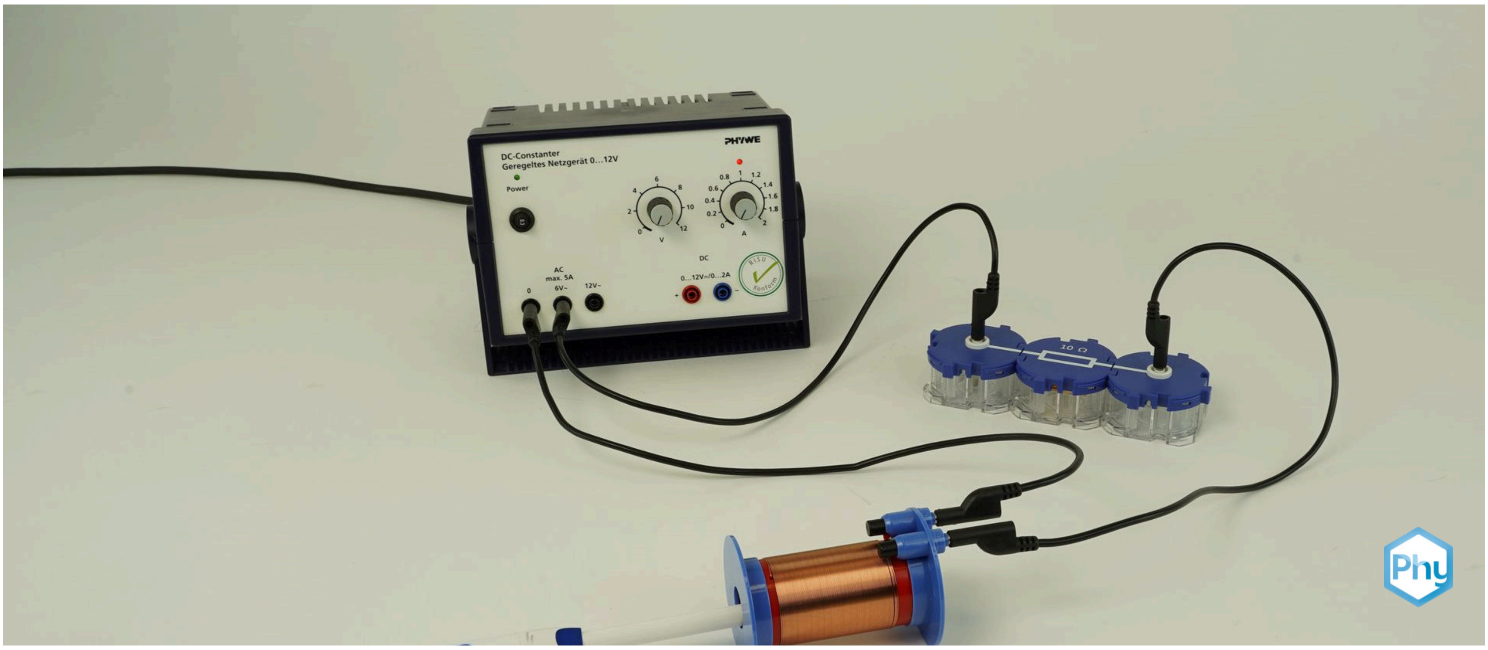
Magnetic field of a coil at alternating current with Cobra SMARTsense



Physics | Electricity & Magnetism | Electromagnetism & Induction

Difficulty level	Group size	Preparation time	Execution time
medium	2	10 minutes	10 minutes

This content can also be found online at:

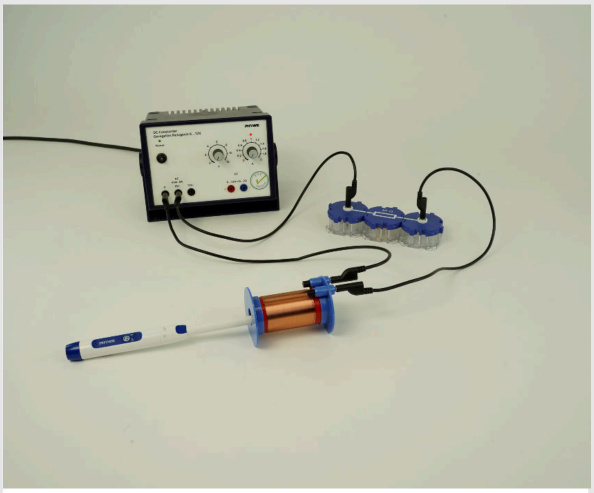
http://localhost:1337/c/5f4bc6d4c3481500038cb7bc

PHYWE

Teacher information

Application

PHYWE



Experiment set-up

A current carrying coil generates a magnetic field. The electromagnetic energy can be used, for example, to move magnetisable metals on the scrap yard with an excavator using electromagnets.

However, in order to transform voltages with the aid of a transformer, for example, the change in the magnetic field over time is important. Accordingly, an alternating voltage is applied to the primary coil. The magnetic field is reversed with the frequency of the primary voltage.

With the help of a magnetic field sensor the frequency of the alternating voltage can be observed. The grid frequency in the European Union is $f = 50Hz$.

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Other teacher information (1/2)

PHYWE

Prior knowledge

Students should be familiar with the basics of magnetic flux density and should know that a current carrying coil generates a magnetic field.

Scientific principle

The magnetic flux density is almost constant within a long thin coil and drops rapidly outside the coil. The magnetic flux density B is at the center of a long coil:

$B=\mu I N/l$

There is μ the magnetic permeability, I the amperage, N the number of turns and l the length of the coil or N/l the so-called coil density.

Other teacher information (2/2)

PHYWE

Learning objective

The alternating magnetic field of the coil has the same frequency as the alternating current from the power supply unit. The students should understand how to quantitatively measure a periodically changing magnetic field.

Tasks

1. measuring the magnetic flux density of a coil in alternating current over time
2. calculating the frequency from the measured data.

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Safety instructions

The general instructions for safe experimentation in science lessons apply to this experiment.

Notes

Alternating current, not direct current, is used in this experiment. The resistor is necessary to limit the current so that the coils do not overheat.

Student Information

Motivation

High voltage line

Alternating current is available as mains voltage in most common households. The reason is that electricity is usually transformed to high voltage for low-loss transport over land. For magnetic induction, the main functional principle of a transformer, the change in magnetic field strength over time is of particular importance.

In the European Union, the grid frequency, i.e. the number of voltage reversals per second, is $f = 50\,Hz$ and may vary in other regions of the world.

In this experiment you learn how to measure an alternating magnetic field with the help of a magnetic field sensor. This also allows you to determine the mains frequency.

Tasks

1. measure the magnetic flux density in a coil of alternating current over time

2. calculate the frequency from your measurement data

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Equipment

Position	Material	Item No.	Quantity
1	Cobra SMARTsense - 3-Axis Magnetic field	12947-00	1
2	PHYWE Power supply, 230 V, DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A	13506-93	1
3	Resistor module 10 Ohm, SB	05612-10	1
4	Junction module, SB	05601-10	2
5	Induction coil,100 turns,dia.40mm	11007-05	1
6	Connecting cord, 32 A, 500 mm, black	07361-05	3
7	measureAPP - the free measurement software for all devices and operating systems	14581-61	1

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Set-up (1/4)

PHYWE

For measurement with the **Cobra SMARTsense sensors** the **PHYWE measureAPP** is required. The app can be downloaded free of charge from the relevant app store (see below for QR codes). Before starting the app, please check that on your device (smartphone, tablet, desktop PC) **Bluetooth** is **activated**.

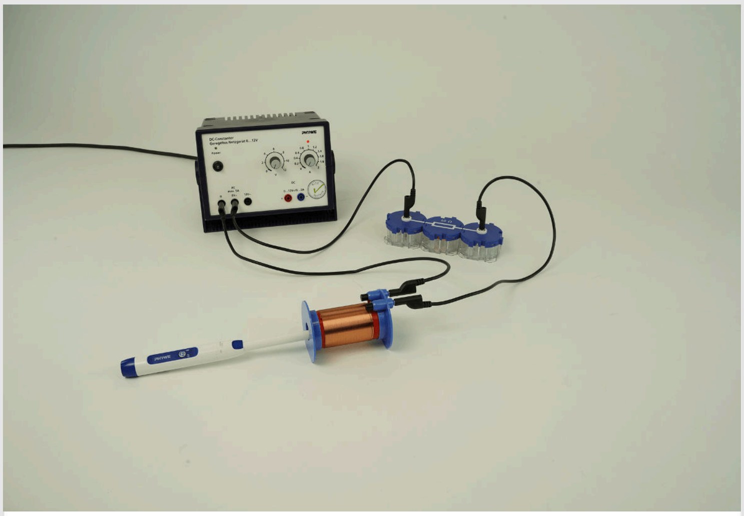
iOS

Android

Windows

Set-up (2/4)

PHYWE



Experiment set-up

Set up the test according to the adjacent figure.

To do this, switch on the power supply unit, the 10 Ω resistance and the coil in series.

Use the sockets for the 6V alternating current source for the circuit on the power supply unit.

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Set-up (3/4)

PHYWE

Start measureAPP on the tablet and switch on the Cobra SMARTsense magnetic field sensor (hold down the I/O button for about 3 seconds).

Select the sensor in measureAPP and connect it to the App. The following settings must be made:

- Fine measuring range (- 5 mT ... + 5 mT)
- Measuring frequency: 200 Hz
- Continuous measurement

Set-up (4/4)

PHYWE

Select only the longitudinal direction under measuring channel B_x of the sensor, so that only the magnetic flux density in the direction of the longitudinal axis of the sensor is measured.

Position the sensor in the coil so that the tip is in the middle of the coil. Calibrate the sensor to zero:

'Settings' > 'Set to zero'.

PHYWE

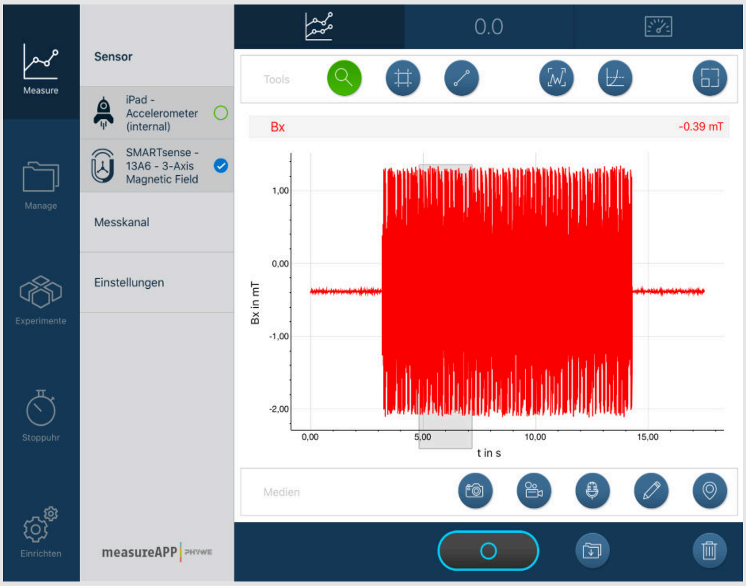
Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Procedure (1/2)

PHYWE



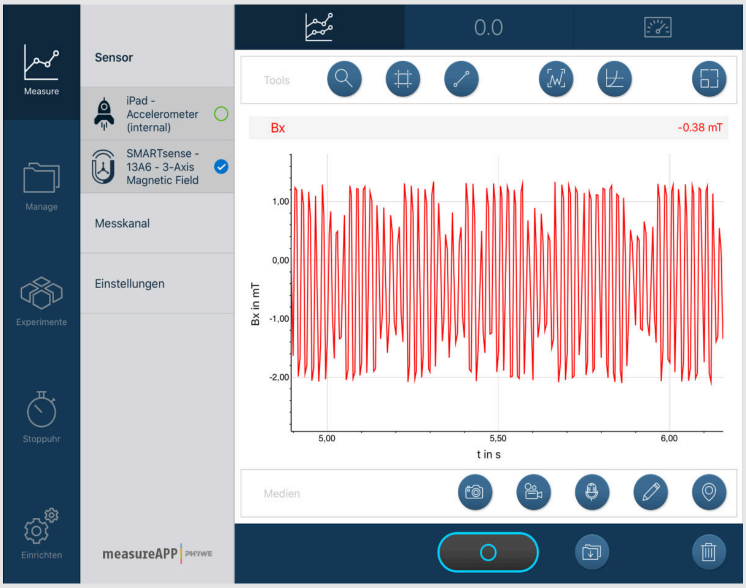
Start a measurement and switch on the power supply unit.

Switch off the power supply unit after about 10 seconds and stop the measurement.

Use the magnifying glass function to zoom into the measured data. For example, select a time span of one second.

Procedure (2/2)

PHYWE



Count the periods in a certain time range (for example one second) and calculate the resulting frequency of the AC voltage at the power supply unit.

When measuring a sinusoidal mains frequency of for example $f = 50\ Hz$ with a sampling frequency of $200\ Hz$ the sinusoidal course is not completely displayed.

For a more precise measurement, the sensor must be connected via USB. This allows the sampling rate to be set to $1000\ Hz$ increase.

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

PHYWE

Report

Task 1

PHYWE

What does the unit Hertz $[Hz]$?

- $1\,Hz = 1/s^2$
- $1\,Hz = 1\,s$
- $1\,Hz = 1\,s^2$
- $1\,Hz = 1/s$

Check

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Task 2

PHYWE

Which statements in connection with the measured frequency are correct?

- ☐ The number of polarity reversals ($N \to S$ or $S \to N$) of the magnetic field per second corresponds to the numerical value of the measured frequency.
- ☐ The frequency of the alternating magnetic field is twice as high as that of the alternating voltage.
- ☐ The frequency of the alternating magnetic field corresponds to the frequency of the alternating voltage.
- ☐ The number of polarity reversals ($N \to S$ or $S \to N$) of the magnetic field per second is twice the numerical value of the measured frequency.

Check

Task 3

PHYWE

Which statements are true?

- ☐ If a coil is operated with alternating voltage, it is particularly suitable for inducing voltages.
- ☐ If a coil is operated with alternating voltage, no energy can be transferred because the average voltage and thus the average magnetic field strength is zero.
- ☐ If a coil is operated with DC voltage, it can be used as an electromagnet.

Check

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Task 4

PHYWE

If the mains frequency is measured with a sampling rate of $200\ Hz$ is measured, the course of the magnetic flux density looks like a triangular voltage and some maxima/minima have smaller deflections. Why?

- [ ] The reason for the unsteady, triangular shape is the so-called Lenz's rule, according to which the current induced in the coil counteracts the change caused by the alternating current.
- [ ] The frequency of the magnetic field sensor at $f = 200\ Hz$ is not sufficient to correctly reproduce the steady course.
- [ ] To measure one period of a sine wave, 5 measuring points are required.

Check

Slide	Score / Total
Slide 17: Unit Hz	**0/1**
Slide 18: Measured frequencies	**0/2**
Slide 19: Energy Consideration	**0/2**
Slide 20: Sampling rate of the measuring probe	**0/2**

Total amount **0/7**

Solutions Repeat

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de