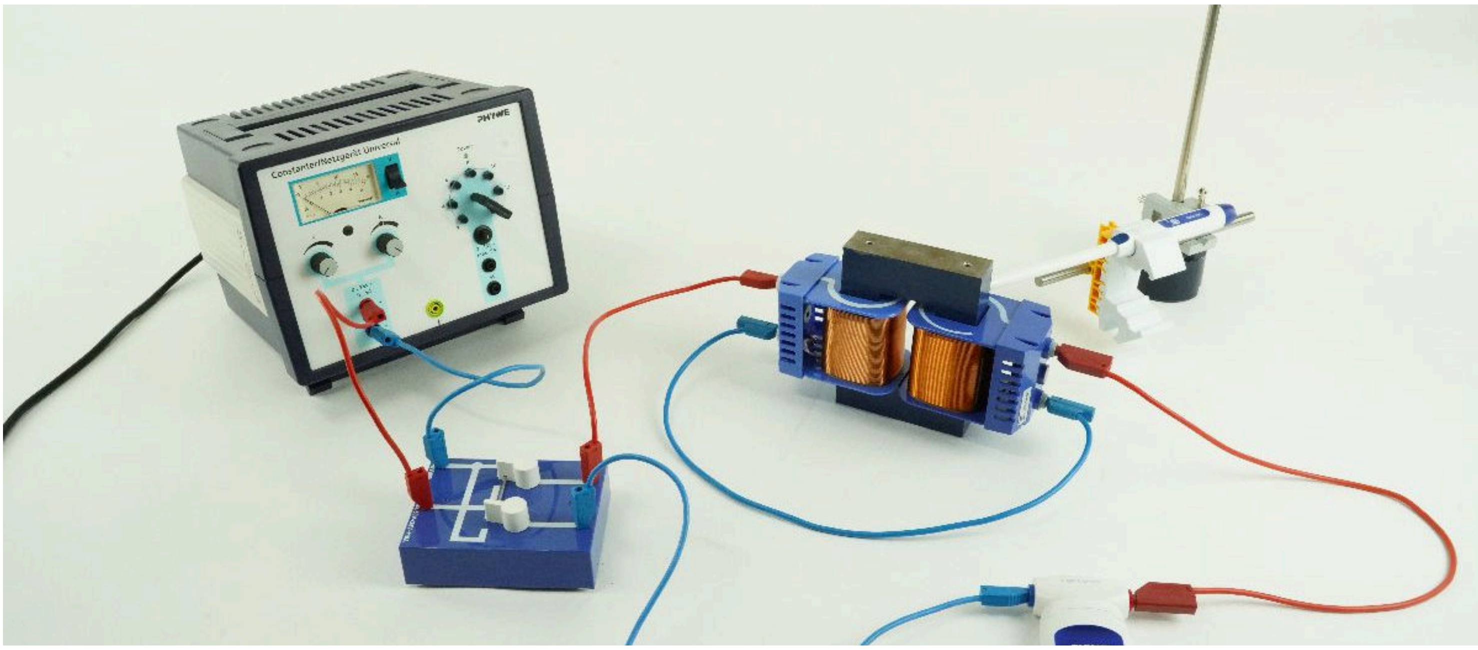
Ferromagnetic hysteresis with Cobra SMARTsense



Physics | Electricity & Magnetism | Magnetism & magnetic field

Difficulty level	Group size	Preparation time	Execution time
-	-	-	-

Robert-Bosch-Breite 10
37079 Göttingen

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

info@phywe.de
www.phywe.de

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General information

Application

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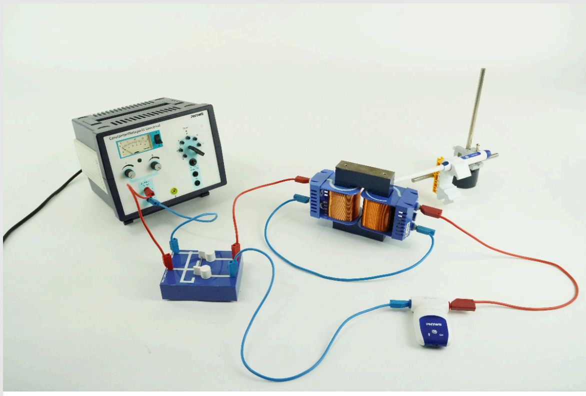

Setup

Ferromagnetic hysteresis has many applications, e.g. in computer sciences. There, the most vivid example is the process that makes it possible to store data on a common hard disc drive.

On a more general level of applications the principles of ferromagnetic hysteresis explain which characteristics of a metal to use for a permanent magnet as compared to an electromagnet.

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Robert-Bosch-Breite 10
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Other information (1/2)

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Prior knowledge

In addition to the standard knowledge of electromagnetism, before performing this experiment, make yourself familiar with the following principles: hysteresis loop, coercive force / coercivity, retention of magnetism / retentivity / remanence / residual magnetism, point of saturation, hysteresis loss, magnetic domains.

The knowledge of these issues is a prerequisite to understand, e.g., that for permanent magnets, material with high retentivity and high coercivity are required versus material with low retentivity and low coercivity for electromagnets.

Main principle

A magnetic field is generated in a ring-shaped iron core by a continuous adjustable direct current applied to two coils. The field strength H and the flux density B are measured and the hysteresis recorded. The remanence and the coercive field strength of two different iron cores are compared.

Other information (2/2)

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Learning objective

The goal of this experiment is to investigate the lasting effects of magnetic fields on iron.

Tasks

1. Record the hysteresis curve both for a massive iron core and for a laminated one.

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Theory

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The field strength is calculated with the formula $H = I \cdot n/L$, where H represents the magnetic field strength, n = number of turns in the coil (600 turns) and L = average field line length in the core. (Solid core: L_{sc} = 232 mm, laminated core: L_{lc} = 244 mm)

The factor n/L changes due to the different dimensions of the two iron cores as follows:

Solid iron core: n/L = 2586 in 1/m, laminated iron core: n/L = 2459 in 1/m

The calculation of the field strength is combined with a change of the x-axis in the visualisation.
The factor in the mathematical formula depends on the used iron core and is equal to n/L.

Now, the coercive field strength and the remanence can be extracted from the hysteresis. Therefore, use the zoom function in the region of the intersection of the axes and obtain the points of intersection of the x and y-axis with aid of the cursor lines, which can be freely moved and shifted. A comparison of fig. 3 and 4 shows that the remanence and coercive field strength are substantially greater in a solid iron core than in a laminated one.

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Equipment

Position	Material	Item No.	Quantity
1	PHYWE Power supply, universal, analogue display DC: 18 V, 5 A / AC: 15 V, 5 A	13503-93	1
2	Coil, 600 turns	06514-01	2
3	Iron core, U-shaped, solid	06491-00	1
4	Iron core, I-shaped, solid	06490-00	1
5	Iron core, U-shaped, laminated	06501-00	1
6	Iron core, I-shaped, laminated	06500-00	1
7	Commutator switch	06006-00	1
8	Barrel base expert	02004-00	1
9	Right angle clamp expert	02054-00	1
10	Support rod, stainless steel, l = 250 mm, d = 10 mm	02031-00	2
11	Cobra SMARTsense - High Current, ± 10 A (Bluetooth + USB)	12925-00	1
12	Cobra SMARTsense - 3-Axis Magnetic field	12947-00	1
13	Holder for Cobra SMARTsense	12960-00	1
14	USB charger for Cobra SMARTsense and Cobra4	07938-99	2
15	Connecting cord, 32 A, 250 mm, red	07360-01	2
16	Connecting cord, 32 A, 250 mm, blue	07360-04	1
17	Connecting cord, 32 A, 500 mm, red	07361-01	1
18	Connecting cord, 32 A, 500 mm, blue	07361-04	1
19	measureLAB, multi-user license	14580-61	1

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Setup and Procedure

Setup (1/3)

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The Cobra SMARTsense sensors Magnetic Field and High Current as well as the measureAPP app for Windows 10 are required to perform the experiment. The app can be downloaded for free from the App Store - QR codes for tablets, smartphones and Windows computers see below. Use the USB connection, and not the Bluetooth connection, for this experiment.

measureAPP for Android operating systems

measureAPP for iOS operating systems

measureAPP for Tablets / PCs with Windows 10

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Setup (2/3)

The experimental set-up is shown in Fig. 1a. Place the solid coil set-up far from the computer and from the Cobra SMARTsense 3-Axis Magnetic Field sensor (MFS) to avoid influences of the magnetic fields on the equipment and sensors. Connect both the MFS and the Cobra SMARTsense High Current sensor with the computer. Attach the MFS above the iron core and under the top iron bar using a distance holder made of strong folded paper, e.g. a business card.

Connect the commutator switch as shown in Fig. 1b to the power supply, the coil and the Cobra SMARTsense High Current sensor.

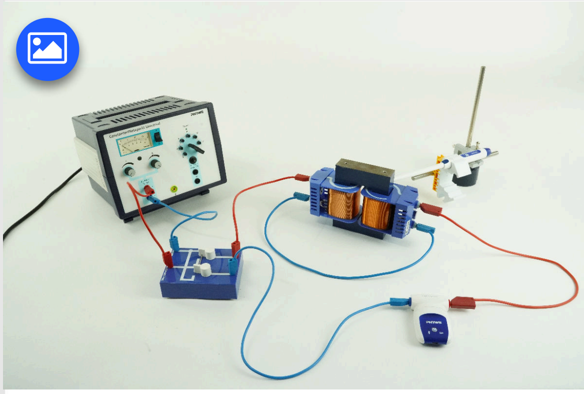


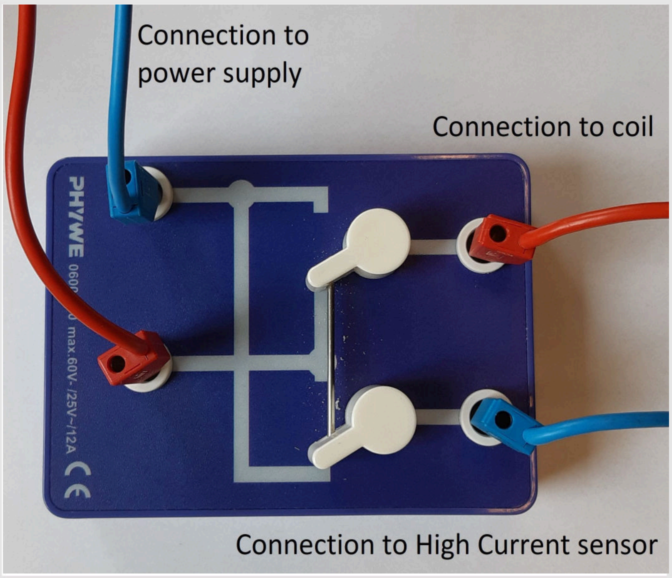
Fig. 1a

Setup (3/3)

The flux density B_0, measured by the MFS, and the current I through the coils are recorded.

Open measureAPP on your Windows computer. Check that the recording rate is set to max. 5 Hz. For the hysteresis measurement the current I and the magnetic flux density B are measured. The magnetic field density H is calculated separately using the formula $H = 2459 \cdot I$

Fig. 1b



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Software setup and data analysis (1/3)

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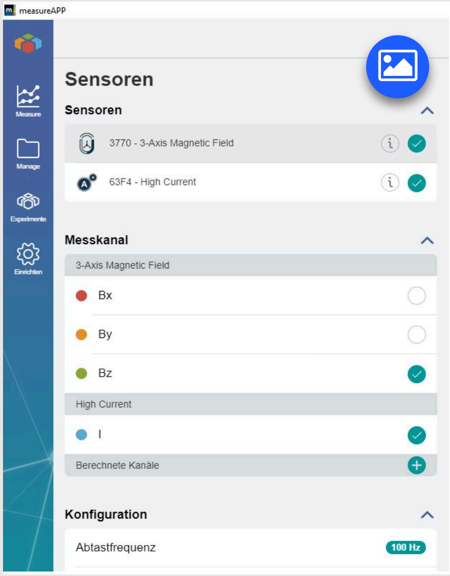
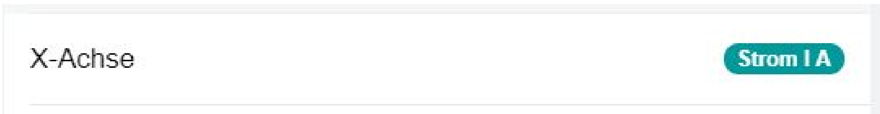


Left image: In measureAPP for Windows 10, activate the two sensors 3-Axis Magnetic Field (MFS) and High Current. Make sure that both sensors are connected to the computer via the USB interface and not wirelessly via Bluetooth. For the MFS activate only the Bz measurement channel. For this sensor the measurement range is set from -130...+130mT. Set the frequency to 100 Hz.

Bottom image: Now choose Current I A for the X-axis.



Software setup and data analysis (2/3)

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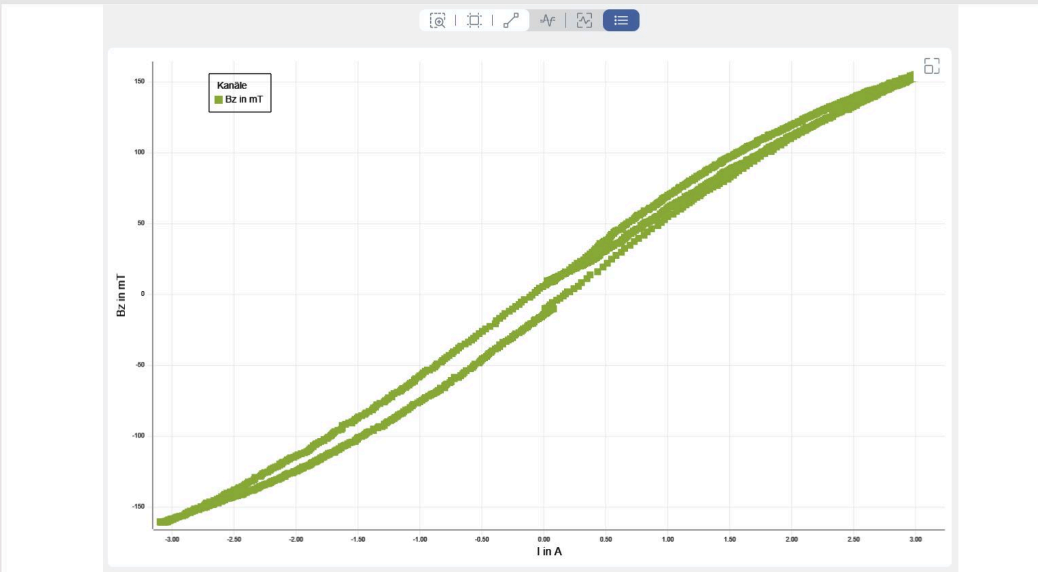
Typical measurement with measureAPP.

If your hysteresis curve is in another orientation despite using the same cabling as described in the setup above, turn the MFS by 180° in the holder.



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Software setup and data analysis (3/3)

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Helpful functions in measureAPP:

1: Fit in-button above the measurement window: press repeatedly during measurement to refresh the display of the complete measurement.

2: Save data-button below the measurement window. After finishing the measurement you can save it in the Manage folder of measureAPP.

3: In the Manage folder, chose the measurement which you want to view or export. With this Export-button you can save your data in the CSV format which can be opended in spreadsheet programs like Microsoft Excel to perform data analysis.

Procedure

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Caution: Do not change the position of the switch while a voltage is applied and do not turn off the voltage rapidly. Otherwise induced current/voltage may damage the setup. Also, limit the current of the power supply to 5 A.

If residual magnetism is present in the iron core, it is demagnetized: Set the commutator switch in such a manner that an opposing field is generated. Slightly increase the voltage till the flux density changes sign. Repeat till the flux density is approximately zero. The MFS might have an offset. You can check if there is residual magnetization by lifting the top iron bar. Alternatively, in measureAPP, you can set all values to zero.

After pressing the icon in the center bottom, slowly and steadily increase the voltage from zero upwards and decrease it to zero again. Using the commutator switch reverse the polarity of the voltage. Again increase and then decrease the voltage in the same way. Once again reverse the polarity of the voltage with the commutator switch and increase the voltage. Click on the icon again to end measurement and reset the voltage to 0 V (Fig. 2, 3). Fig. 2 shows flux density B as a function of time, fig. 3 as a function of current.

Repeat the experiment with the laminated coil set

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Evaluation

Task (part 1)

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Typical values for this experimental set-up are:

iron core:	massive	laminated
coercive field strength:	436 A/m	80 A/m
remanence:	143 mT	41 mT

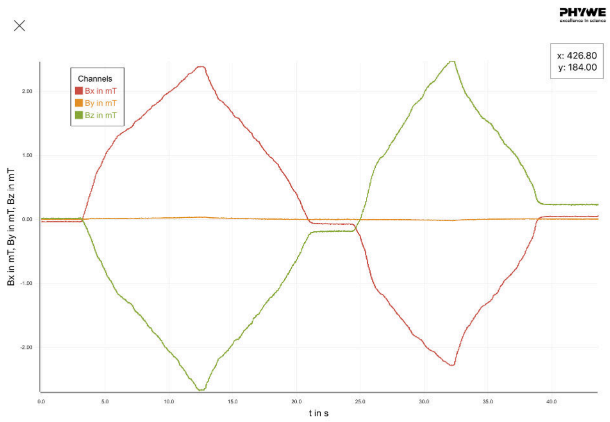

Fig. 2: Example curve for flux density measurement.

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Task (part 2)

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Remarks

After importing the data into a spreadsheet program, you need to convert the current values I into magnetic field density values H. Use the n/L factors for conversion as described above.

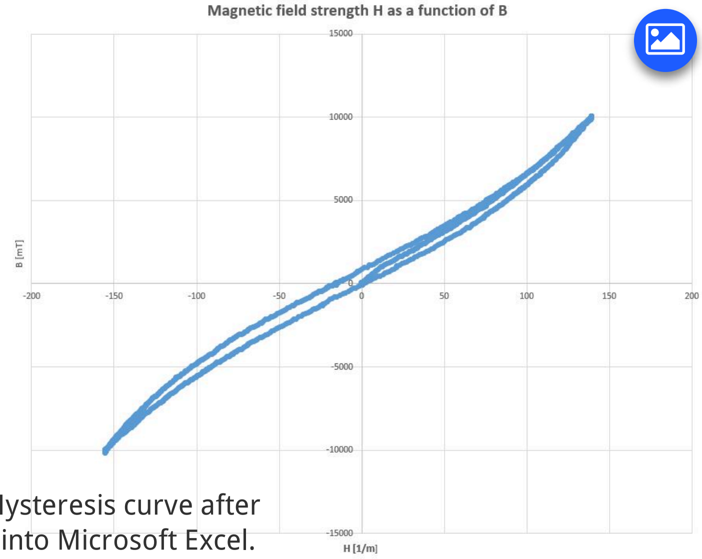

Fig. 3: Hysteresis curve after import into Microsoft Excel.

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