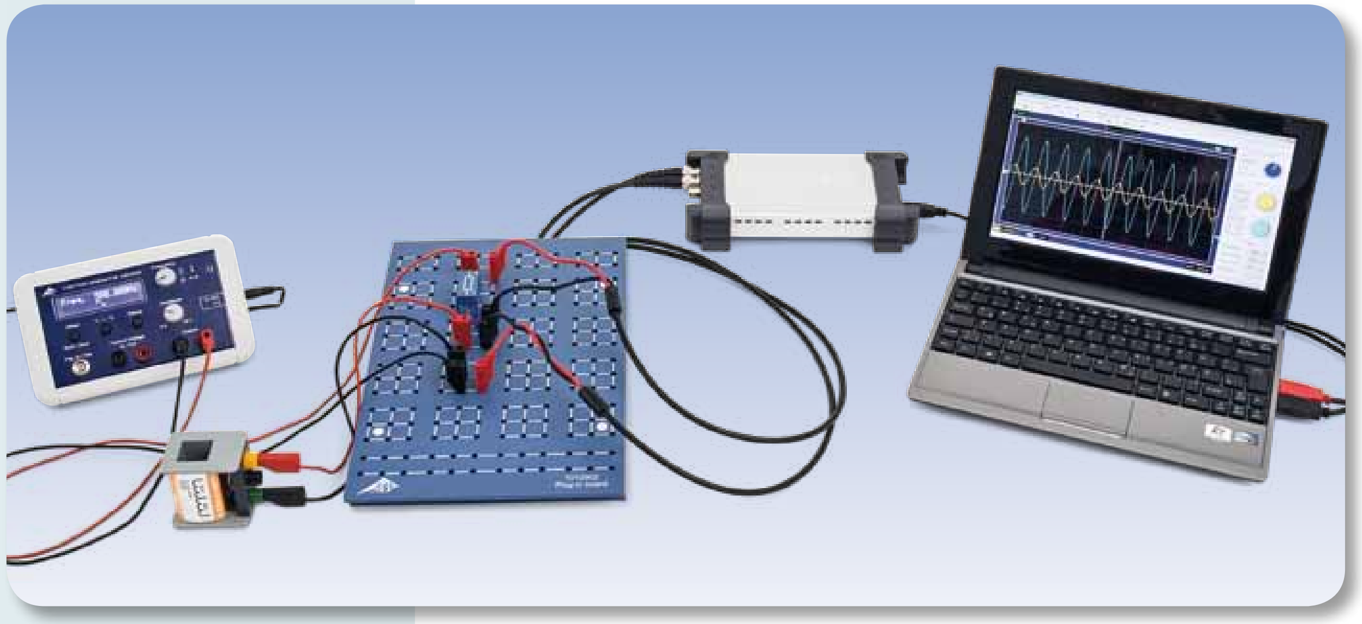
IMPEDANCE OF A COIL IN AN AC CIRCUIT

UE3050211



EXPERIMENT PROCEDURE

- **Determine the amplitude and phase of inductive impedance as a function of the inductance.**
- **Determine the amplitude and phase of inductive impedance as a function of the frequency**

OBJECTIVE

Determine inductive impedance as a function of inductance and frequency

SUMMARY

Any change in the current through a coil induces a voltage. If an alternating current flows, an AC voltage will be induced, which is shifted in phase with respect to the current. In mathematical terms, the relationship can be expressed most easily if current, voltage and impedance are regarded as complex values, whereby the real components need to be considered. In this experiment, a frequency generator supplies an alternating voltage with a frequency of up to 2 kHz. A dual-channel oscilloscope is used to record the voltage and current, so that the amplitude and phase of both can be determined. The current through the coil is given by the voltage drop across a resistor with a value which is negligible in comparison to the inductive impedance exhibited by the coil itself.

REQUIRED APPARATUS

Quantity	Description	Number
1	Plug-In Board for Components	**1012902**
2	Coil S with 1200 Taps	**1001002**
1	Resistor 10 Ω, 2 W, P2W19	**1012904**
1	Function Generator FG 100 (230 V, 50/60 Hz)	**1009957 or**
	Function Generator FG 100 (115 V, 50/60 Hz)	**1009956**
1	USB Oscilloscope 2x50 MHz	**1017264**
2	HF Patch Cord, BNC/4 mm Plug	**1002748**
1	Set of 15 Experiment Leads, 75 cm 1 mm²	**1002840**

2

BASIC PRINCIPLES

Any change in the current through a coil induces a voltage which acts such as to oppose the change in current. If an alternating current flows, an AC voltage will be induced, which is shifted in phase with respect to the current. In mathematical terms, the relationship can be expressed most easily if current, voltage and impedance are regarded as complex values, whereby the real components need to be considered.

The relationship between current and voltage for a coil is as follows:

(1) $$U = L \cdot \frac{dI}{dt}$$

I: Current, U: Voltage, L: Inductance

Assume the following voltage is applied:

(2) $$U = U_0 \cdot \exp(i \cdot 2\pi \cdot f \cdot t)$$

This gives rise to a current as follows:

(3) $$I = \frac{U_0}{i \cdot 2\pi \cdot f \cdot L} \cdot \exp(i \cdot 2\pi \cdot f \cdot t)$$

The impedance associated with the inductor L can then be defined as in the following equation:

(4) $$X_L = \frac{U}{I} = i \cdot 2\pi \cdot f \cdot L$$

The real component of this is measurable, therefore

(5a) $$U = U_0 \cdot \cos \omega t$$

(6a) $$I = \frac{U_0}{2\pi \cdot f \cdot L} \cos\left(\omega t - \frac{\pi}{2}\right) = I_0 \cos\left(\omega t - \frac{\pi}{2}\right)$$

(7a) $$X_L = \frac{U_0}{I_0} = 2\pi \cdot f \cdot L$$

In this experiment, a frequency generator supplies an alternating voltage with a frequency of up to 2 kHz. A dual-channel oscilloscope is used to record the voltage and current, so that the amplitude and phase of both can be determined. The current through the capacitor is related to the voltage drop across a resistor with a value which is negligible in comparison to the inductive impedance exhibited by the coil itself.

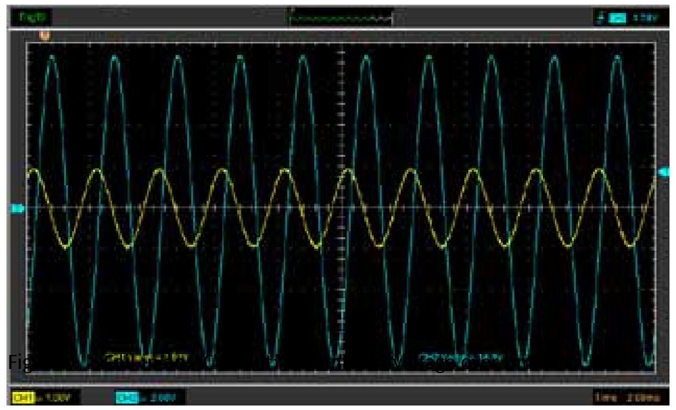


Fig. 1: Coil in an AC circuit: Current and voltage over time

EVALUATION

As per equation (4), the inductive impedance X_L is proportional to the frequency f and the inductance L. In the relevant graphs, the measurements therefore lie along a straight line through the origin within the measurement tolerances.

The phase of the current through the coil is 90° behind that of the voltage, since every change in current induces an opposing voltage.

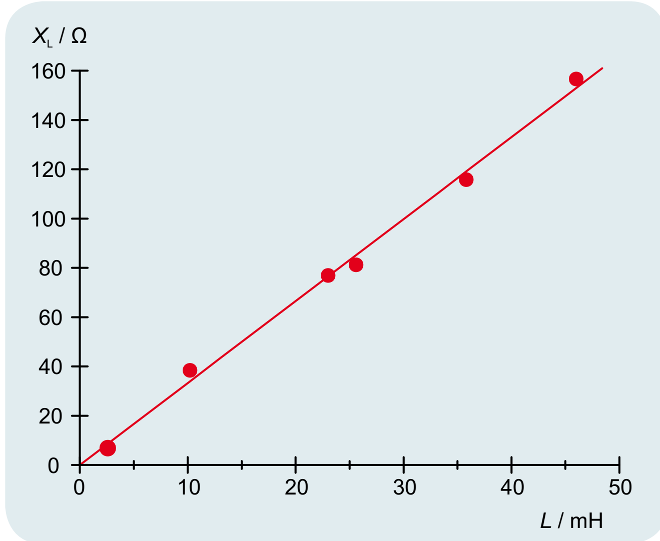


Fig. 2: Inductive impedance X_L as a function of inductance L

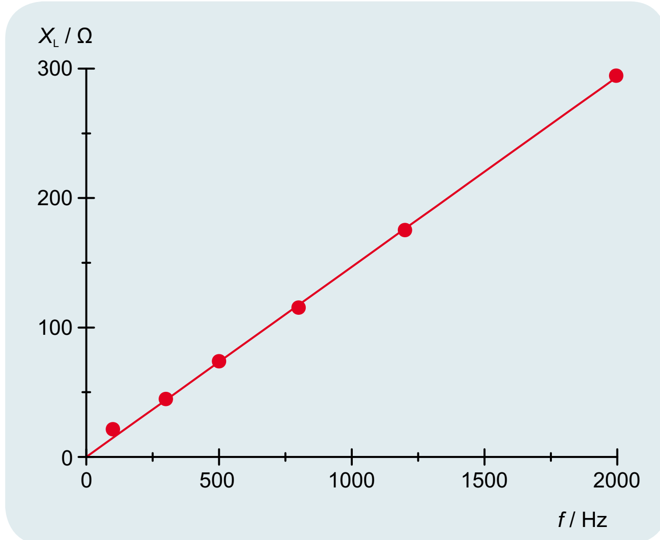


Fig. 3: Inductive impedance X_L as a function of frequency f