RESISTANCE-INDUCTANCE AND RESISTANCE-CAPACITANCE FILTER CIRCUITS

PREPARATORY WORK

1. Explain the operation of low pass filter circuits.
2. Explain the operation of high-pass filter circuits.
3. Obtain the expressions for the corner frequency of R-L and R-C filters
4. Describe the experimental calculation of the corner frequency in R-L and R-C filters.

NOTE: Come to the experiments by preparing the preparatory work as a report (with the report cover). Those without a preparation report will not be admitted to the experiments.

HIGH-FREQUENCY LOW-FREQUENCY FILTERS

Series RC and RL circuits are often used as filters. They act as a high-frequency filter by attenuating low-frequency components while passing high-frequency components, and as a low-frequency filter by attenuating high-frequency signals while passing low-frequency components.

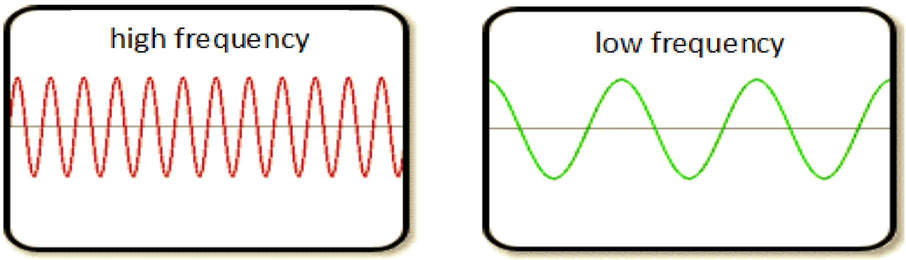

Figure 1. High and low frequency signals

For various circuits (such as amplifiers and filters) the frequency dependence of the input/output ratios can be easily seen. $\left[\frac{(V_p)}{(V_p)}\right]$ value, in "decibels, DB", gives the gain of an amplifier or filter.

High-Frequency RC Filters

Figure 2 shows how a series RC circuit must be connected to work as a high-frequency filter. In each case, the input and output are indicated by the voltages $(V_V)V$ and $(V_V)V$.

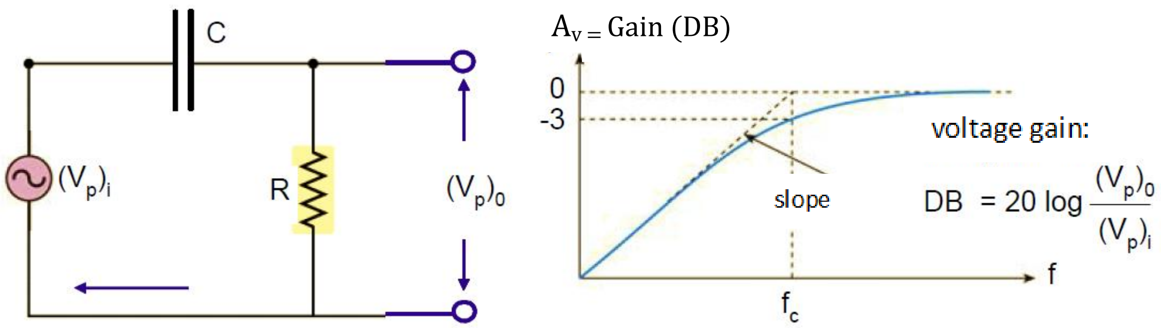

Figure 2. High frequency RC filter and Bode diagram

$$w_c = \frac{1}{CR} \qquad f_c = \frac{w_c}{2\pi} = \frac{1}{2\pi RC}$$

For an RC circuit to be used as a high-frequency filter, the output voltage must be taken at the terminals of resistor R. The peak (maximum) current in this circuit,

$$I_p = \frac{(V_p)i}{\sqrt{R^2 + \left(\frac{1}{wC}\right)^2}}$$

Since the voltage drop across the resistor is in phase with the current,

$$I_p = \frac{(V_p)_0}{R}$$

is. The ratio of the peak output voltage to the peak input voltage is found by dividing the first equation by the second and rearranging.

$$\frac{(V_p)_0}{(V_p)_i} = \frac{R}{\sqrt{R^2 + \left(\frac{1}{wC}\right)^2}} = \frac{1}{\sqrt{1 + \left(\frac{1}{wRC}\right)^2}}$$

$$V_{çıkış,rms} = V_{rms}\frac{R}{\sqrt{R^2 + \left(\frac{1}{wC}\right)^2}} = V_{rms}\frac{1}{\sqrt{1 + \left(\frac{1}{wRC}\right)^2}}$$

Low-Frequency RC Filters

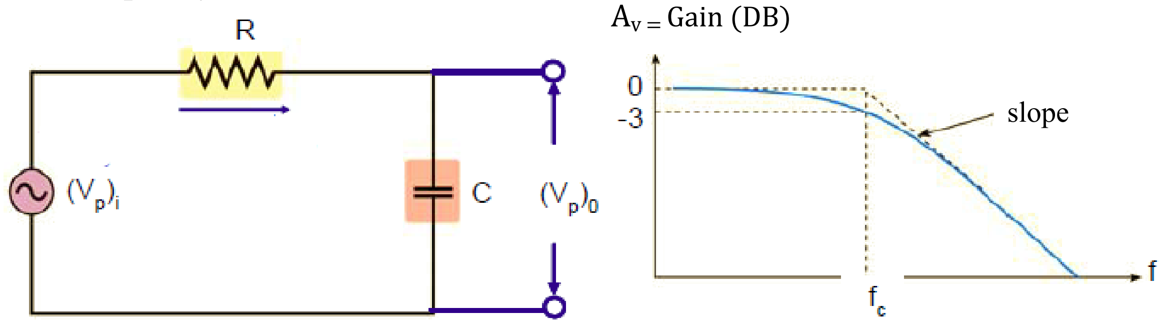

Figure 3. Low frequency RC filter and Bode diagram

For the low-frequency filter shown in Figure 3,

$$(V_p)_0 = I_p X_c = \frac{I_p}{wC}$$

$$\frac{(V_p)_0}{(V_p)_i} = \frac{1}{wC\sqrt{R^2 + \left(\frac{1}{wC}\right)^2}} = \frac{1}{\sqrt{1 + (wCR)^2}}$$

$$V_{çıkış,rms} = V_{rms} = \frac{\frac{1}{wC}}{\sqrt{R^2 + \left(\frac{1}{wC}\right)^2}} V_{rms}\frac{1}{\sqrt{1 + (wCR)^2}}$$

RL Filters

RL circuits can also be used as filters. In these, the potential between the terminals of the reactive element is used for high-frequency filters and the potential between the terminals of the resistor for low-frequency filters. The behavior of these filters is the opposite of RC circuits. Low- and high-frequency filters are very important in the design of electronic circuits.

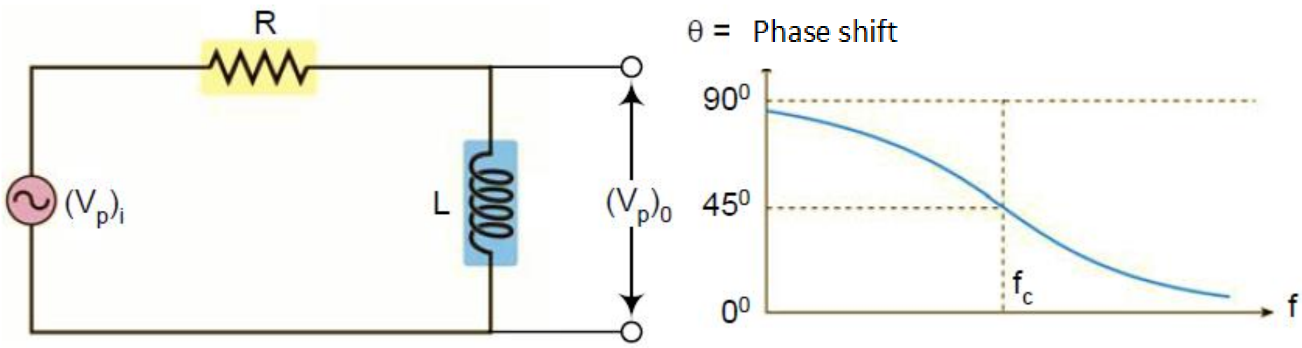

Figure 4. High frequency RL filter circuit

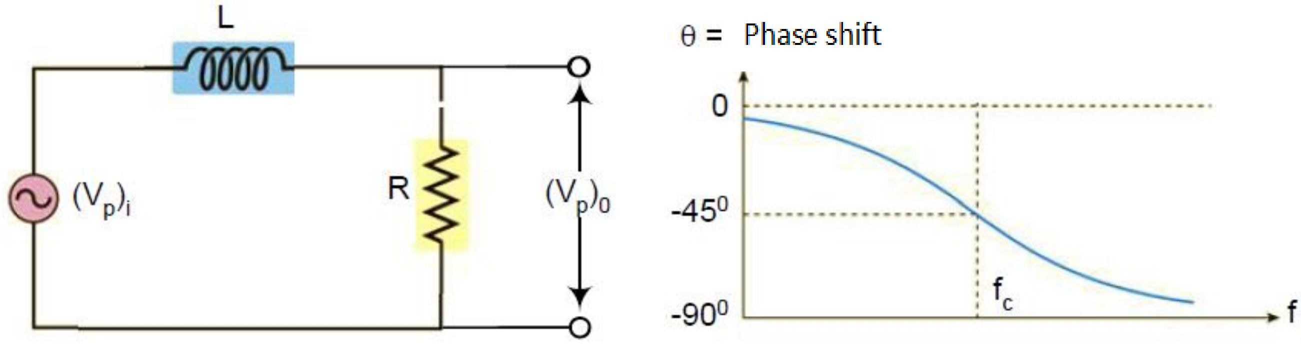

Figure 5. Low frequency RL filter circuit

$$w_C = \frac{R}{L} \qquad f_c = \frac{w_C}{2\pi} = \frac{R}{2\pi L}$$

The frequency at which the output voltage is 0.7 times the input voltage is called the corner frequency (fc). At this frequency, the phase shift between output and input is 45°.

Expressions of corner frequencies of RC and RL filters:

$$f_c = \frac{1}{2\pi RC}, \quad f_c = \frac{R}{2\pi L}$$

is calculated as.

EXPERIMENTS

Components Used in the Experiment

- Circuit module, Signal generator, A measuring instrument that can measure in the range of 20 mA AC and 20 V AC, Oscilloscope, Connection elements.
- 2 pcs 1 kΩ resistors
- 22 nF, 47 nF and 100 nF capacitors
- 68 mH, 100 mH and 10 mH inductances.

1. RESISTANCE-CAPACITANCE FILTER CIRCUITS

Purpose of the Experiment

- To learn the working principle of low-pass and high-pass filter circuits consisting of resistance and capacitance elements.
- To make a low-pass and high-pass filter circuit consisting of resistance and capacitance elements.
- Calculating the corner frequency using experimental measurements.

- To examine the frequency dependent changes of the output voltages of filters consisting of R and C elements.

Conducting Experiments

Experiment 1.1.

The experimental connection diagram of the low-pass filter circuit made of resistor and capacitance elements is given in Figure 6.

1. Set up the circuit as shown in Figure 6.
2. On the oscilloscope, Ch. 1 input voltage and Ch. 2 output voltage on the oscilloscope.
3. Measure and adjust the output of the signal generator on an oscilloscope to obtain a sinusoidal voltage (V_i) of 6 volts peak-to-peak at the input of the circuit.
4. Apply a sinusoidal voltage of 6 volts peak-to-peak to the input of the circuit and observe the output voltageV_0 for 100Hz,1kHz,10kHz,100kHz values of the frequency from Ch 2 on the oscilloscope and record the measured values in Table 1.
5. Ch. Adjust the frequency so that the amplitude of the signal in Ch. 2 is 0.7 times the input. Record the frequency you find in Table 1. This value is the corner frequency of the circuit.
6. Measure the phase shift between the signal at Ch 1 (input voltage) and the signal at Ch 2 (output voltage) for 100Hz, corner frequency, 100kHz. Record the values obtained in Table 1.

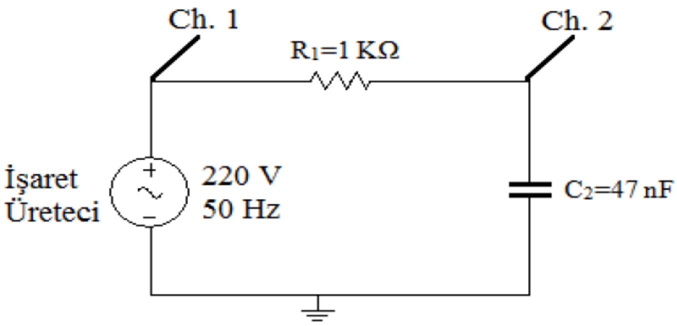

Figure 6. R-C low-pass filter circuit.

Table 1. Measurement results of R-C low-pass filter experiment

Frequency	100 Hz	1 kHz		10 kHz	100 kHz	Components
Input (Volt)	6	6	6	6	6	R=1 kΩ
Output (Volt)			4.2			C=47 nF
Phase Difference						Low pass

Experiment 1.2.

Change the positions of R and C elements in Figure 6. In this case the circuit will be a High Pass Filter. Repeat the same process and record the values in Table 2.

Table 2. Measurement results of R-C high-pass filter experiment

Frequency	100 Hz	1 kHz		10 kHz	100 kHz	Components
Input(Volt)	6	6	6	6	6	R=1kΩ
Output (Volt)			4.2			C=47nF
Phase Difference						Low pass

Draw the characteristics of R-C low-pass and high-pass filters on the axes in Figure 7 below.

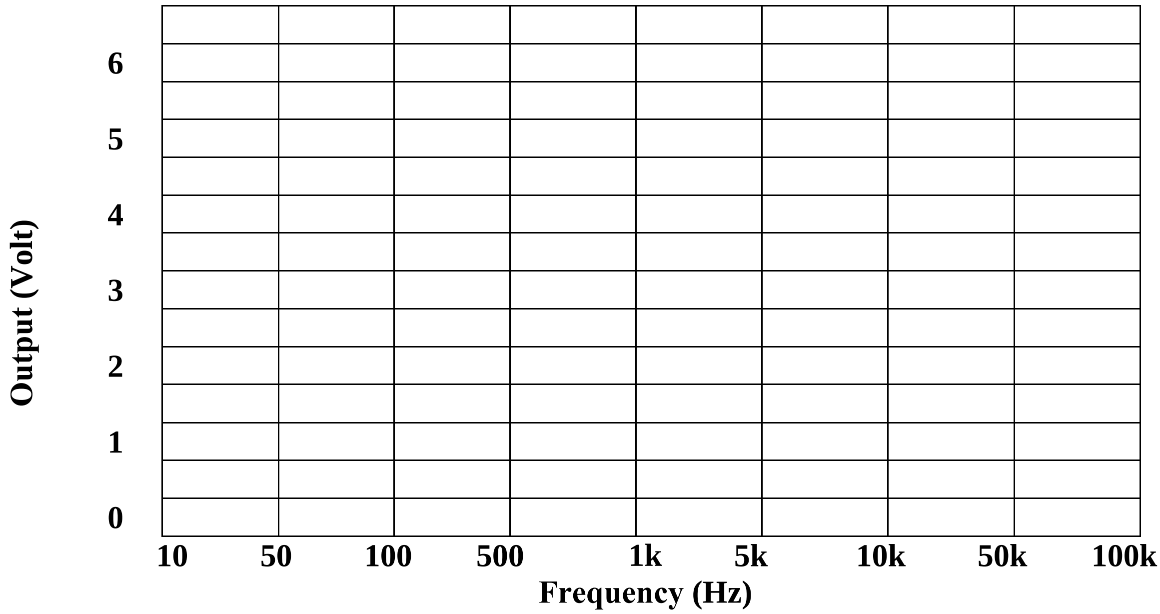

Figure 7. Experimental characteristics of R-C low-pass and high-pass filters.

Experimenet 1.3.

Turn the circuit back into a low-pass filter and repeat the experiment for R= 1 kΩ, C=100 nF, R= 1 kΩ, C=22 nF and R= 2 kΩ, C=22 nF and record the measured values in Table 3.

Table 3. Low-pass filter test measurement results for different R-C values

Frequency	100 Hz	1 kHz		10 kHz	100 kHz	Components
Input (Volt)	6	6	6	6	6	R=1 kΩ C=100 nF Low pass
Output(Volt)			4.2			
Input(Volt)	6	6	6	6	6	R=1 kΩ C=22 nF Low pass
Output(Volt)			4.2			
Input(Volt)	6	6	6	6	6	R=2 kΩ C=22 nF Low pass
Output (Volt)			4.2			

Draw the characteristics of the low-pass filter consisting of different R-C values on the axes in Figure 8 below.

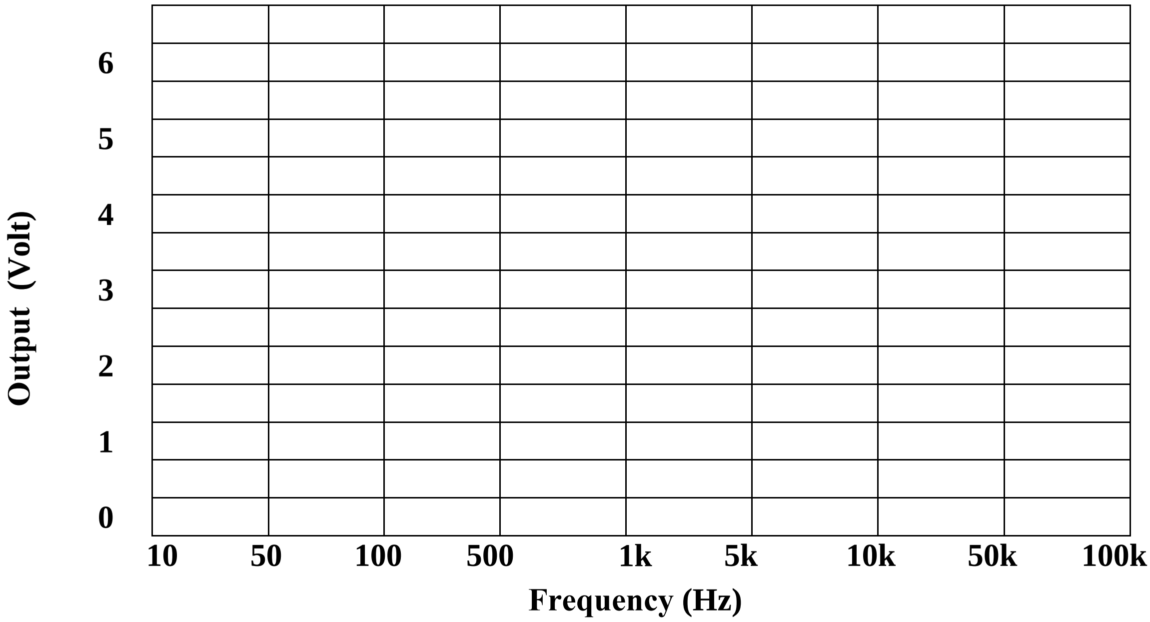

Figure 8. Experimental characteristics of the low-pass filter for different R-C values.

2. RESISTANCE-INDUCTANCE FILTER CIRCUITS

Purpose of the Experiment

- To learn the working principle of low-pass and high-pass filter circuits consisting of resistance and inductance elements
- To make a low-pass and high-pass filter circuit consisting of resistance and inductance elements
- Calculating the corner frequency using experimental measurements.
- To investigate the frequency dependent changes of the output voltages of filters consisting of R and L elements

Conducting the Experiments

Experiment 2.1.

The experimental connection diagram of the high-pass filter circuit made of resistance and inductance elements is given in Figure 9.

.

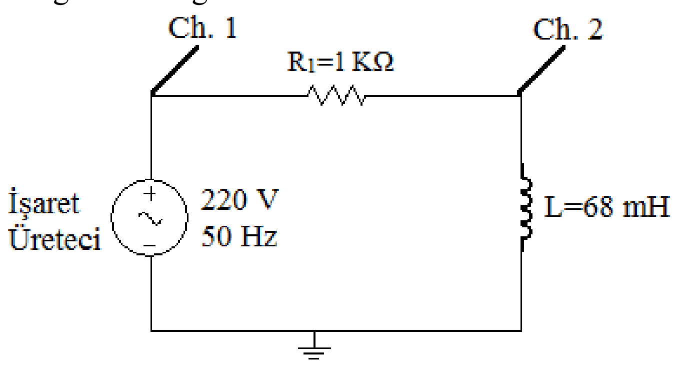

Figure 9. R-L high-pass filter circuit.

1. Set up the circuit as shown in Figure 9.
2. On the oscilloscope, Ch. 1 input voltage and Ch. 2 output voltage on the oscilloscope.
3. Adjust the output of the signal generator by measuring it on an oscilloscope to obtain a sinusoidal voltage (V_i) of 6 volts peak to peak at the input of the circuit.

4. Apply a sinusoidal voltage of 6 volts peak-to-peak to the input of the circuit and observe the output voltageV0 for 100Hz,1kHz,10kHz,100kHz values of the frequency from Ch 2 on the oscilloscope and record the measured values in Table 4.

5. Ch. Adjust the frequency so that the amplitude of the signal in Ch. 2 is 0.7 times the input. Record the frequency you find in Table 1. This value is the corner frequency of the circuit.

6. Measure the phase shift between the signal at Ch 1 (input voltage) and the signal at Ch 2 (output voltage) for 100Hz, corner frequency, 100kHz.

Table 4. Measurement results of R-L high-pass filter experiment

Frequency	100 Hz	1 kHz		10 kHz	100 kHz	Components
Input (Volt)	6	6	6	6	6	R=1 kΩ
Output (Volt)			4.2			L=68 mH
Phase Difference						High Pass

Experiment 2.2.

Change the positions of R and L elements in Figure 9. In this case the circuit will be a Low Pass Filter. Repeat the same process and record the values you find in Table.5.

Table 5. Measurement results of R-L low-pass filter experiment

Frequency	100 Hz	1 kHz		10 kHz	100 kHz	Components
Input (Volt)	6	6	6	6	6	R=1 kΩ
Output(Volt)			4.2			L=68 mH
Phase Difference						Low Pass

Draw the characteristics of R-L low-pass and high-pass filters on the axes in Figure 10 below.

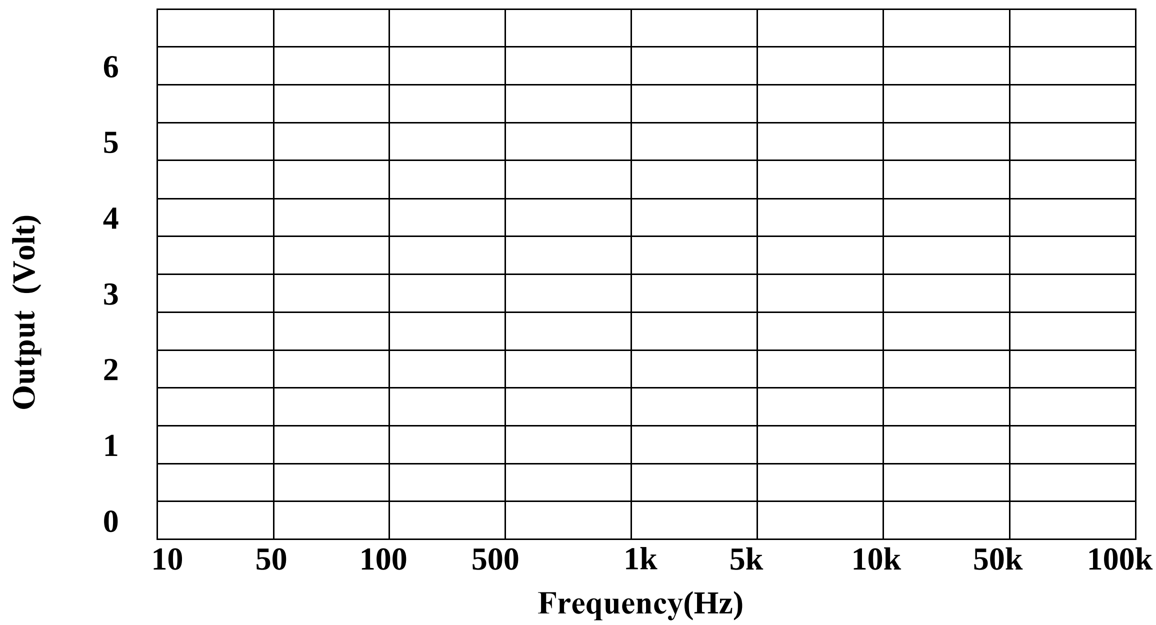

Figure 10. Experimental characteristics of R-L low-pass and high-pass filters.

Experiment 2.3.

Turn the circuit back into a high-pass filter and repeat the experiment for R= 2 kΩ, L=68 mH and R= 1 kΩ, L=136 mH and record the measured values in Table 6.

Table 6. Measurement results of high-pass filter experiment for different R-L values.

Frequency	100 Hz	1 kHz		10 kHz	100 kHz	Components
Input (Volt)	6	6	6	6	6	R=2 kΩ
Output (Volt)			4.2			L=68 mH High pass
Input (Volt)	6	6	6	6	6	R=1 kΩ
Output(Volt)			4.2			L=136 mH High pass

Draw the characteristics of the high-pass filter consisting of different R-L values on the axes in Figure 11 below.

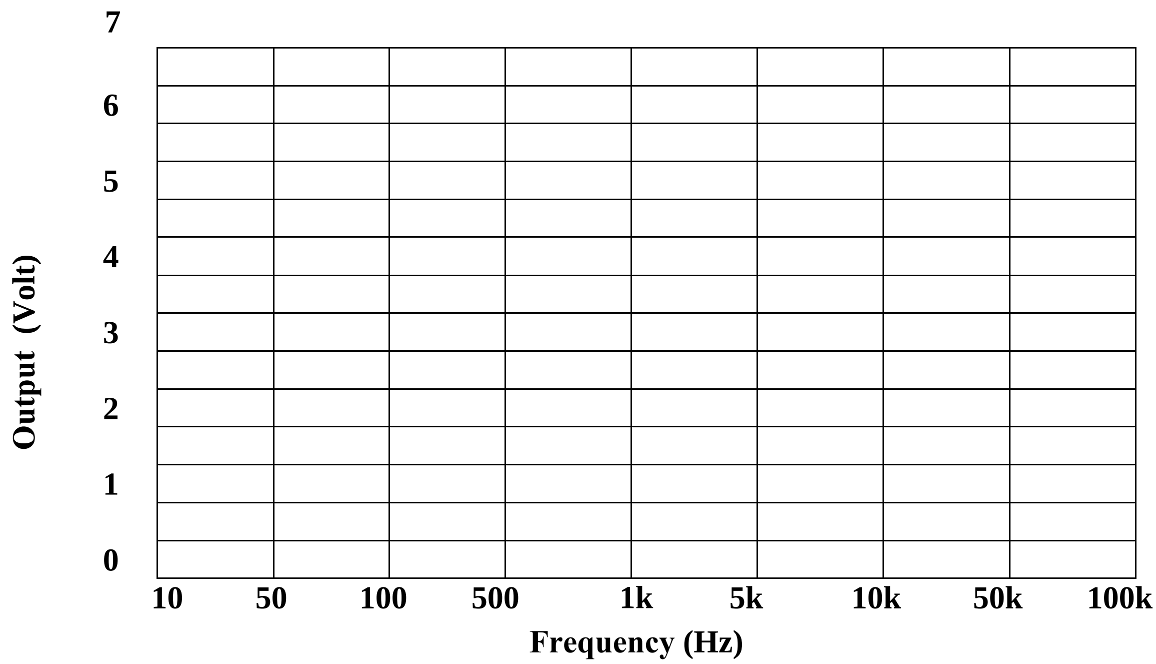

Figure 11. Experimental characteristics of the high-pass filter for different R-L values.

IMPORTANT NOTE

In order to perform the experiments properly, preparatory questions should be done and the theoretical part of the methods should be well known.