is now equivalent to the one depicted in *Figure 2b*.

   a. Compute the differential equation describing the intensity $i(t)$ crossing the coil.
   b. Solve this equation, resulting in the analytical expression of $i(t)$, the intensity through the coil as a function of time.
   c. Provide a qualitative graphical representation of the evolution of i versus time. Comment on the value of $i(t)$ when t tends to infinity.
   d. Suggest and draw an electrical set-up that will allow the observation of $i(t)$ using an oscilloscope. Do not forget to represent the connections of the oscilloscope.

3. The switch being closed, the steady state is reached. Suddenly, at a given time t' (considered in the following as the time reference), the switch is accidentally opened. The circuit of interest corresponds to the set-up of *Figure 2a*.

   a. Explain qualitatively the reason why the lamp lights on in these conditions. Scheme the new equivalent circuit.
   b. How long does it take for the lamp to switch off? Justify **precisely** your reasoning. (For this question particularly, your capacity to provide a well-argued reasoning will be assessed).

4. (*BONUS*) What could be the use of such a set-up?

Data: E=1.0 V; R_L = 0.1 Ω; R_M = 0.1 Ω; L = 200 mH; I_{min} = 10 mA