Boğaziçi University

Introductory Phys Labs

ELECTROMAGNETIC OSCILLATIONS IN AN RLC CIRCUIT

PHYL202

THEORY

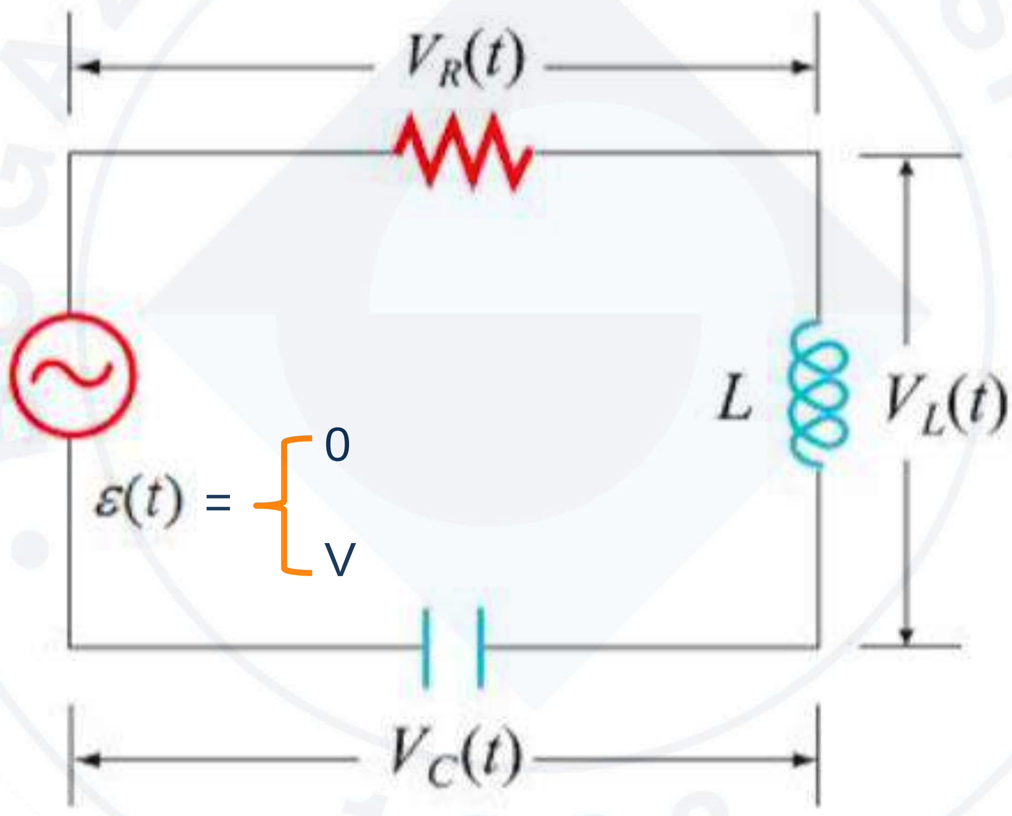
RLC series circuits are also known as tuned or acceptor circuits. They have many applications particularly for oscillating circuits.

Series RLC circuit has applications in radio and communication engineering.

They can be used to select a certain narrow range of frequencies from the total spectrum of ambient radiowaves.

For example: AM/FM radio with analog tuners use a RLC circuit to tune a radio frequency.

Series RLC Circuit:



Applying Kirchhoff's loop rule, we obtain

$$\varepsilon(t)-V_R(t)-V_L(t)-V_C(t)=\varepsilon(t)-i(t)R-L\frac{di}{dt}-\frac{q(t)}{C}=0$$

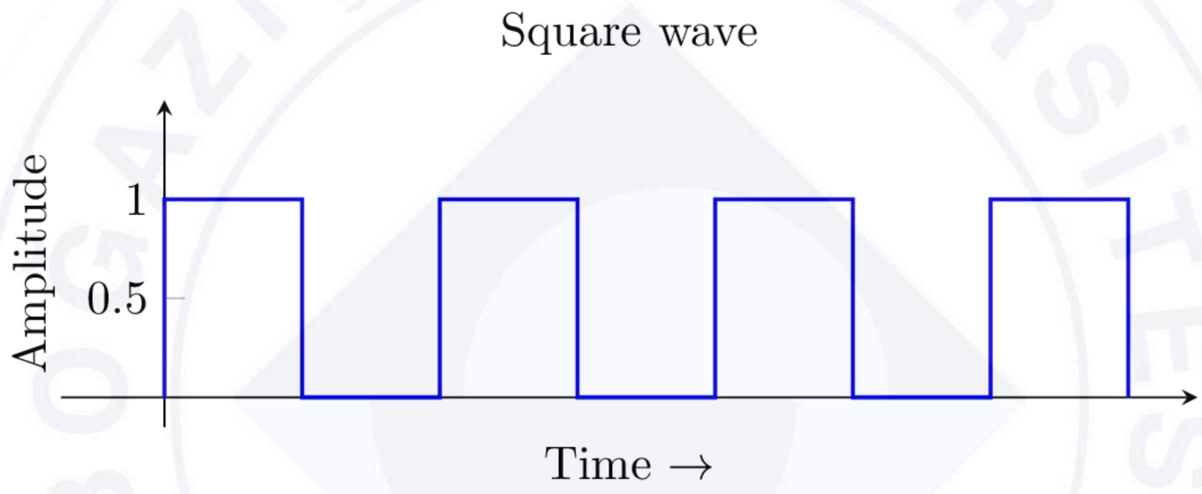
This is an equation for a damped oscillator driven by a time dependent voltage source or a signal generator.

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.

$$L\frac{di}{dt}+i(t)R+\frac{q(t)}{C}=\varepsilon$$

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

Our Power Supply generates Square Wave:



Our differential equation becomes

$$L\frac{d^2q}{dt^2}+R\frac{dq}{dt}+\frac{q(t)}{C}=\begin{cases}0\\ V\end{cases}$$

Underdamped Oscillation:

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

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

Then the solution will be:

$$q(t) = q_0 A e^{(-Rt/2L)} \mathrm{Sin}(\omega_0 t + \delta)$$

and the voltage across the capacitor will be:

$$V_c(t) = V_0 A e^{(-Rt/2L)} \mathrm{Sin}(\omega_0 t + \delta)$$

where V_0 is the voltage when the square wave is at the maximum value and δ is the phase.

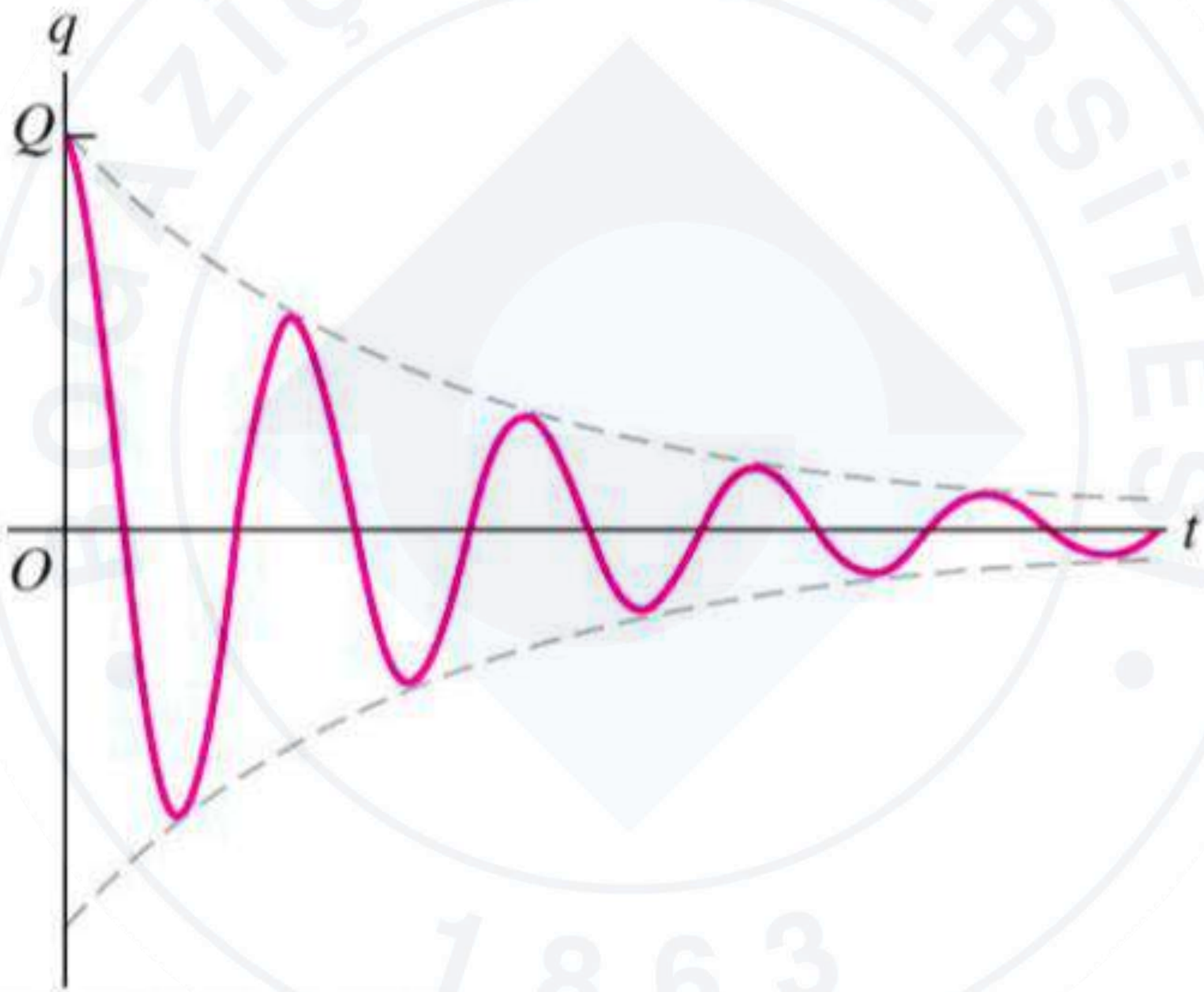
ω_0 is given by:

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

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

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

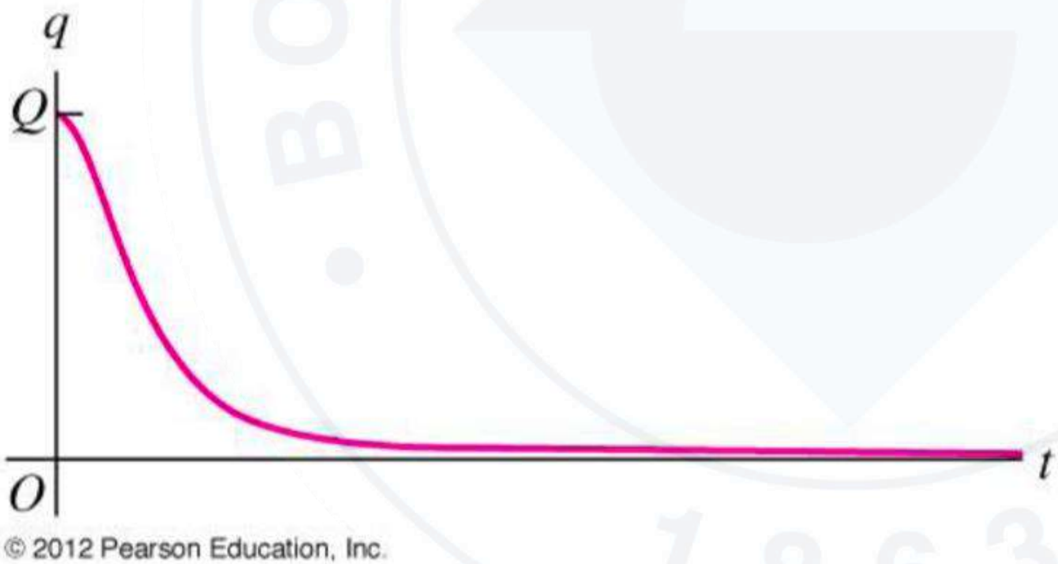
which we can call half-life of the signals.


q
Q
O
t

Critically damped Oscillation:

If $$\frac{R^2 C}{4L} = 1$$ the circuit is critically damped. As you see from the equation for ω_0,

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



the frequency of the oscillations is zero which means there is only an exponential decay.

Over damped Oscillation:

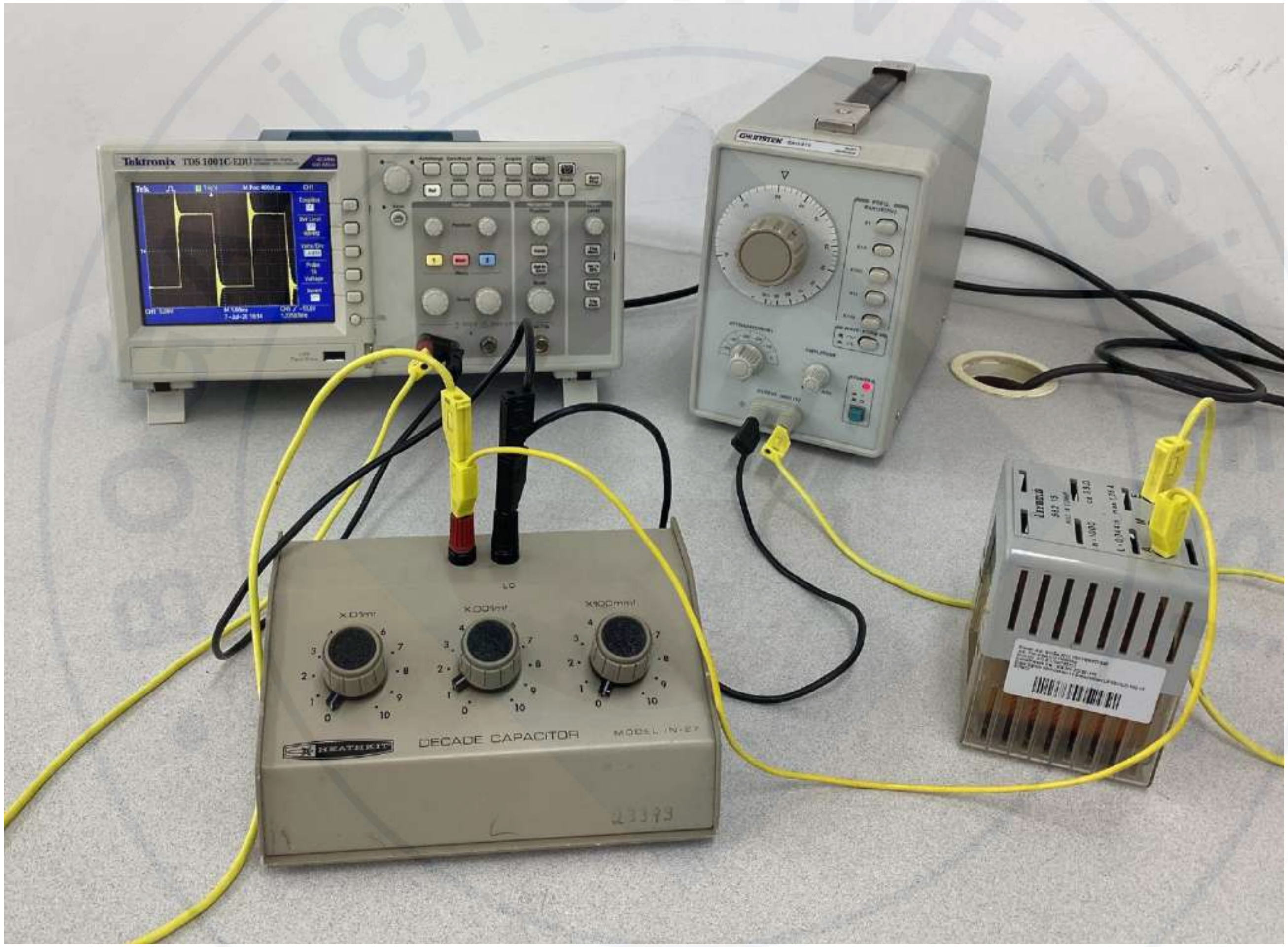
If

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

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

ELECTROMAGNETIC OSCILLATIONS IN AN RLC CIRCUITS



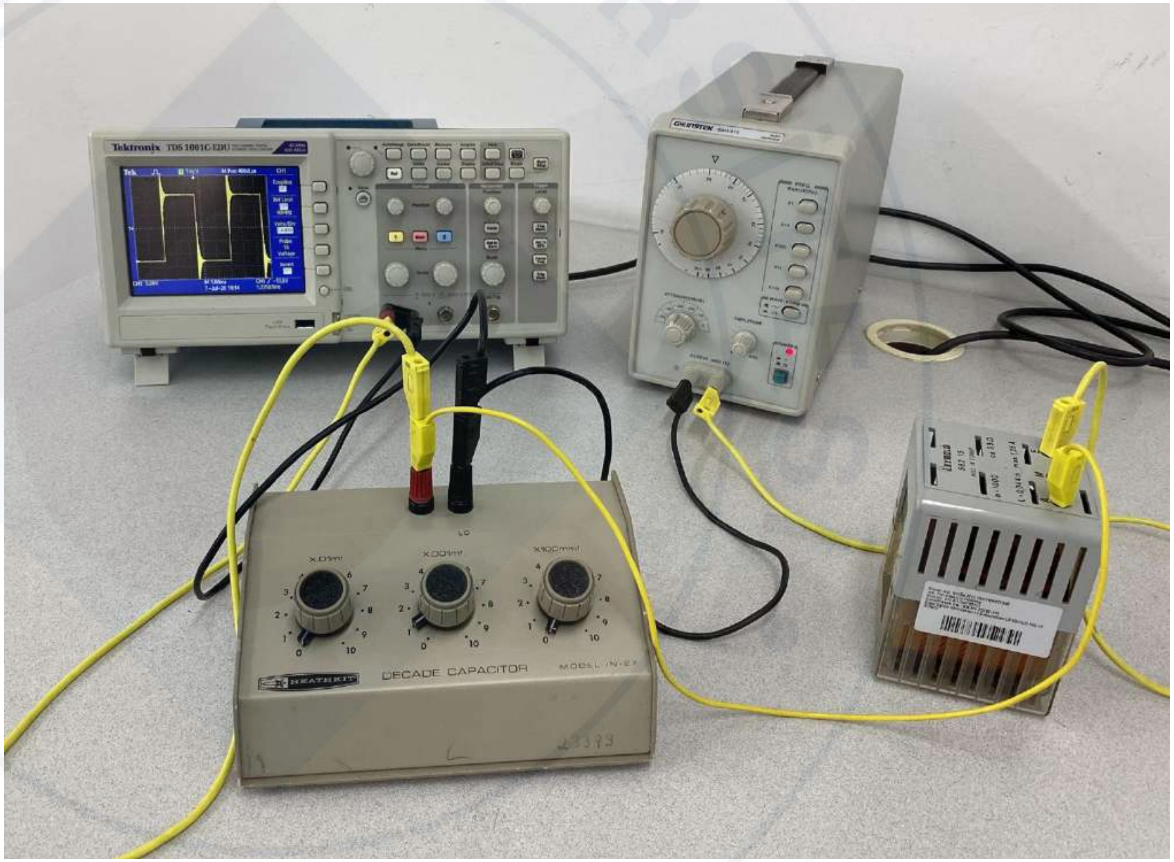
Oscilloscope, square wave generator, inductor and capacitor. Resistance will come from the internal resistances of circuit elements.

EXPERIMENT

Part-1: Without iron block inside the inductor

AC Power Supply, Capacitor and Inductor are connected series.

Internal resistance of the square wave generator and the coil resistance will be the total resistance in the circuit.



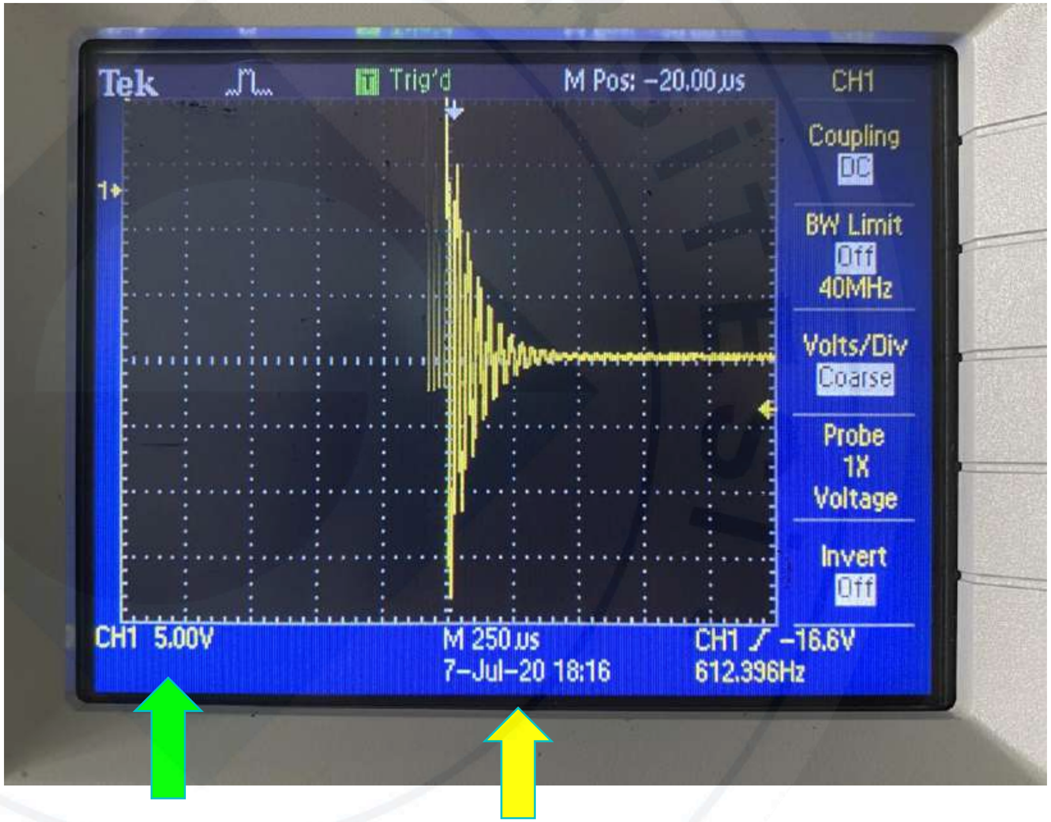
PhysLabs

EXPERIMENT: Without iron block inside the inductor

Connect the circuit by using the A-E terminals of the coil for the inductor and capacitor, turn on the oscilloscope and make the initial adjustments.

EXPERIMENT: Without iron block inside the inductor

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.



Volt / DIV

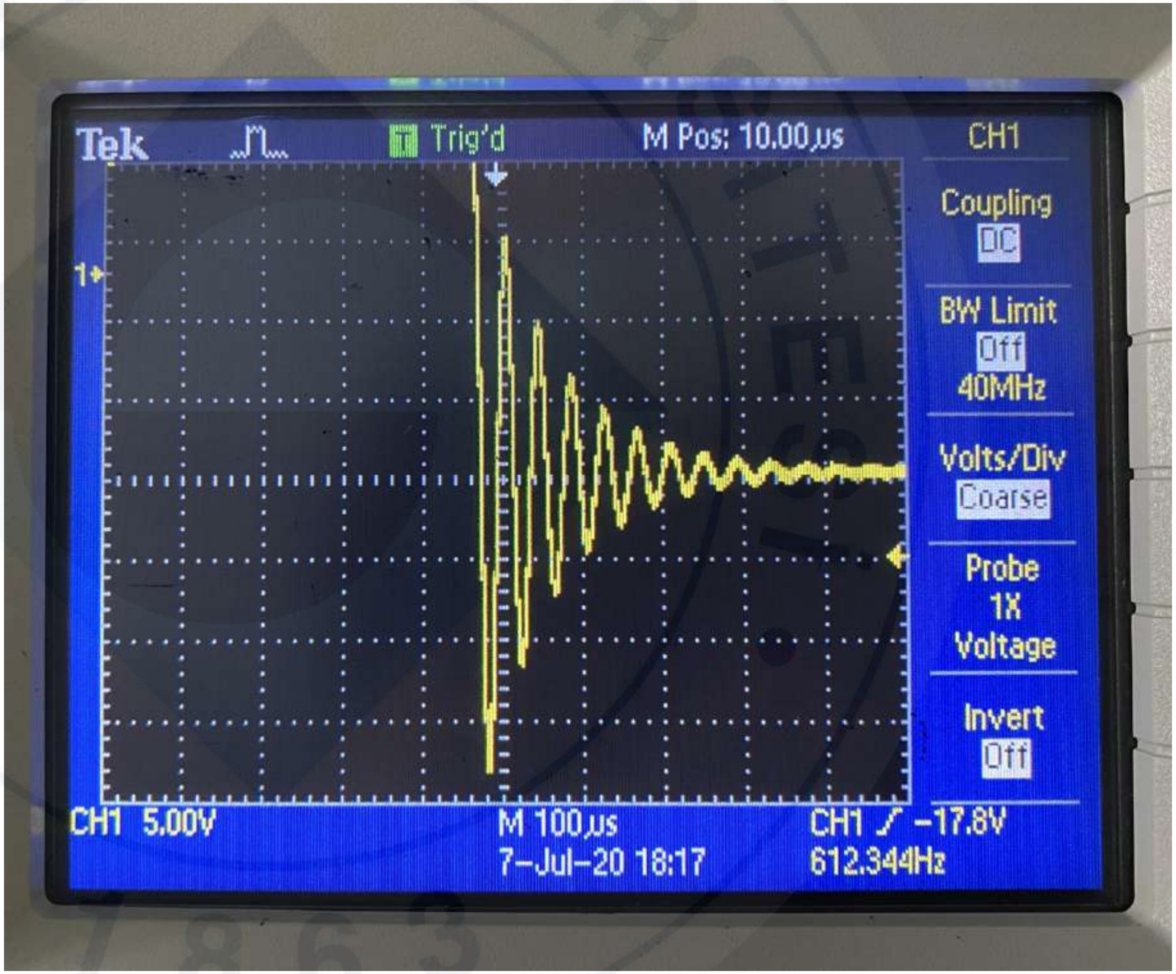
Time / DIV

EXPERIMENT: Without iron block inside the inductor

For frequency measurement:

Choose two peaks at least 4-5 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.



EXPERIMENT: Without iron block inside the inductor

For frequency measurement:

Choose two peaks at least 4-5 cm far from each other and count the number of the complete cycles in this chosen range ℓ.

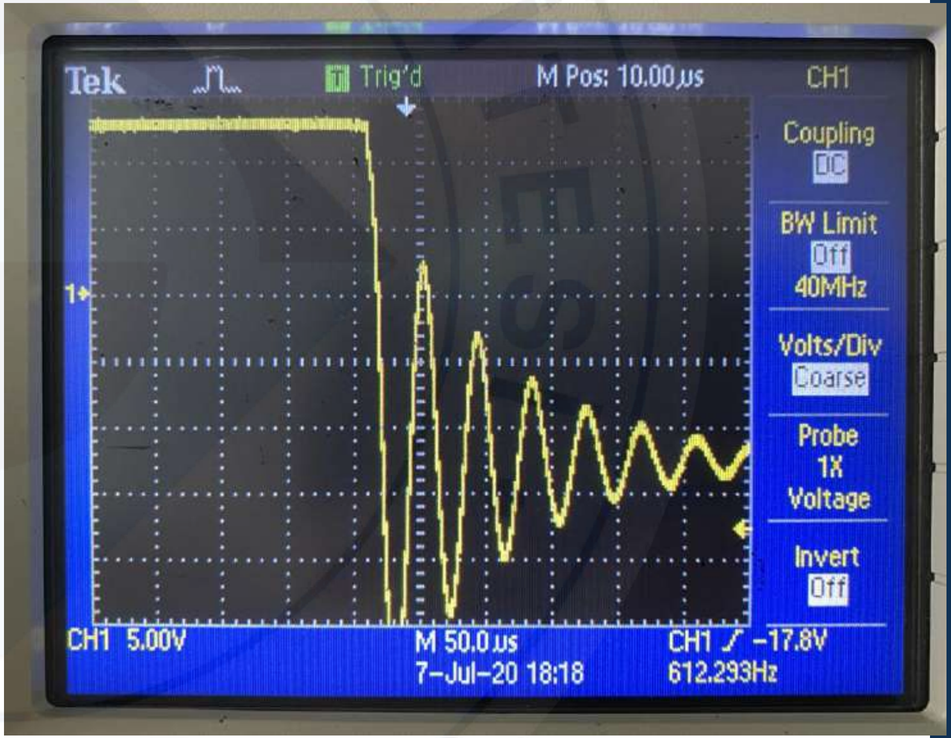
Determine the length of one complete cycle, period, and the frequency of the decaying oscillations.

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

Zuhal Kaplan Arık, Physics Department, Boğaziçi University

EXPERIMENT: Without iron block inside the inductor

Measure the half-life of the decaying oscillations.



EXPERIMENT: Without iron block inside the inductor

Using the half-life equation, calculate the inductance *L* of the coil in millihenries and calculate the frequency of oscillations by using this value.

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

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

EXPERIMENT: Without iron block inside the inductor

$\lambda = l / n$

$T = \lambda \times \text{Time/DIV}$

$f_{measured} = 1 / T$

$f_{calculated} = f_0$

(Take f_0 as true value)

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

WITHOUT IRON BLOCK INSIDE THE INDUCTOR

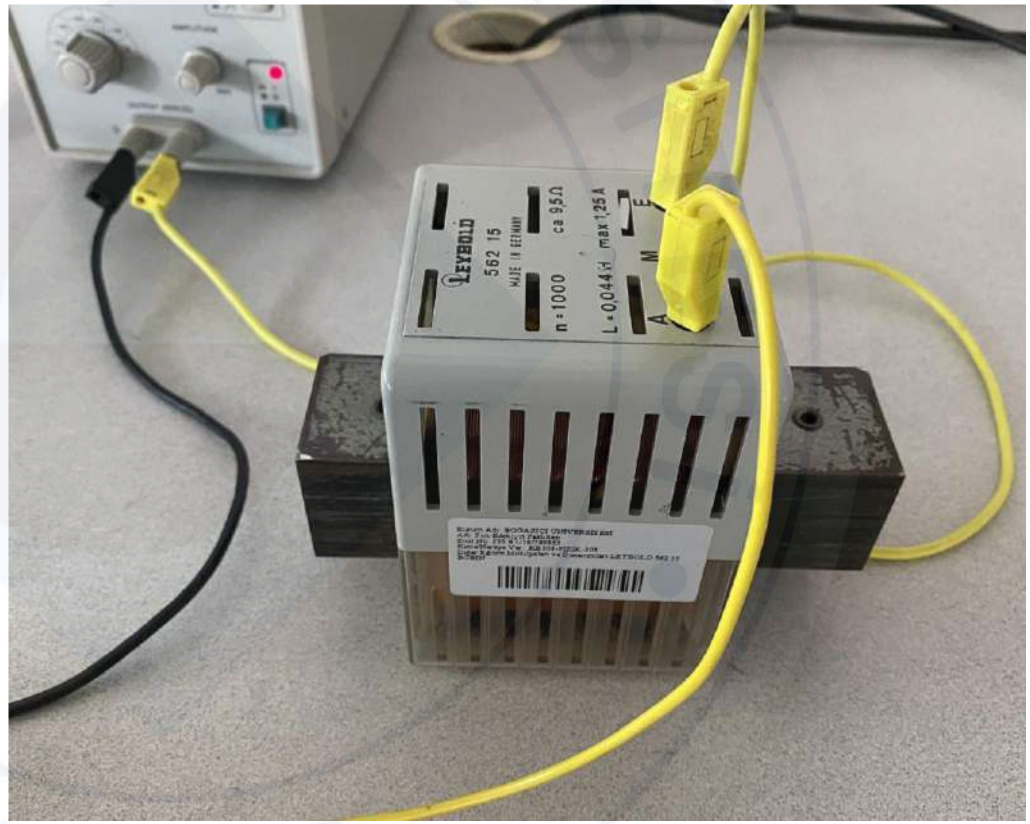
Description / Symbol		Value / Calculations (show each step)	Result
Half-Life	$t_{1/2}$ (cm) =	....	....
Half-Life	$t_{1/2}$(sec) =	....	....
Inductance of the coil	L_1 =	....	....
Wavelength	λ =	....	....
Period of the Oscillations	T =	....	....
Frequency of the Oscillations	$f_{measured}$ =	....	....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

% Error for f:

Part-2: With iron block inside the inductor

When a piece of iron is inserted into the coil, a large change occurs in the inductance of the coil.

With the iron fully inserted, determine the new value of the inductance.



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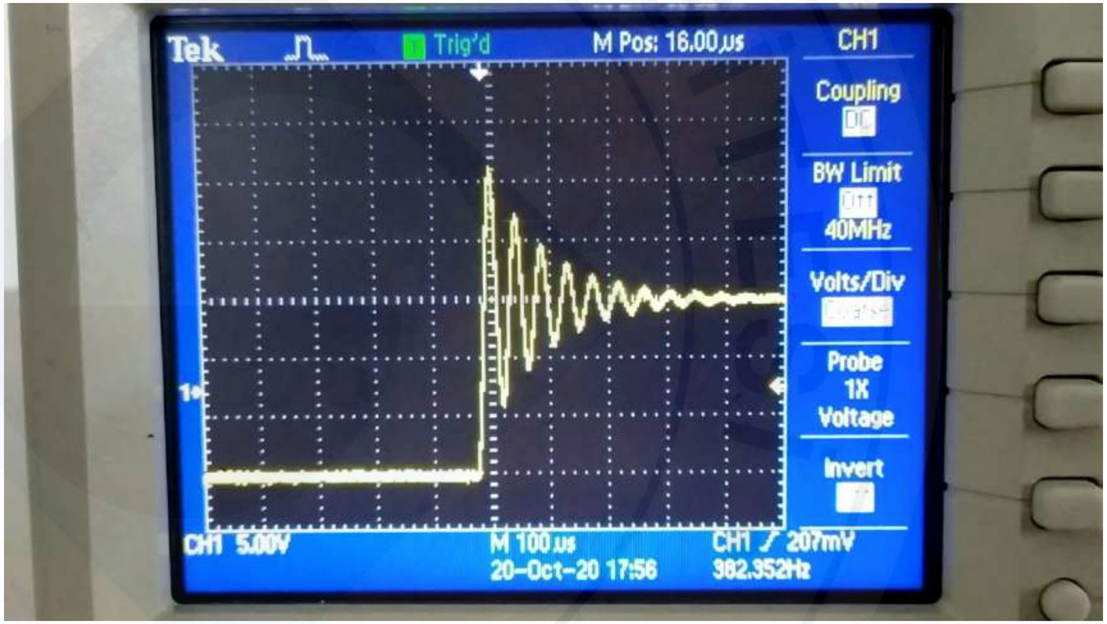
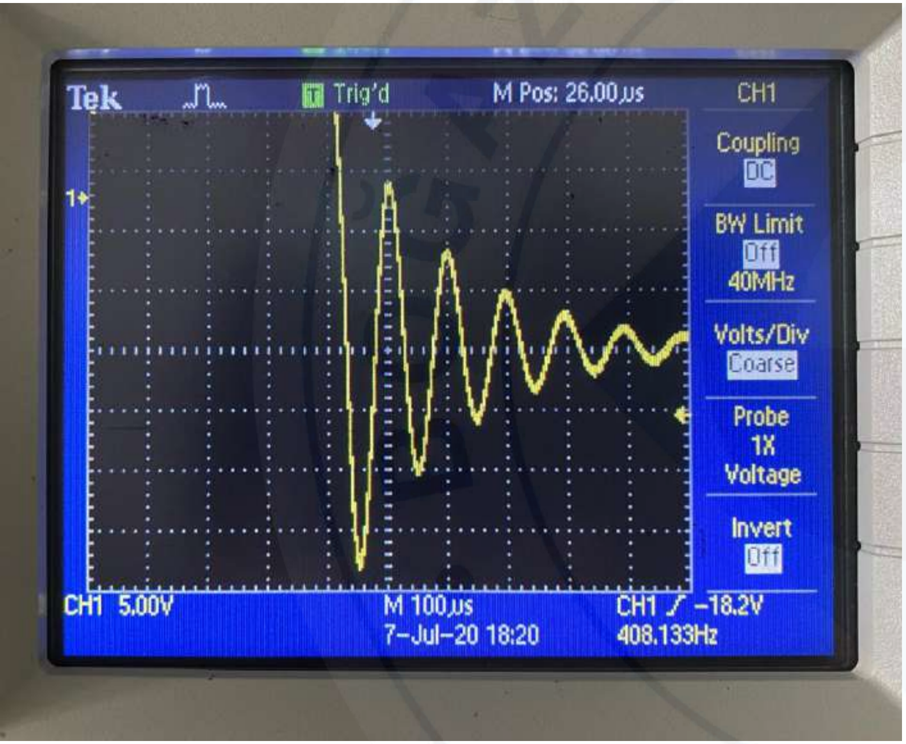
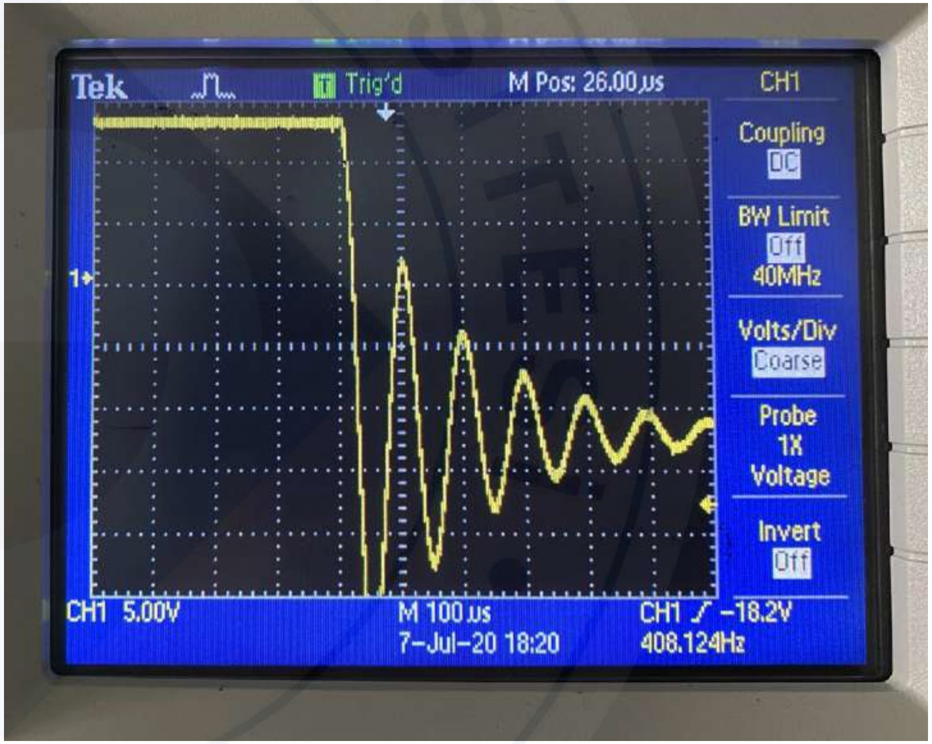


EXPERIMENT: With iron block inside the inductor





EXPERIMENT: With iron block inside the inductor

WITH 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_2 =	....	....
		....	

Show the Dimensional Analysis of L clearly: