INSA INSTITUT NATIONAL DES SCIENCES APPLIQUÉES LYON

SCAN 1st

Year 2023-2024 - Semester 2

Physics - Exam 1

Friday, March 29, 2024 — Duration : 1h30

No document allowed. No mobile phone. Non-programmable calculator and calculator in exam mode allowed. The marks will account not only for the results, but also for the justifications, and the way you analyze the results. The proposed grading scale is only indicative.

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1) Measure of an unknown capacitance (~ 2 points)

We consider the Wheatsone bridge circuit represented in figure 1. The circuit is fed by a sinusoidal voltage $u(t)$ and contains the following dipoles : a fixed resistor R_1, a variable resistor R_2, a known capacitor C, and an unknown capacitor C_X for which we want to measure the capacitance.
The measure consists in adjusting the value of R_2 so that the bridge is balanced, which means that $u_{MN}(t) = 0$ (this voltage bias is measured by an ideal voltmeter in AC mode). Show that in this case C_X can be written as a simple expression using R_1, R_2 and C.

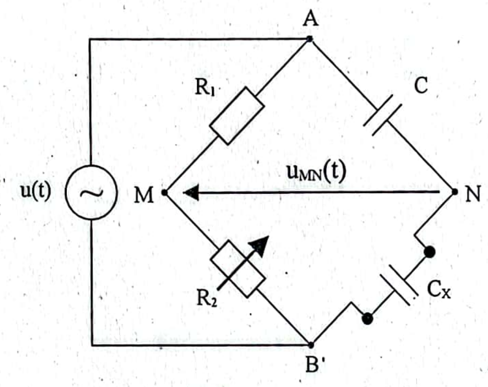

FIGURE 1 - Wheatstone bridge for measuring an unknown capacitance.

2) Study of a RLC parallel circuit (~ 7 points)

We consider the circuit depicted in Figure 2, made of a resistor (R), an ideal coil (L) and an ideal capacitor (C) is fed by an ideal sinusoidal voltage source $e(t) = E\ \cos(\omega t)$ (no internal resistance).

1. Determine the expression of the complex currents $\underline{i_R}(t)$, $\underline{i_L}(t)$ and $\underline{i_C}(t)$ that flow respectively through the resistor, the coil and the capacitor.
2. What is the relation between the different currents defined in Figure 2? Deduce the literal expression of the amplitude I of current $i(t)$ and of the phase-shift Φ of the current $i(t)$ with respect to voltage $e(t)$.
3. For which value of the angular frequency ω_0 does the amplitude I of the current $i(t)$ is taking a minimum value? Express ω_0 in terms of (R, L, C).

4. For $\omega = \omega_0$ determined previously, draw a phasor diagram representing currents $i_R(t)$, $i_L(t)$, $i_C(t)$ and $i(t)$ (use voltage $e(t)$ as horizontal phase reference).

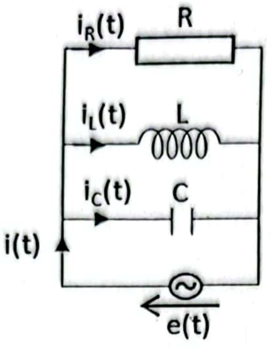

FIGURE 2 - *RLC* parallel circuit.

3) Phasor diagram and electrical power (~ 7 points)

An ideal voltage source $e = E\cos(\omega t + \phi_e)$, with maximum amplitude E and frequency $f = 50$ Hz, feeds a passive circuit consisting of a resistance $R = (41.1 \pm 0.1)\ \Omega$ in series with an unknown dipole X. Voltages across the generator and the two dipoles are measured, resulting in the phasor diagram depicted in Figure 3.

We denote $i = I\cos(\omega t)$, $u_R = U_R\cos(\omega t)$ is the voltage diference across R while $u_X = U_X\cos(\omega t + \phi_X)$ is the voltage difference across dipole X.

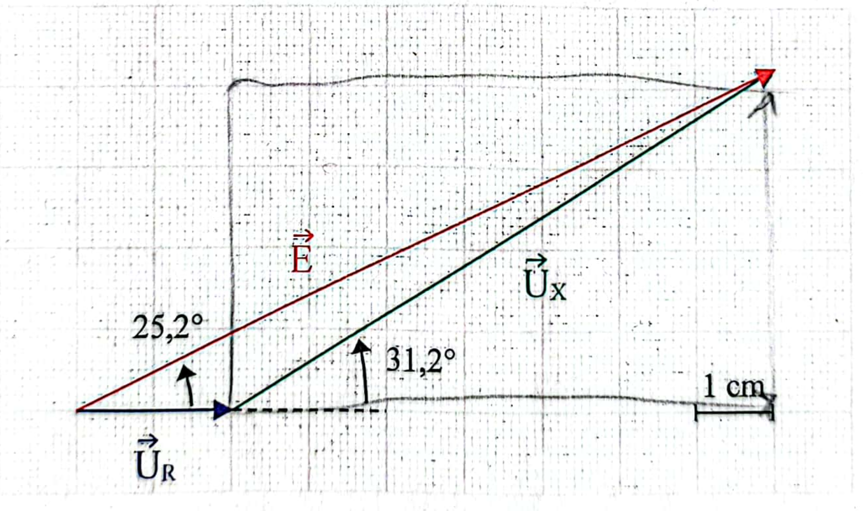

FIGURE 3 - Phasor diagram at scale 2 : 1 (2 cm represents 1 V)

1 - Dipole X contains two dipoles in series. Determine the characteristics of these two dipoles together with their uncertainties.

2 - Calculate the active power absorbed both by dipole X and the whole circuit together with their uncertainties.

3 - Check that Boucherot's theorem is verified : *the active power absorbed by any series/parallel association of dipoles equals the sum of the indiviual active power absorbed by each dipole.*

4) Analysis of a 2-channels filter for loudspeaker (~ 4 points)

A person, who is a music lover and handy with tools, purchases a DIY speaker kit (see Figure 4-a) which includes a two-channel passive filter (see Figure 4-b), a large speaker for bass sounds (commonly known as a *woofer* or *boomer*), and a smaller speaker for high-frequency sounds (*tweeter*). The filter inside the speaker serves to route the audio signal provided by an amplifier to each of the two speakers by separating the low and high-frequency components of the signal.
The electrical diagram of the two-channel passive filter (Figure 5) shows that there are actually two independent filters on the same printed circuit board, which share the same input signal $u_E(t)$ (issued from the amplifier). The output of filter 1 goes to speaker 1, and the output of filter 2 goes to speaker 2.

1 - Unfortunately, the person has lost the assembly instructions for the kit and no longer knows which type of speaker corresponds to the outputs HP 1 and HP 2. Should the *woofer* (low frequencies) be connected to output HP 1 and the *tweeter* (high frequencies) to output HP 2, or is it the other way around? Could you help him/her? (We're not asking for calculations, but rather an asymptotic analysis at very low or high frequencies).

2 - Establish the transfer function of Filter 1 and deduce the asymptotic expression and values of the filter's gain at high & low frequencies.

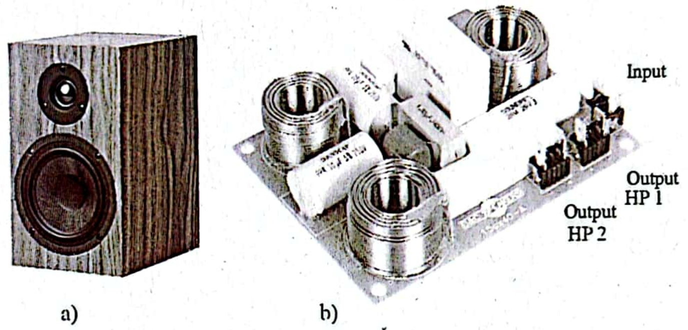

FIGURE 4 - a) Acoustic loudspeaker; b) 2-channel passive Filter (B&C Speakers FB15CX40).

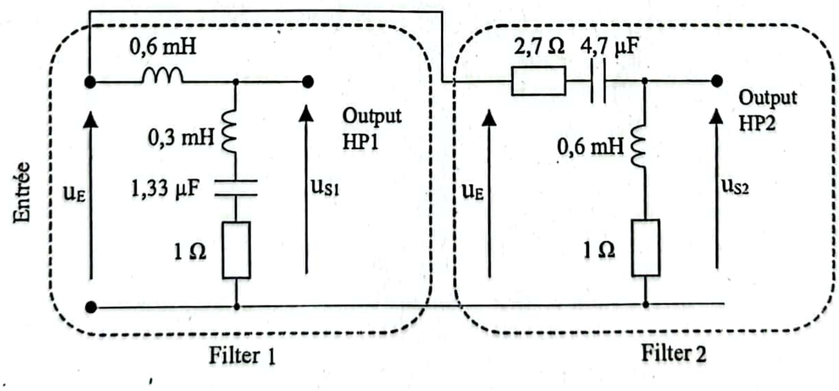

FIGURE 5 - Scheme of the passive 2-channel filter.