

EXP.3: Electromagnetic Oscillations in an RLC Circuit

Lab Report

Complete this report YOURSELF except DATA taking parts! This report will not be submitted (except the very last page), but you should carefully complete it as preparation for the applied exam.

Suggested Pre-Lab Questions

Q1. If you apply Kirchhoff's law to the circuit you will get the following relation:

$$L \frac{d^2q}{dt^2} + R \frac{dq}{dt} + \frac{q}{C} = V_{app}(t)$$

Convince yourself by inserting $q(t) = q_0 A e^{-Rt/2L} \sin(\omega_0 t + \delta)$ with $\omega_0 = \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$ is a solution to this equation.

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Q2. Show dimension analysis for Inductance L, Capacitance C and Resistance R clearly.

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Experiment

OBJECTIVE : To study the oscillations of potential difference across a charged capacitor in series with a resistor and an inductor.

THEORY : In a series RLC circuit, the Kirchoff's loop rule results in the following:

$$L \frac{di}{dt} + Ri + \frac{q}{C} = V_{app}(t) \quad \text{or} \quad L \frac{d^2q}{dt^2} + R \frac{dq}{dt} + \frac{q}{C} = V_{app}(t)$$

since $I = dq/dt$. This is an equation for a damped oscillator driven by a time dependent voltage source or a signal generator. There are three different combinations of R, L, and C values where we can get specific solutions to this equation for a square wave signal as the applied voltage.

Underdamped:

If the values satisfy the following conditions, the circuit will be underdamped:

$$\frac{R^2 C}{4L} < 1$$

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Then the solution will be:

$$q(t) = q_o A e^{(-Rt/2L)} \sin(\omega_o t + \delta)$$

and the voltage across the capacitor will be:

$$V_C(t) = V_o B e^{(-Rt/2L)} \sin(\omega_o t + \delta),$$

where V_o is the voltage when the square wave is at the maximum value and δ is the phase. ω_o is given by:

$$\omega_o = \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$$

Oscillations decay exponentially with a time constant $2L/R$. Signals reach their half values in:

$$t_{1/2} = \frac{2L}{R} \ln 2$$

which we can call half-life of the signals.

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Critically Damped:

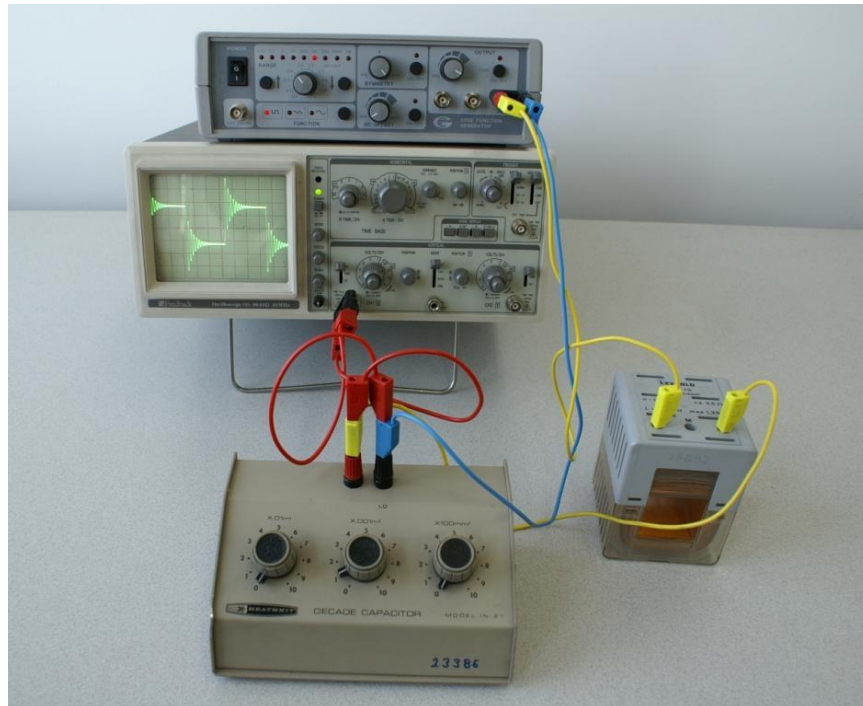
If $\frac{R^2 C}{4L} = 1$, the circuit is critically damped. As you see from the equation for ω_0 above, the frequency of the oscillations is zero which means there is only an exponential decay.

Overdamped:

If, $\frac{R^2 C}{4L} > 1$ the circuit is overdamped. The frequency of the oscillations, ω_0 , is an imaginary number which means there is only an exponential decay similar to the Critically Damped Case.

APPARATUS : Capacitance and resistance boxes, inductor with an iron block, oscillator, oscilloscope.

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PROCEDURE :

- Connect the circuit by using the A-E terminals of the 1000 turn coil for the inductor and 0.001 μ F capacitor, turn on the oscilloscope and make the initial adjustments. Internal resistance of the square wave generator and the coil resistance will be the total resistance in the circuit.
- Adjust the square wave frequency and the sweep frequency of the oscilloscope so that one complete cycle of decaying oscillations cover the whole screen of the oscilloscope. Record the value of the sweep frequency in your report.
- Choose two peaks at least 5-6 cm far from each other and count the number of the complete cycles in this chosen range l . Determine the length of one complete cycle, period, and the frequency of the decaying oscillations.
- Measure the half-life of the decaying oscillations.
- Using the half-life equation, calculate the inductance L of the coil in millihenries and calculate the frequency of oscillations by using this value.

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$$t_{1/2} = \frac{2L}{R} \ln 2$$

$$f_o = \frac{1}{2\pi} \left[\frac{1}{LC} - \frac{R^2}{4L^2} \right]^{1/2}$$

- When a piece of iron is inserted into a coil, a large change occurs in the inductance of the coil. With the iron fully inserted, determine the new value of the inductance.

CIRCUIT DIAGRAM

Draw the circuit diagram

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DATA & CALCULATIONS

Description / Notation	Value & Unit	# of Significant Figures
Capacitance C =		
Resistance R =		
Frequency of the Square Wave f_{SWG} =		
Generator		

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Description / Notation	Value & Unit	# of Significant Figures
[TIME / DIV] Dial of the Oscilloscope <u>without</u> Iron Block =		
[TIME / DIV] Dial of the Oscilloscope <u>with</u> Iron Block =		
Length between the chosen peaks ℓ =		
Number of complete Cycles in ℓ n =		

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DATA & CALCULATIONS

WITHOUT IRON BLOCK INSIDE THE INDUCTOR

Description / Symbol	Value / Calculations (show each step)	Result
Half-Life $t_{1/2}$ (cm) =
Half-Life $t_{1/2}$ (sec) =
Inductance of the coil L_1 =
Wavelength λ =
Period of the Oscillations T =
Frequency of the Oscillations f_{measured} =
Frequency of the Oscillations $f_{\text{calculated}}$ =
% Error for f:		

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WITH IRON BLOCK INSIDE THE INDUCTOR

Description / Symbol	Value / Calculations	Result
	(show each step)	
Half-Life	$t_{1/2}(\text{cm}) =$
Half-Life	$t_{1/2}(\text{sec}) =$
Inductance		
of the coil	$L_2 =$
	

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Suggested Post-Lab Questions

Q1. What is the reason for the difference you observe when you insert the iron block inside the inductor?

Post-Lab Report

Aim of the experiment:

Suggestions for possible solutions to the problems experienced during the experiment:

Conclusion:

9 I have completed this experiment myself as specified in the lab sheet and as explained by the lab instructor.

Name & Surname:

Student ID:

Lab Section:

Table #:

Date:

Signature of the
student

As the instructor of this Lab Section I confirm that the student has participated in and completed this experiment on time.

Stamp of the PHYS
Labs and signature of
the instructor

This page serves as proof of the fact that the student participated in and completed the experiment, only if it is submitted in time and accepted by the Lab instructor. The student and the instructor shall sign it along with the stamp of the Physics Laboratories.