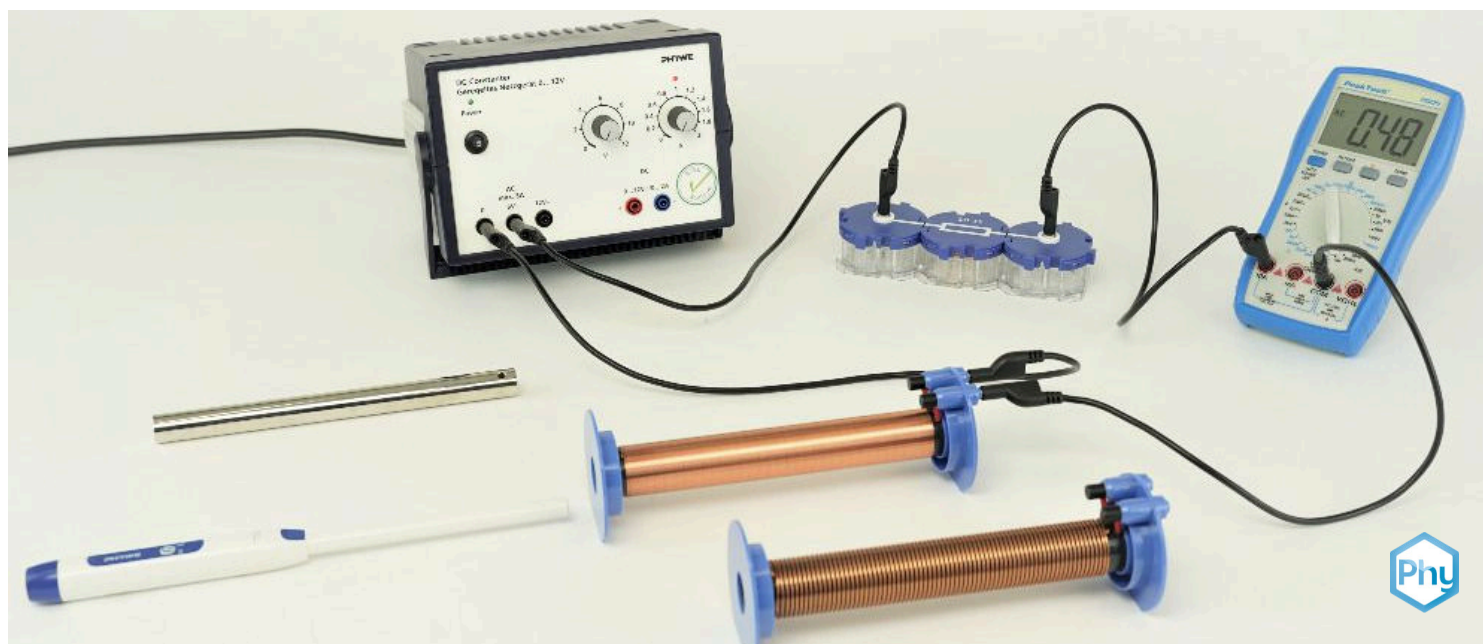


The magnetic permeability with Cobra SMARTsense



Physics

Electricity & Magnetism

Electromagnetism & Induction



Difficulty level

medium



Group size

2



Preparation time

10 minutes



Execution time

20 minutes

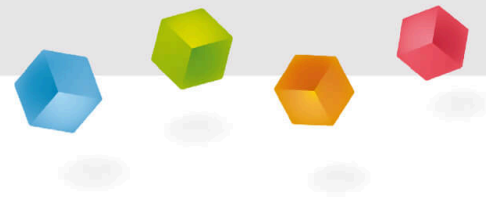
This content can also be found online at:



<http://localhost:1337/c/5f4bc7fcc3481500038cb7d9>

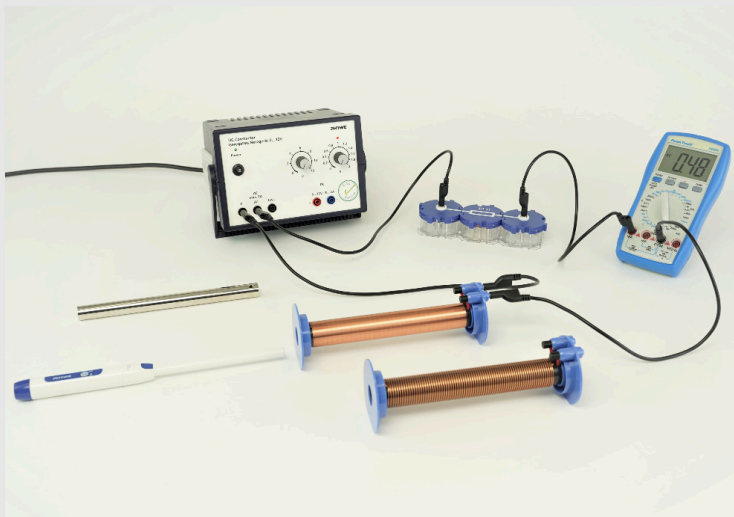
PHYWE

Teacher information



Application

PHYWE



Experiment set-up

To increase the magnetic flux density and thus the magnetic induction in transformers, soft iron cores are generally inserted into the transformer coils.

Air has a relative magnetic permeability of one, whereas iron cores have a relative magnetic permeability far greater than one, so the magnetic flux density is also greater by this factor than the magnetic field generated by the coil through which the current flows.

The magnetic permeability depends on the magnetizability of the material.

Other teacher information (1/2)

PHYWE

Prior knowledge



Students should know the principle of the law of induction and be familiar with the basics of electricity. The relationship between current and the resulting magnetic field strength of a thin cylindrical coil should be known.

Scientific principle



The magnetic permeability μ is the ratio of the magnetic flux density B on magnetic field strength H .

$$\mu = \frac{B}{H} \Leftrightarrow B = \mu \cdot H \quad \text{mit} \quad \mu = \mu_0 \cdot \mu_r$$

With the magnetic field constant μ_0 (magnetic permeability of the vacuum) and the relative magnetic permeability of the material concerned.

Other teacher information (2/2)

PHYWE

Learning objective



This experiment should help the students to understand that the magnetic permeability of a material can increase the magnetic flux density.

Tasks



1. Measurement of the magnetic flux density of two coils at direct current with and without iron core as a function of the current intensity. Calculate the magnetic permeability of the iron core.
2. Measuring the magnetic flux density of two coils in alternating current with and without iron core. Calculate the magnetic permeability and compare the result with the first task.

Safety instructions

PHYWE

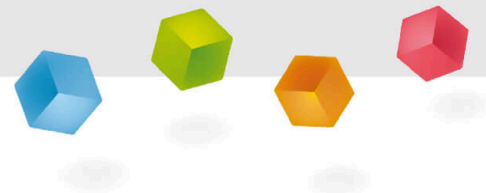


The general instructions for safe experimentation in science lessons apply to this experiment.

Notes

In this experiment, alternating current and not direct current is partly used. The resistor is necessary to limit the current so that the coils do not overheat.

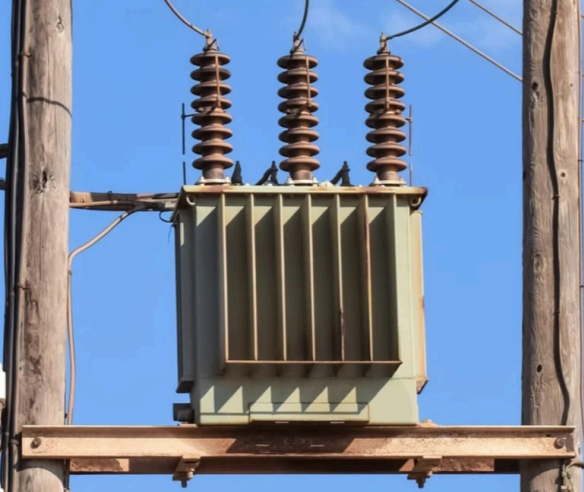
PHYWE



Student Information

Motivation

PHYWE



High voltage transformer

Transformers are based on the principle of electromagnetic induction. Here, an electric field is induced by a magnetic field that changes over time, which in turn generates a current. Both high-voltage transformers and, for example, large cranes with electromagnets in the scrap yard generally use soft iron cores inside the coils to enhance the desired effect.

The reason for this is the so-called magnetic permeability, which is based on the magnetizability of a material. Iron cores have a high permeability number and thus increase the magnetic flux density. In this experiment you will learn about magnetic permeability.

Tasks

PHYWE



1. measure the magnetic flux density of two coils at direct current with and without iron core as a function of the current intensity. Calculate the magnetic permeability of the iron core.
2. measure the magnetic flux density of two coils in alternating current with and without iron core. Calculate the magnetic permeability and compare the result with the first task.

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, 300 turns, dia. 25mm	11007-03	1
6	Induction coil, 75 turns, dia. 25mm	11007-07	1
7	iron core, rod-shaped, d = 16 mm, l = 200 mm	11005-00	1
8	Connecting cord, 32 A, 500 mm, black	07361-05	4
9	Connecting cord, 32 A, 500 mm, blue	07361-04	2
10	Connecting cord, 32 A, 500 mm, red	07361-01	1
11	measureAPP - the free measurement software for all devices and operating systems	14581-61	1

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



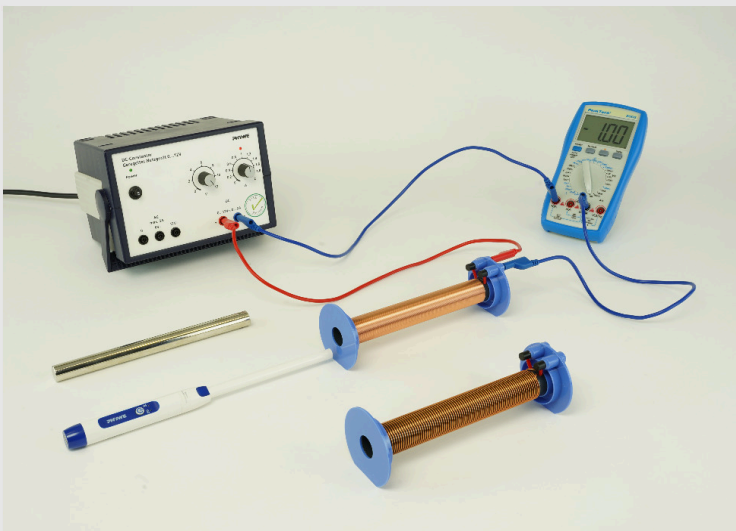
Android



Windows

Set-up (2/4)

PHYWE



Experiment set-up

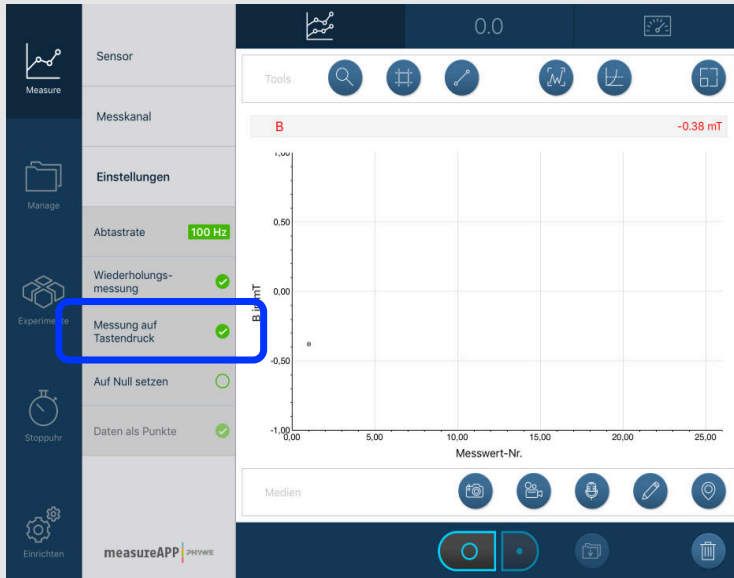
Set up the test according to the left figure: To do this, connect the power supply unit (direct current), an ammeter and the coil with $N = 300$ Coils in a row.

Select a sufficiently large current measuring range on the ammeter. Set the power supply unit to 0 A (left stop) and 12 V (right stop). The current limiter activated by this can now be used to control the current.

Switch on the power supply unit.

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).

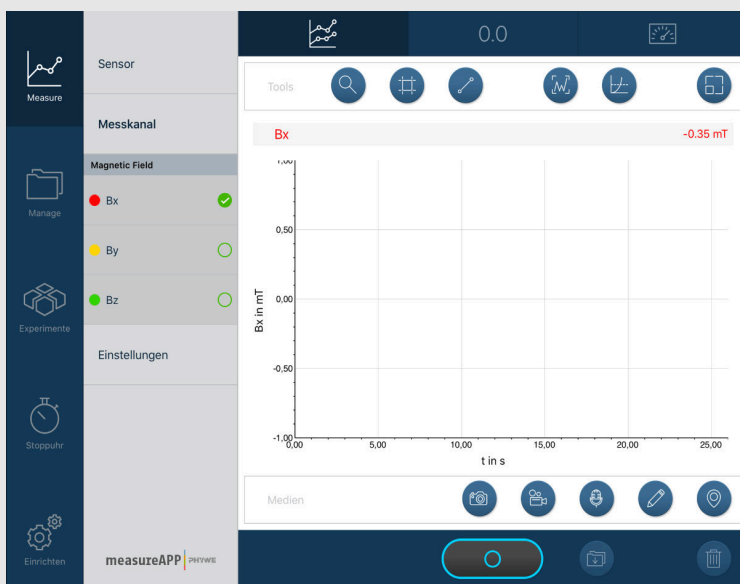
Select the sensor in measureAPP and connect it to the App. The following settings must be made:

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

Also select measurement at the touch of a button.

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'.

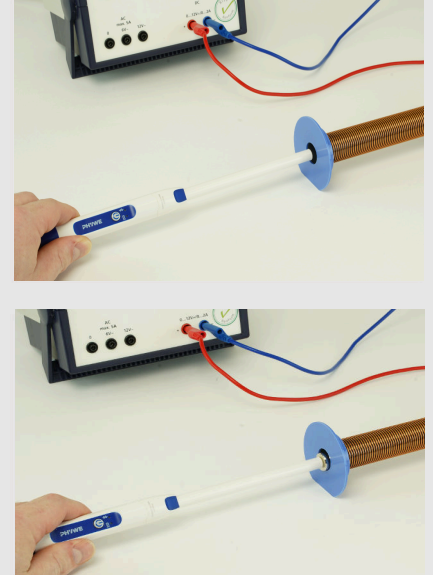
Procedure (1/5)

PHYWE

- Position the tip of the sensor at the end of the coil, increase the current in 0.1 A increments and record one measurement point for each current by pressing a button. In this way, the x-axis corresponds to the measurement: $I[100 \text{ mA}]$.

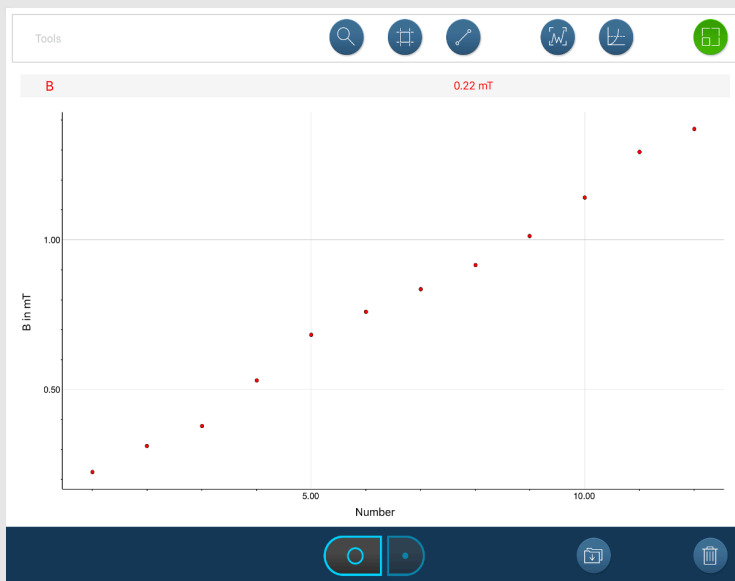
The maximum allowable current for this coil is $I = 1,2 \text{ A}$.

- After the last measured value, adjust the current to zero and save your measured values.
- Insert the iron core into the coil and repeat the above measurement.
- Save the second series of measurements as well, adjust the current to zero and switch off the power supply.



Procedure (2/5)

PHYWE

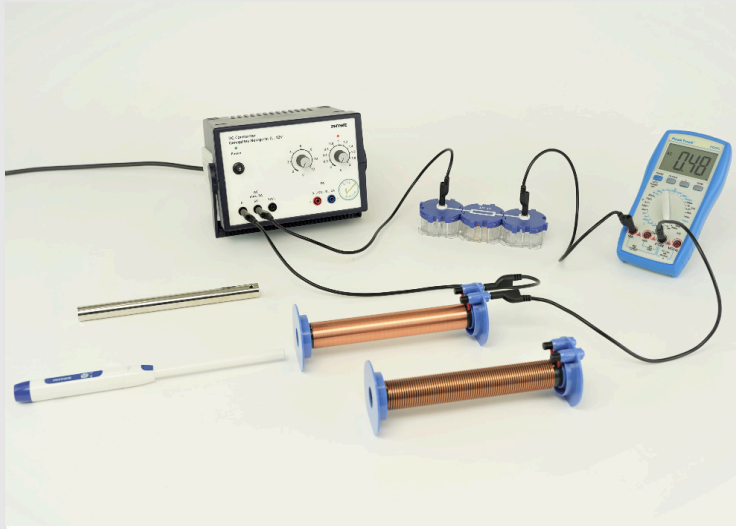


- Replace the installed coil with the coil with a number of turns $N = 75$ and switch the power supply unit on again.
- Increase the current as before, starting from zero in steps of 0.1 A and resume a measurement point for each current by pressing a button.
- Repeat the measurement with inserted iron core and switch off the power supply unit after the last measured value.

Each measurement series is to be saved again.

Implementation (3/5)

PHYWE



Test setup with alternating voltage

Modify the test according to the adjacent figure.

To do this, switch on the power supply unit, the $10\ \Omega$ resistance, the ammeter and the coil with $N = 300$ Coils in a row.

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

The iron core is initially not plugged into the coil and the power supply unit is switched off.

Now switch off the measurement in measureAPP by pressing a key, so that measured values are continuously recorded.

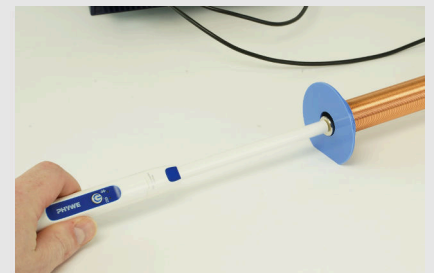
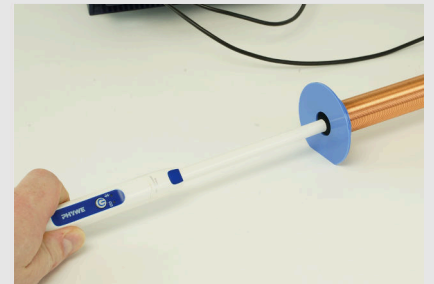
Procedure (4/5)

PHYWE

- Position the tip of the sensor at the end of the coil, start a measurement and switch on the power supply for a few seconds during the measurement.

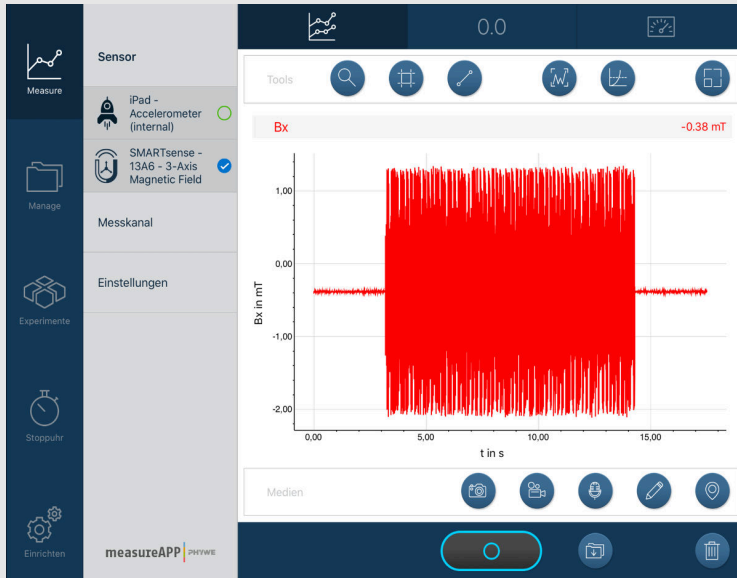
Attention: Do not use the coils without $10\ \Omega$ Connect the resistor to the alternating current, otherwise the coils may overheat.

- Save your measurements, insert the iron core into the coil and repeat the above measurement.
- Also save the second series of measurements and check that the power supply unit is switched off.
- Determine the maximum deflection of the respective magnetic flux density for both measurements using the evaluation tools and note the values in the table in the protocol.



Procedure (5/5)

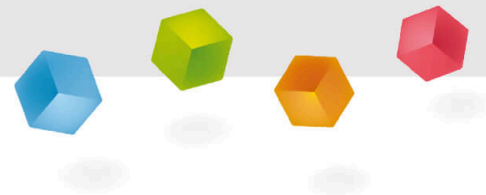
PHYWE



- Replace the installed coil with the coil with a number of turns $N = 75$ off.
- Repeat both measurements (with and without iron core) for this coil. Start a measurement and switch on the power supply again for a few seconds.
- Determine the maximum magnetic flux density again with the aid of the evaluation tools, note the resulting values in the table in the protocol and save the respective measurement.

PHYWE

Report



Table

PHYWE

Determine the slope of the measuring points for the four measurements with direct current and enter them in the following table: $B[mT] = m \cdot I[100mA]$. Determine the maximum magnetic flux densities for the four measurements with alternating current $B_{x,max}$ and enter them in the table as well. Then determine the ratios for all measuring pairs (with and without iron core) μ^* from the gradients or the maximum magnetic flux densities and also enter them in the table.

Coil / Iron core	$m [mT/A]$	$\mu^* [1]$	$B_{x,max} [mT]$	$\mu^* [1]$
300 / with	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
300 / without	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
75 / with	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
75 / without	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>

Task 1

PHYWE

Which of the following statements are correct for DC current measurement?

- The slope is more than one order of magnitude greater for the two measurements with iron core than for the measurements without iron core.
- The calculated ratio μ^* is larger for the coil with more turns.
- In all four measurement series, the magnetic flux density increases linearly with the current intensity of the respective coil.
- The other answers are all wrong.

Check

Task 2

PHYWE

Drag the words to the right places.

The series of measurements with and without [] differ considerably, as the resulting [] differs greatly. The measured magnetic flux density [] iron core is much higher than that []. The reason for this is the [] by the so-called [] of iron, which is usually several [] above that of air ($\mu_r = 1$) and depends on the [] of the material.

- with
- iron core
- magnetic flux density
- without
- relative magnetic permeability μ_r
- orders of magnitude
- magnetisability
- amplification

Task 3

PHYWE

Drag the words to the right places.

The [] of air is approximately identical to that of the [] and is therefore close to 1, whereas that of [] is in the range $300 < \mu_r < 10.000$. The measured ratio μ^* is significantly lower. A major reason for this is that the [] does not completely fill the inside of the [].

- iron
- vacuum
- iron core
- coil
- relative magnetic permeability

✓ Check

Task 4

PHYWE

The relationship μ^* is slightly lower in the case of alternating current than in the case of direct current. Why is that?

- The statement is false. In the case of alternating current, the ratio is even more than twice as high.
- The iron core has a kind of magnetic memory, the so-called magnetic remanence, which ensures that the measured maximum magnetic flux density is reduced when the external magnetic field is reversed.

 Check

Task 5

PHYWE

Consider the measuring pairs for one coil each with each other. As you know, the magnetic field strength H of the thin cylindrical coil proportional to the applied current. Nevertheless, the course of the magnetic flux density B great differences in the course of time. Which formula is correct? (It applies $\mu = \mu_0 \cdot \mu_r$ with the magnetic field constant μ_0)

$H = \mu \cdot B$

$\mu = H \cdot B$

$B = \mu \cdot H$

 Check

Slide	Score / Total
Slide 21: Curve of the direct current measurements	0/3
Slide 22: Justification of the measurement results 1	0/8
Slide 23: Justification of the measurement results 2	0/5
Slide 24: Magnetic permeability in alternating current	0/1
Slide 25: Equation for magnetic permeability μ	0/1

Total amount

 0/18 Solutions Repeat Exporting text