PHYSIKSOLYMPIAD LËTZEBUERG 2023

Final (EN)

25.03.2023

Instructions:

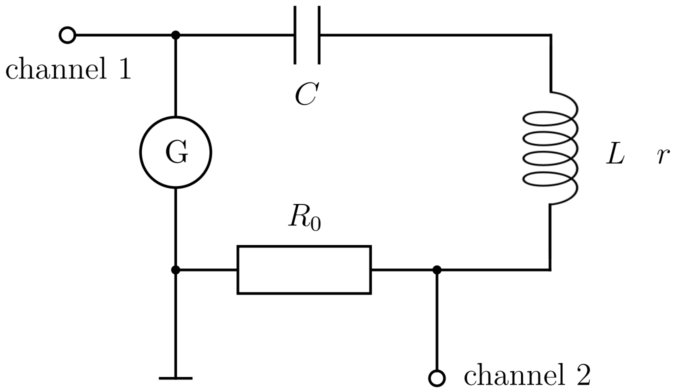
- Write your full name and school on each sheet.
- Clearly state the sub-question/question you are answering.
- Explain the steps of your reasoning and indicate your intermediate calculations.
- Number the pages.

Part 1: Free oscillations of an *RLC* circuit

This is a study of the natural period of an oscillating electric circuit in terms of the capacitance of the capacitor and the inductance of the coil.

A generator applies a square-wave voltage of frequency $10\ \mathrm{Hz}$ across a RLC series circuit.

The series circuit consists of a capacitor of capacitance C, a coil of inductance L and a resistor of resistance R. The resistor consists of two resistors in series, a resistor R_0 and the internal resistance r of the coil. The total resistance is equal to $R = R_0 + r$.



The oscilloscope displays:

- on "channel 1" input the voltage u_1 across the RLC circuit.
- on "channel 2" input the voltage u_2 across the terminals of R_0 which is proportional to the current i.

1) Influence of the capacity on the natural period

a) Choose a 300 turns coil without iron core.

b) Determine the period T of the oscillations for different values of the capacitance C of the capacitor.

c) Graphically represent T^2 as a function of C. Add a regression function to the graph.

d) From this, deduce the relationship between period and capacitance for a given inductance.

2) Influence of the inductance on the natural period

a) Choose a capacitor with a capacity of $C = 1\ \mu\mathrm{F}$.

b) Determine the period T of the oscillations for different values of the inductance L of the coil.

c) Graphically represent T^2 as a function of L. Add a regression function to the graph.

d) Deduce the relationship between period and inductance for a given capacitance.

3) Conclusion and application

From the results of the previous experiments, show that the natural period of the oscillations in terms of the capacitance of the capacitor and the inductance of the coil can be written as:

$$T = 2\pi\sqrt{L\,C}\ .$$

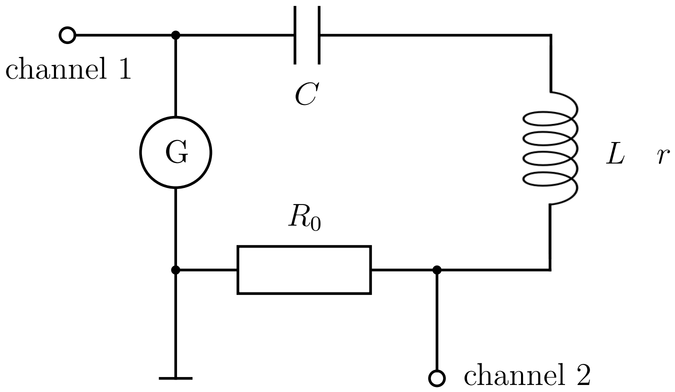
Application: Use this expression to calculate the inductance of the 300 turns coil with an iron core.

Part 2: Forced oscillations of an *RLC* circuit

This involves plotting the resonance curve of an electrical oscillator, determining the resonance frequency, and studying the resonance width in terms of the circuit resistance and the circuit inductance.

A generator applies a sinusoidal voltage across a RLC series circuit.

The series circuit consists of a capacitor of capacitance C, a coil of inductance L and a resistor of resistance R. The resistor consists of two resistors in series, a resistor R_0 and the internal resistance r of the coil. The total resistance is equal to $R = R_0 + r$.



The oscilloscope displays:

- on "channel 1" input the voltage u_1 across the circuit RLC ;
- on "channel 2" input the voltage u_2 across the terminals of R_0 which is proportional to the current i.

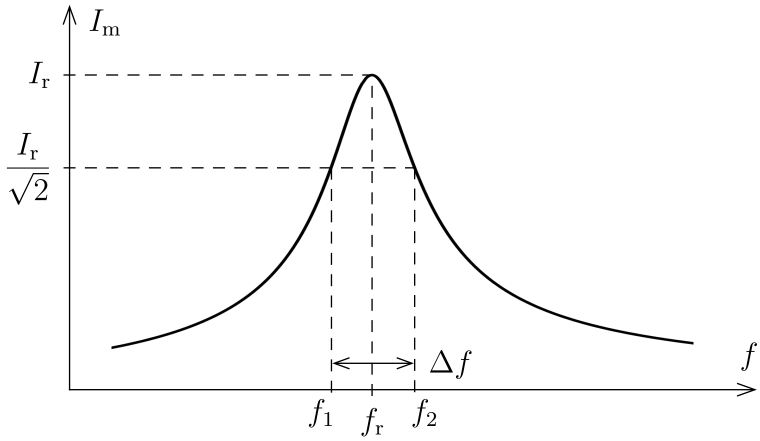
Choose a capacitor of capacitance $C = 1$ μF and a coil of 300 turns without an iron core.

1) Resonance curve

The current intensity is given by the relation:

$$i = \frac{u_2}{R_0} \Rightarrow I_\mathrm{m} = \frac{\hat{u}_2}{R_0}$$

where $\hat{u}_2$ is the peak voltage. The figure shows the graphical representation of the amplitude I_m of the current as a function of the frequency f of the generator, called the resonance curve.



a) Find the frequency f_r for which the amplitude $\hat{u}_2$ is maximum, if necessary, reduce the output voltage of the generator.

b) At maximum, set the generator output voltage so that the intensity is $I_r = 500$ mA.

c) Measure for different frequencies f the amplitude $\hat{u}_2$ keeping the amplitude $\hat{u}_1$ constant. Calculate the amplitude I_m of the intensity. Choose frequencies for which $I_m > 100$ mA.

d) Represent I_m as a function of f and manually add a regression curve.

e) Compare the resonance frequency f_r to the natural frequency f_0 that you calculate with $f = \frac{1}{T}$.

2) Resonance width

The resonance width Δf is the width of the frequency domain for which the amplitude of the intensity satisfies:

$$I_m > \frac{I_r}{\sqrt{2}}.$$

If this domain is delimited by the frequencies f_1 and f_2 we have $\Delta f = f_2 - f_1$.

a) For different coils measure the frequencies f_1 and f_2 and calculate the resonance width. Determine the total resistance.

b) From the results, show that the resonance width is proportional to the ratio $\frac{R}{L}$. Determine the constant factor.