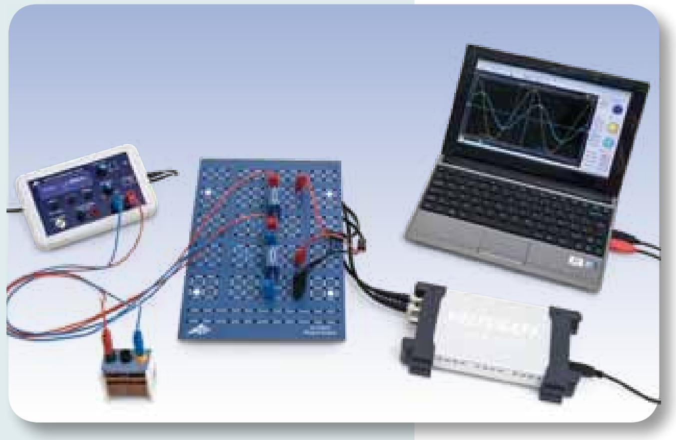
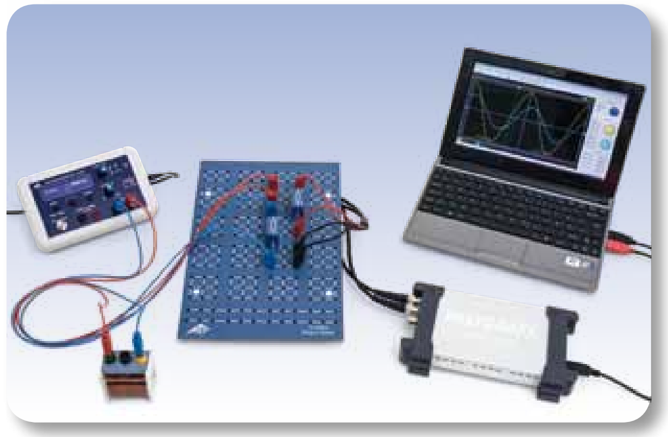
UE3050311 **AC RESISTANCE**





EXPERIMENT PROCEDURE

- **Determine the amplitude and phase of the overall resistance as a function of frequency for a series circuit.**
- **Determine the amplitude and phase of the overall resistance as a function of frequency for a parallel circuit.**

OBJECTIVE

Determine the AC resistance in a circuit with inductive and resistive loads.

SUMMARY

In AC circuits, not only ohmic resistance needs to be taken into account but also the resistance due to inductive loads. The combination of the two may be connected in series or parallel. This has an effect on both the amplitudes and phase of the current and voltage. In the experiment, this will be investigated using an oscilloscope and a function generator supplying alternating current with frequencies between 50 and 10000 Hz.

REQUIRED APPARATUS

Quantity	Description	Number
1	Plug-In Board for Components	1012902
1	Resistor 1 Ω, 2 W, P2W19	1012903
1	Resistor 100 Ω, 2 W, P2W19	1012910
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
1	HF Patch Cord, BNC/4 mm Plug	1002748
1	Set of 15 Experiment Leads, 75 cm 1 mm²	1002840
1	Coil S with 600 Taps	1001000
2	Coil S with 1200 Taps	1001002

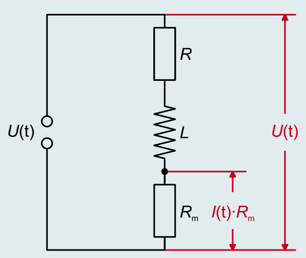


Fig. 2: Measurement set-up for series circuit

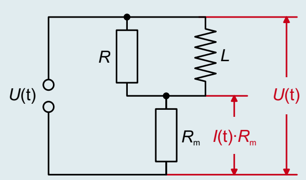


Fig. 3: Measurement set-up for parallel circuit

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GENERAL PRINCIPLES

In AC circuits, it is common to use complex numbers to describe the resistance in circuits with inductors because this actually makes calculation easier. This is because not only the amplitude of the current and voltage is a factor, but also the phase relationships between the two need to be taken into account (this complex resistance is usually called impedance). Series and parallel circuits with both ohmic and inductive resistance can then be described quite easily, although in each case, only the real component is measurable).

The complex resistance (impedance) of a coil of inductance *L* in a circuit with an alternating current of frequency *f* is as follows:

(1) $$X_L = i\cdot 2\pi\cdot f\cdot L$$

Angular frequency $\omega = 2\pi\cdot f$

Therefore the total resistance (impedance) of a series circuit containing a coil with a resistance *R* is

(2) $$Z_S = i\cdot 2\pi\cdot f\cdot L + R$$

For a parallel circuit, the total resistance can be assigned thus:

(3) $$Z_P = \frac{1}{\frac{1}{i\cdot 2\pi\cdot f\cdot L}+\frac{1}{R}}$$

The usual way of writing this is as follows:

(4) $$Z = Z_0\cdot\exp(i\cdot\varphi)\ .$$

This becomes

(5) $$Z_S = \sqrt{(2\pi\cdot f\cdot L)^2 + R^2}\cdot\exp(i\cdot\varphi_S)$$

where $\tan\varphi_S = \frac{2\pi\cdot f\cdot L}{R}$)

and

(6) $$Z_P = \frac{2\pi\cdot f\cdot L\cdot R}{\sqrt{(2\pi\cdot f\cdot L)^2 + R^2}}\cdot\exp(i\cdot\varphi_P)$$

where $\tan\varphi_P = \frac{R}{2\pi\cdot f\cdot L}$

In this experiment a function generator supplies an AC voltage with an frequency *f*, which is adjusted between 50 and 10000 Hz. Voltage *U* and current *I* are recorded on an oscilloscope, whereby, *I* is displayed in the form of the voltage drop across a small auxiliary resistor. This allows the real components of the voltage across the relevant resistance *Z* to be measured.

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

The resulting current is as follows:

(8) $$I = \frac{U_0}{Z_0}\cdot\exp(i\cdot(2\pi\cdot f\cdot t - \varphi)) = I_0\cdot\exp(i\cdot(2\pi\cdot f\cdot t-\varphi))\ .$$

The amplitudes I_0 and U_0, plus the phase shift φ can all be read from the oscilloscope.

EVALUATION

The magnitude of the overall resistance is $Z_0 = \frac{U_0}{I_0}$ displayed as a function of frequency *f* or of the inductive resistance $X_L = 2\pi\cdot f\cdot L$. If the inductive impedance is large, the resistance of the series circuit will have the value of the inductive resistance and the parallel circuit will have the value of the ohmic resistance. The phase shift is between 0° and 90° and equals 45° if the ohmic and inductive resistance values are the same.

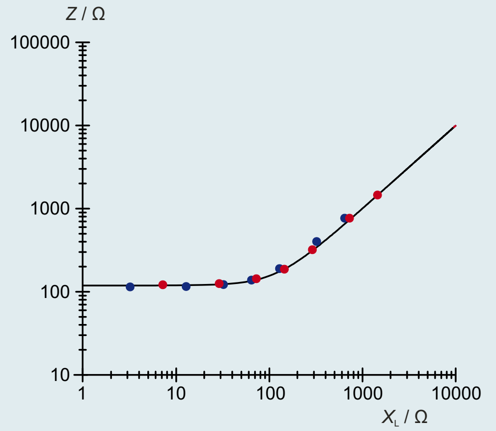

Fig. 3: Overall resistance for series circuit

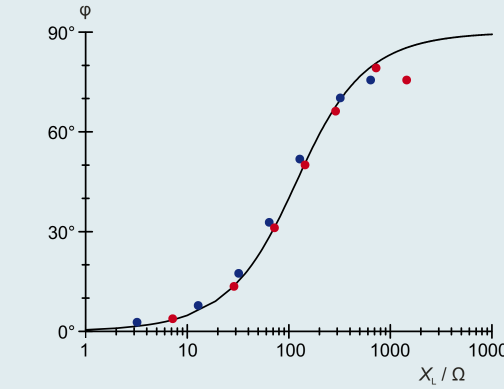

Fig. 4: Phase shift for series circuit

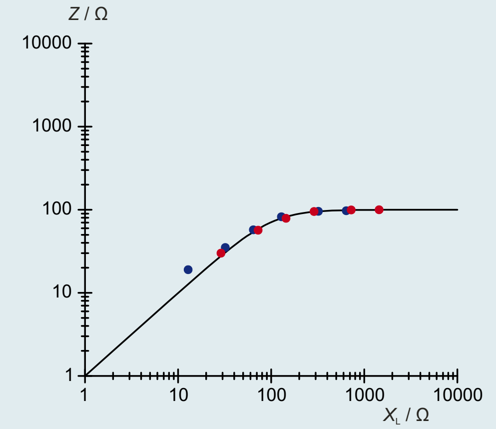

Fig. 5: Overall resistance for parallel circuit

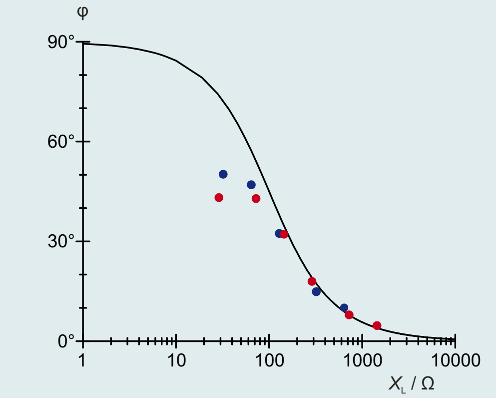

Fig. 6: Phase shift for parallel circuit

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