The Ohm’s law applies to circuits with resistors, capacitors, and inductors. This lab is intended to do experiments with resistors and inductors.

1. Inductors and inductance

An inductor is a passive electrical component that can store energy in a magnetic field created by the electric current passing through it. The inductance $L$ is measured in units of Henries (H). Typically an inductor is a conducting wire shaped as a coil; the loops help to create a strong magnetic field inside the coil due to Ampere's Law. Due to the time-varying magnetic field inside the coil, a voltage is induced, according to Faraday's law of electromagnetic induction, which by Lenz's Law opposes the change in current that created it. Inductors are one of the basic components used in electronics where current and voltage change with time, due to the ability of inductors to delay and reshape alternating currents. Inductors called chokes are used as parts of filters in power supplies or can be used to block AC signals from passing through a circuit.

When inductors are connected together in parallel or in series, the equivalent inductance is given by the following laws:

$$\frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2} + \cdots + \frac{1}{L_n}$$

$$L_{eq} = L_1 + L_2 + \cdots + L_n$$

2. Transient Response of RL Circuit

When a DC voltage is applied to the circuit below, the current $i(t) = \frac{V}{R} [1 - \exp(-t/\tau)]$ is shown at the right plot. We observe the current increase at a time constant $\tau$, which depends on the values of the resistance and inductance.

![RL Circuit Diagram](image)
The **Time Constant** \((\tau=L/R)\) is a measure of time required for certain changes in voltages and currents in RC and RL circuits. The time constant can be measured to be the time that the current reaches **63%** of the steady state (maximum) current.

<table>
<thead>
<tr>
<th>Time (t)</th>
<th>(\tau)</th>
<th>(2\tau)</th>
<th>(3\tau)</th>
<th>(4\tau)</th>
<th>(5\tau)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(e^{-t/\tau})</td>
<td>0.368</td>
<td>0.135</td>
<td>0.050</td>
<td>0.018</td>
<td>0.0067</td>
</tr>
</tbody>
</table>

A **Pulse** is a voltage or current that has finite repetitive duration called the **period** \((T)\). We consider a square wave that has flat voltage pulse.

The **pulse width** \((t_p)\) of an ideal square wave is equal to half the time period. Generally, when the elapsed time exceeds **five time constants** \((5\tau)\) after switching has occurred, the currents and voltages have nearly reached their final value, which is also called steady-state response.

**Experiment Procedure:**

i. Set up the circuit above with \(R = 1k\Omega\) and \(L = 10mH\) and switch on the breadboard power supply. The **time constant** is \(\tau=\) s.

ii. Use the Function Generator on the breadboard and apply a square wave at about 10 kHz as input voltage about 2 V peak-to-peaks to the circuit.

\[
T \text{ (period)} = s; \quad f \text{ (frequency)} = Hz; \quad V \text{ (peak-peak)} = V
\]

iii. Bring the input voltage signal to channel 2, and trigger on channel 2. Bring the voltage across the resistor to oscilloscope. The circuit is shown in the figure below. You should see a square wave of the generator shown in the bottom trace of the right graph below; and an increasing voltage across the resistor shown in the top trace of the right graph.

The time constant \(\tau=L/R\) can be determined by the voltage (across the resistor) reaching 0.63 of the maximum voltage \(V_{\text{max}}\). In the above example, the scope has 10 \(\mu s\) per division, thus the period is 95 \(\mu s\), and the frequency is 10.5 kHz. The time constant is about 6 \(\mu s\).
Experimental report:

a. Carry out experiments with \( R = 1 \text{k}\Omega \) and \( L = 10 \text{ mH} \) and measure the time constant. Compare your measured time constant with the theoretical number:

\[
\tau_{\text{measured}} = \text{s}; \quad \tau_{\text{theory}} = \frac{L}{R} = \text{s}.
\]

b. Does your measured time constant depend on the applied voltage?

c. Change the circuit to \( R = 500 \text{ }\Omega \) and \( L = 10 \text{ mH} \). What is the new time constant?

3. Sinusoidal wave in RL circuit

Now replace the DC supply on the RL circuit (\( R = 500 \text{ }\Omega, L = 20 \text{ mH} \)) by an AC sinusoidal voltage supply. First measure the signal from the function generator for \( V \) (peak-peak) about 2 V.

a. Describe what you see.

b. Use the oscilloscope to measure the amplitude of the voltage across the resistor and Fill the table below and plot the measured voltage vs frequency. Plot the ratio \( V_{\text{out}}/V_{\text{in}} \) as a function of frequency.

\[
\begin{array}{|c|c|c|c|}
\hline
\text{Frequency (Hz)} & \text{Input voltage (V)} & \text{Voltage_peak-peak (V)} & V_{\text{out}}/V_{\text{in}} \\
\hline
1,000 & & & \\
2,000 & & & \\
5,000 & & & \\
10,000 & & & \\
20,000 & & & \\
30,000 & & & \\
40,000 & & & \\
50,000 & & & \\
60,000 & & & \\
70,000 & & & \\
80,000 & & & \\
100,000 & & & \\
\hline
\end{array}
\]
In your plot, the frequency is in log-scale horizontal axis, and the ratio is in the vertical in log scale. What is your observation?