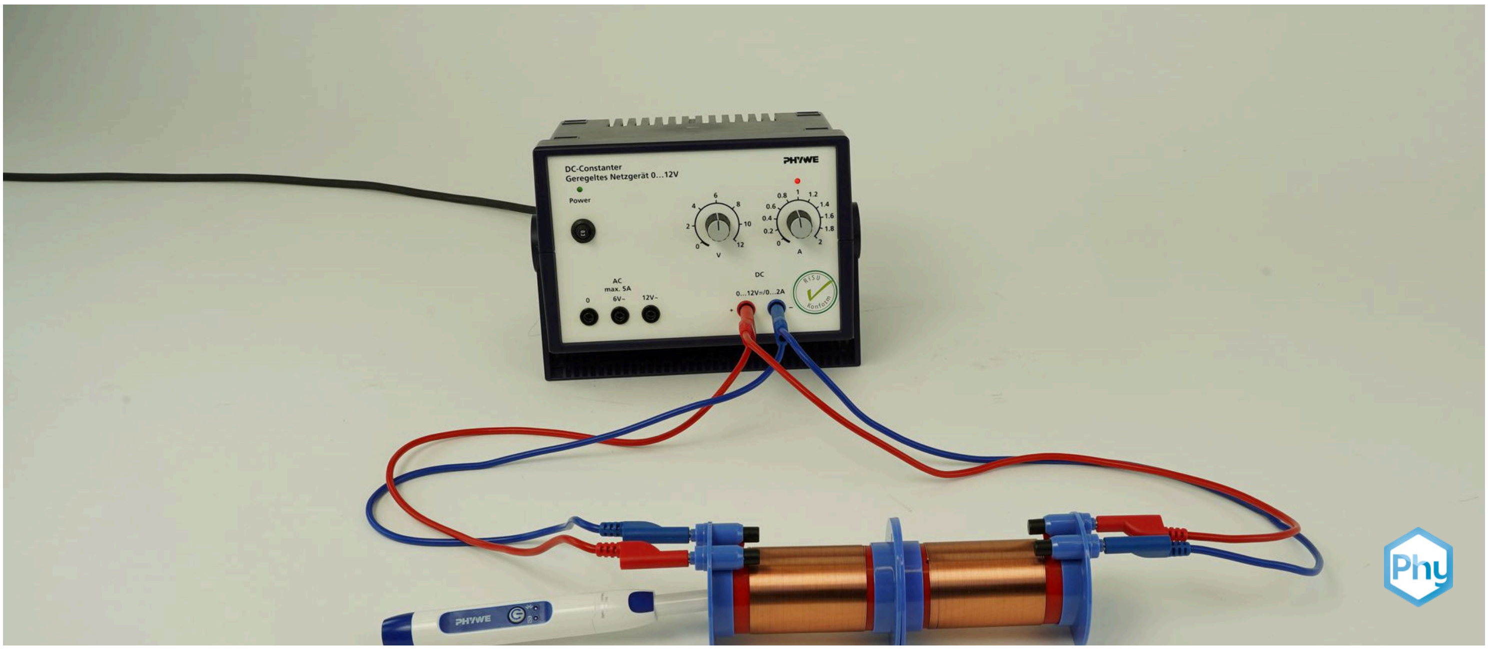
Superposition of two magnetic fields of coils with Cobra SMARTsense



Physics | Electricity & Magnetism | Electromagnetism & Induction

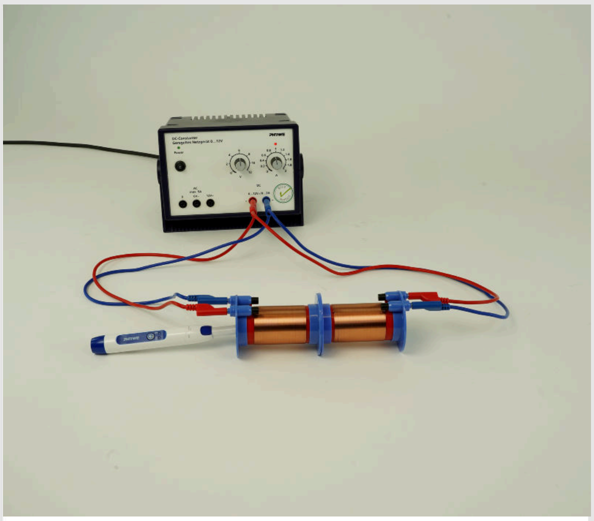
Difficulty level	Group size	Preparation time	Execution time
medium	2	10 minutes	10 minutes

This content can also be found online at:

http://localhost:1337/c/5f4b3466c3481500038cb453

Teacher information

Application



Experiment set-up

The superposition of magnetic fields is a fundamental principle for many scientific studies and applications. For example, by arranging two coils to form the so-called Helmholtz coil, a homogeneous field can be obtained over a large volume that is accessible from all sides.

Applications from the field of cutting-edge research are the deflecting and focusing magnets in the form of dipole and quadrupole magnets or the stellarator in the nuclear fusion reactor. The latter is a torus-shaped device (shaped like a donut/rescue ring) for magnetically confining a hot plasma with the aim of generating energy by nuclear fusion.

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Other teacher information (1/3)

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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. It can be well related to the superposition of two electric fields.

Scientific principle

The principle of superposition of two or more fields is that of vector addition. For this, the vectorial sum of the individual fields is calculated. This is especially true for magnetic fields:

$\vec{B} = \sum \vec{B}_i$respectively $\vec{H} = \sum \vec{H}_i$

Other teacher information (2/3)

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Learning objective

In this experiment the magnetic flux density of two coils is to be measured. The superposition of two fields of cylindrical coils is investigated. In the first part the two magnetic fields are in the same direction and in the second part they are in opposite directions.

Tasks

Measuring the magnetic flux density of two cylindrical coils.

1. the coils have the same polarity, so that the magnetic fields of the coils complement each other positively

2. a coil is reversed so that the magnetic fields of the coils cancel each other out.

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Other teacher information (3/3)

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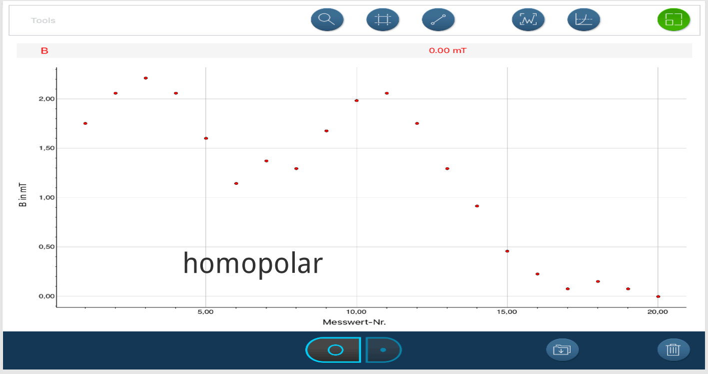
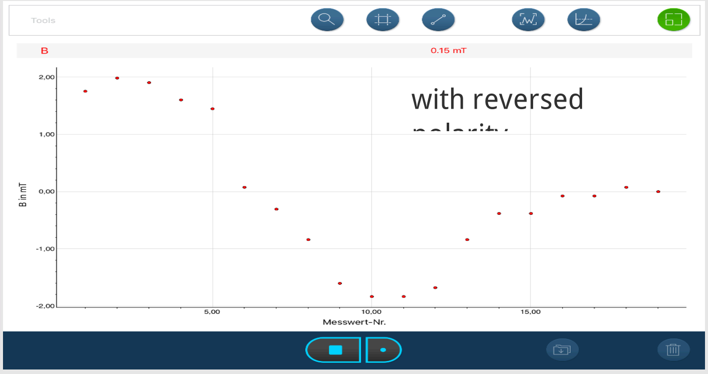
Note: When measuring the magnetic field of the coils, make sure that the magnetic flux density is measured at the tip of the magnetic field sensor. In addition, care must be taken how the coils are poled. The windings of the two coils run in opposite directions, but both coils have the same spiral orientation, so the more attention should be paid to the polarity.





Safety instructions

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

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Student Information

Motivation

Experimental setups for specific electron charge and the Zeeman effect

Some of the most fundamental and important physical discoveries share the fundamental principle of superimposing two magnetic fields of current-carrying coils. The determination of the specific electron charge with the filament ray tube and the proof of the so-called Zeeman effect of splitting energy levels in the magnetic field are two of many examples that were so groundbreaking that they were even honoured with the Nobel Prize.

In this experiment you learn how two magnetic fields of cylindrical coils overlap.

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Tasks

Measure the magnetic flux density along the two short coils with 41mm Ø and 100 turns.

1. the coils have the same polarity.

2. the coils have opposite polarity.

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Equipment

Position	Material	Item No.	Quantity
1	Cobra SMARTsense - 3-Axis Magnetic field	12947-00	1
2	Induction coil,100 turns,dia.40mm	11007-05	2
3	Ruler, l = 30 cm	09851-40	1
4	Connecting cord, 32 A, 500 mm, red	07361-01	2
5	Connecting cord, 32 A, 500 mm, blue	07361-04	2
6	measureAPP - the free measurement software for all devices and operating systems	14581-61	1
7	PHYWE Power supply, 230 V, DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A	13506-93	1

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Set-up (1/4)

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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)

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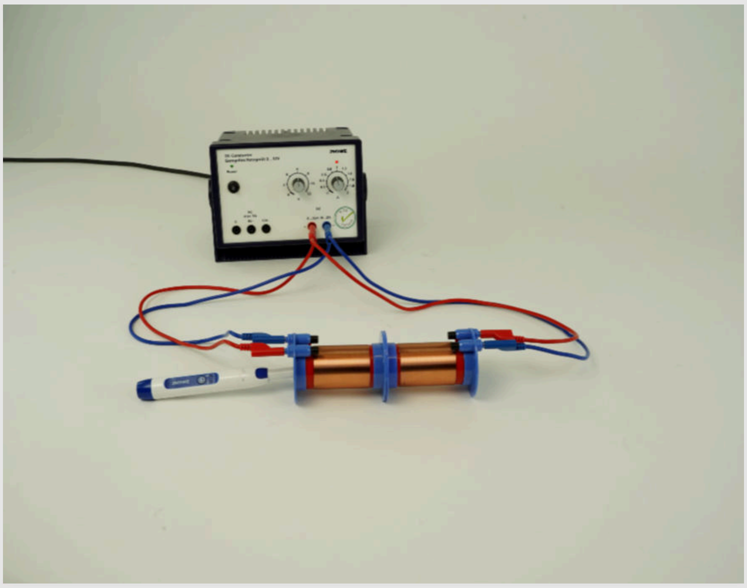

Set up the test according to the left figure: Switch both coils with $N = 100$ Windings parallel to each other and each in series with the power supply unit (direct current). Position both coils side by side as shown in the picture. Make sure that the polarity is the same for both coils.

Set the power supply unit to 0 A to 12 V (right stop) The current limiter activated by this setting can now be used to control the current intensity.

Switch on the power supply unit.

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Set-up (3/4)

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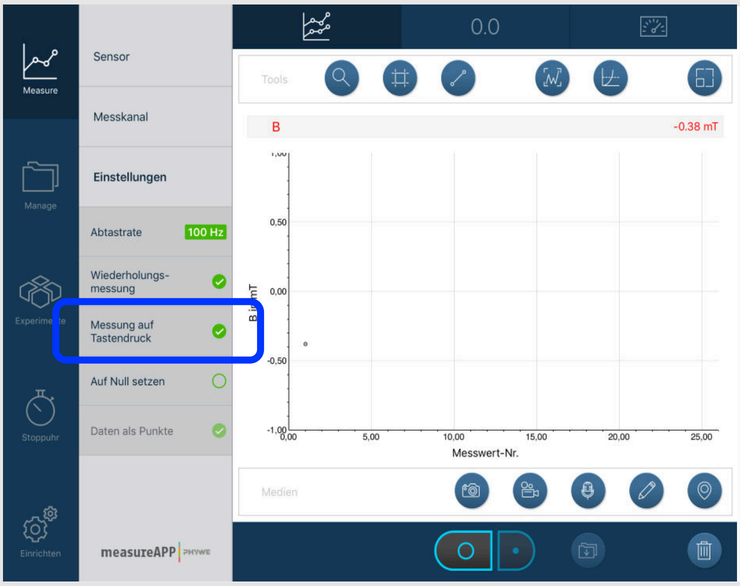

Start measureAPP on the tablet and switch on the Cobra SMARTsense magnetic field sensor (hold down the I/O button for about 3 seconds).

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

Also select measurement at the touch of a button.

Set-up (4/4)

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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'.

Now set the current at the power supply unit to the right stop (~2 A). Since the coils are connected in parallel, the maximum permissible current of 1.2 A is not exceeded.

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Procedure (1/2)

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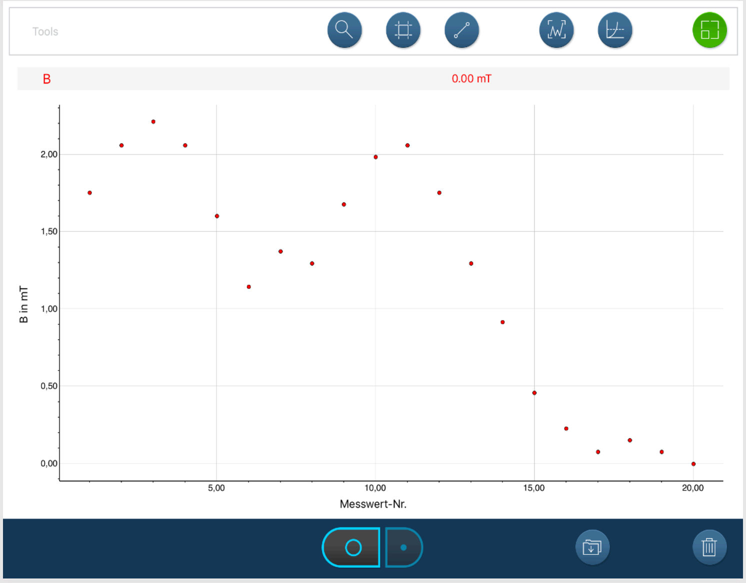

Insert the sensor as far as possible into the two coils. Since the tip of the coil is not visible, you can use the ruler to determine where you measure the magnetic flux density.

1. pull out the sensor in 1 cm steps and record a measuring point for each position by pressing a button.

In this way, the x-axis corresponds to the measurement: $\Delta x[cm]$ to the starting point.

2. after the last measured value (a few centimetres outside the coil), adjust the current to zero and switch off the power supply unit Save your measured values.

Procedure (2/2)

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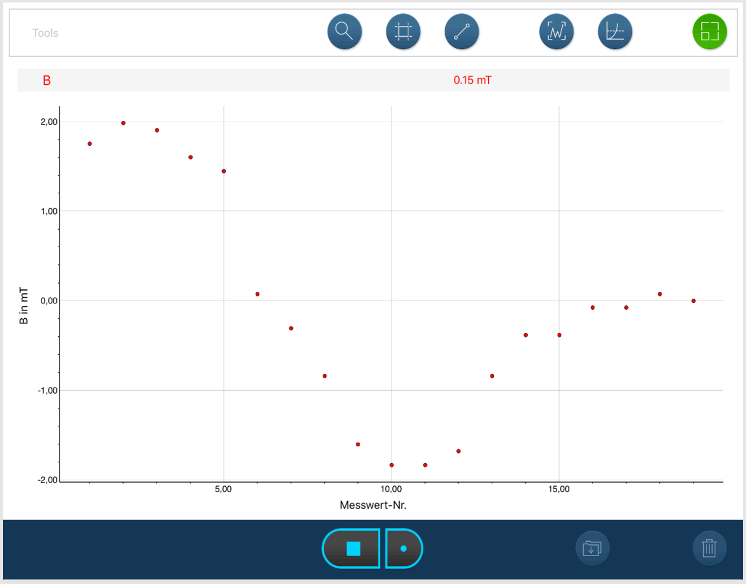

1. exchange the cable connections on one of the two coils, reposition the sensor at the starting point and switch the power supply unit on again.

2. pull the sensor out of the coils again in 1 cm increments and record a measuring point for each position by pressing a button.

3. switch off the power supply unit after the last measured value and save your measured values.

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Report

Task 1

Compare your readings. Which of the following statements are correct?

- ☐ If the coils have the same polarity, the magnetic field between the coils is zero.
- ☐ If the coils have the same polarity, the magnetic field between the coils hardly drops.
- ☐ If the coils are oppositely poled, the magnetic field between the coils hardly drops.
- ☐ If the coils are oppositely poled, the magnetic field between the coils is zero.

Check

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Task 2

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What if we had not only two coils, but a lot of them?

- The resulting total field would be the product of all individual magnetic fields.
- If there are too many coils, the magnetic field disappears.
- The magnetic field becomes stronger and stronger no matter how the coils are connected.
- All deficient fields add up to a total field (superposition).

Check

Task 3

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In this experiment, two different magnetic fields were observed in but only one direction in space. Does the superposition principle also apply in 3-dimensional space?

- No, there are only fields overlapping in one direction in space.
- Yes, the fields can be added using vector calculation.
- Yes, but as soon as a different spatial direction is added, the fields must be multiplied by cross product.

Check

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Slide	Score / Total
Slide 18: Comparison of the measured values	**0/2**
Slide 19: Superposition principle of fields.	**0/1**
Slide 20: Superposition direction of space	**0/1**

Total amount **0 / 4**

Solutions Repeat

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