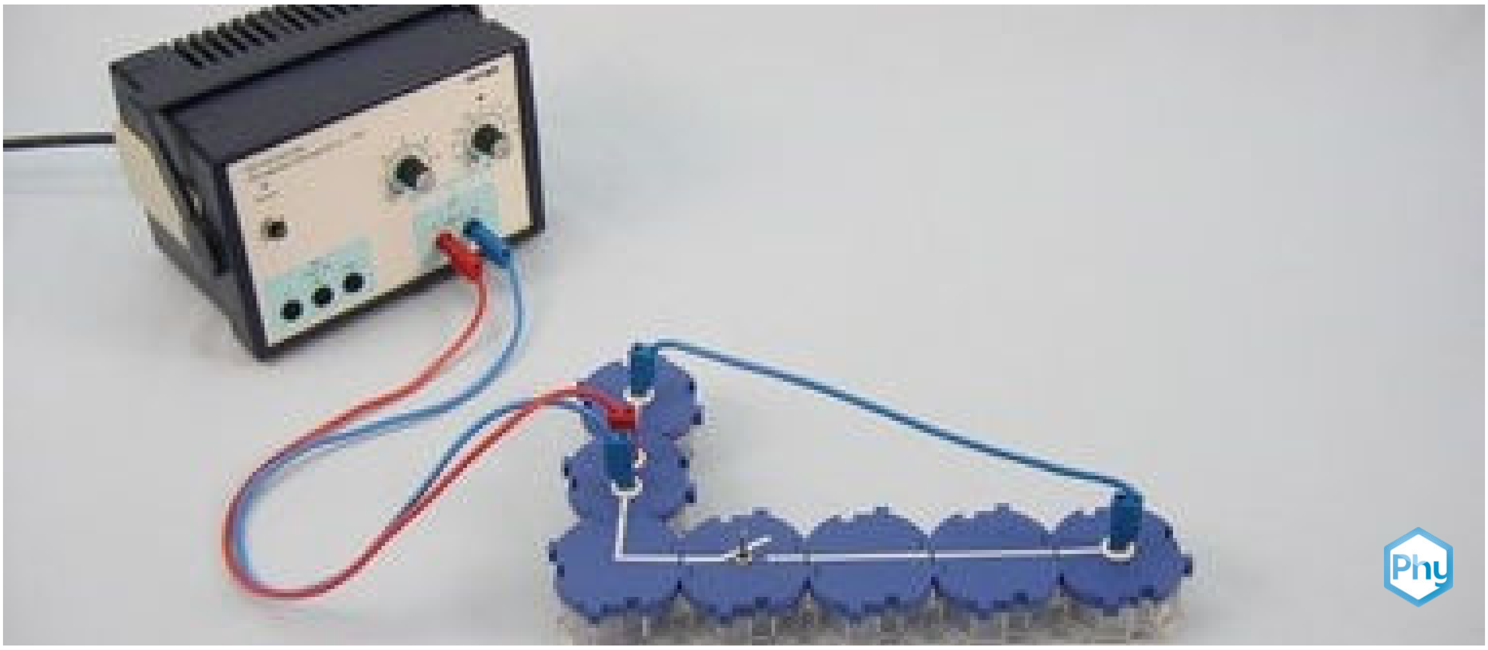
The magnetic effect of a current-carrying conductor



Physics | Electricity & Magnetism | Electromagnetism & Induction

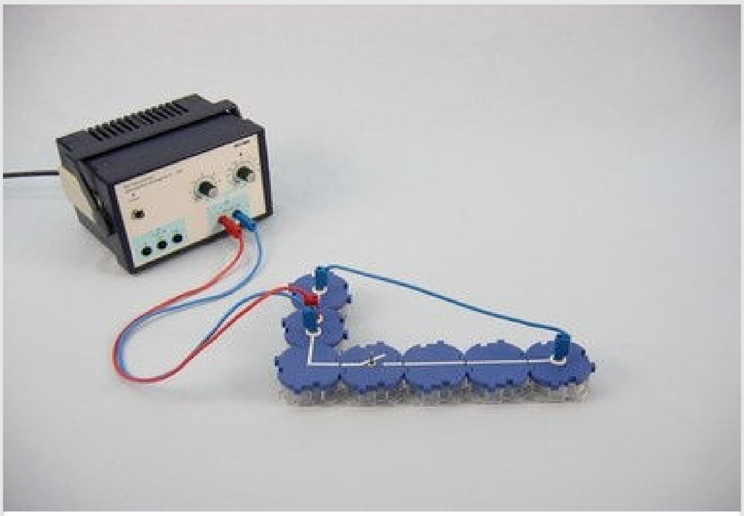
Difficulty level	Group size	Preparation time	Execution time
medium	2	10 minutes	10 minutes

This content can also be found online at:

http://localhost:1337/c/5f4ebaeb38db8d0003265cc0

Teacher information

Application



Experiment set-up

While the thermal and light effects of electric current are directly accessible to the human senses, this is not true of the chemical and magnetic effects.

The magnetic effect of a current carrying conductor is essential for an electromagnet, electric motors or generators, for example.

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Other teacher information (1/3)

Prior knowledge

Students should have a basic knowledge of simple electrical circuits and of magnetism (forces between magnets, magnetic poles, magnetic fields, etc.).

Scientific principle

The Maxwell equations explain the magnetic vortex field which a current flowing through a conductor causes.

The law of flow is:

$$\vec{\nabla} \times \vec{B} = \mu_0 \vec{j} + \mu_0 \epsilon_0 \frac{\partial \vec{E}}{\partial t}$$

Other teacher information (2/3)

Learning objective

The aim of this experiment is to show the students that a conductor through which current flows is surrounded by a magnetic field. This enables them to see through electrical equipment and devices that they are familiar with in practice, e.g. the electric bell and the electric motor.

Tasks

1. examining, with the aid of a magnetic needle, whether a straight conductor through which an electric current flows has a magnetic effect

2. prove that a current carrying coil acts like a bar magnet and investigate what the strength of the magnetic field depends on.

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Other teacher information (3/3)

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Notes

This experiment is a de facto short circuit. It is permitted because the power supply unit is equipped with electronic current limitation. Students should be made aware of this, otherwise they may underestimate the dangers associated with short circuits.

As the connecting lines are made of copper, they cannot be associated with the magnetic effects, as copper is not magnetic by itself.

The fact that these are field lines that do not run in the direction from one pole to the other and do not run into or out of a body is surprising and often difficult for students to understand.

The introductory experimental steps in the second part of the experiment with the bar magnet are intended to reactivate the students' knowledge of the permanent magnet and thus facilitate the recognition of essential analogies to the electromagnet.

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

Electromagnet on an excavator

Coils are built into electromagnets, as here in the excavator at the scrap yard, but also into transformers or in loud speakers. This makes use of the fact that a current carrying conductor generates a magnetic field.

If a permanent magnet were used in the picture shown, the scrap could be picked up but not thrown off again.

In this experiment you will investigate the magnetic properties of a conductor through which current flows.

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Tasks

1. Investigation with the help of a magnetic needle whether a straight conductor through which an electric current flows has a magnetic effect.
2. How a current flowing through a coil acts like a bar magnet and examine what the strength of its magnetic field depends on.

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Equipment

Position	Material	Item No.	Quantity
1	PHYWE Power supply, 230 V, DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A	13506-93	1
2	Analog multimeter, 600V AC/DC, 10A AC/DC, 2 MΩ, overload protection	07021-11	1
3	Straight connector module, SB	05601-01	2
4	Angled connector module, SB	05601-02	2
5	Interrupted connector module with sockets, SB	05601-04	2
6	Junction module, SB	05601-10	2
7	On-off switch module, SB	05602-01	1
8	Coil, 400 turns	07829-01	1
9	Coil, 1600 turns	07830-01	1
10	Iron core, I-shaped, laminated	07833-00	1
11	Drawing compass , 1 units	06350-03	2
12	Connecting cord, 32 A, 250 mm, red	07360-01	2
13	Connecting cord, 32 A, 250 mm, blue	07360-04	2
14	Connecting cord, 32 A, 500 mm, red	07361-01	1
15	Connecting cord, 32 A, 500 mm, blue	07361-04	1
16	magnet, l = 72mm, rodshaped, colored poles	07823-00	1

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Set-up (1/2)

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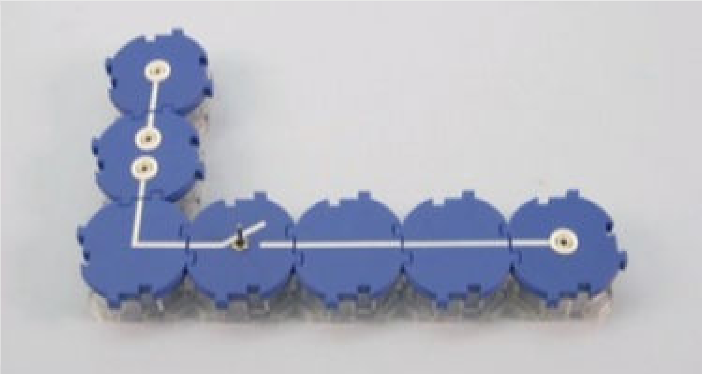
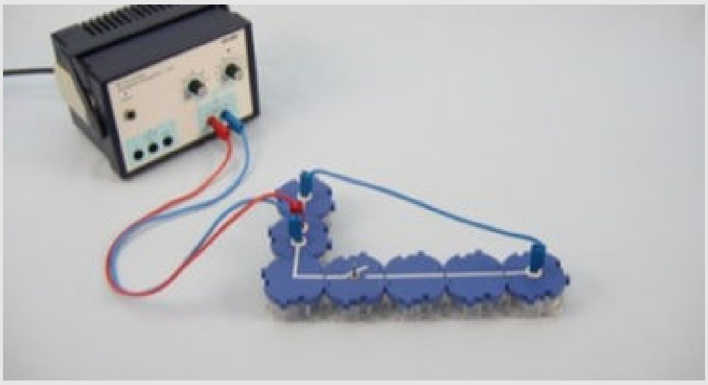
Set up the circuit as shown in the figures. Insert a short connecting line into the connection modules and align them so that the line runs in a north-south direction.

Set the current limitation to 2 A and the voltage to 0 V on the power supply unit. Close the switch, increase the voltage until the indicator light of the current limiter lights up and open the switch again.

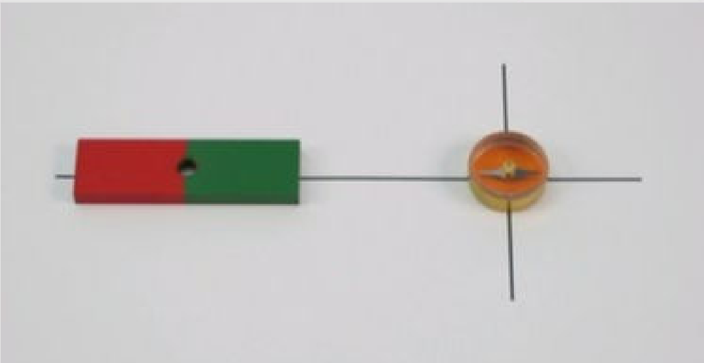


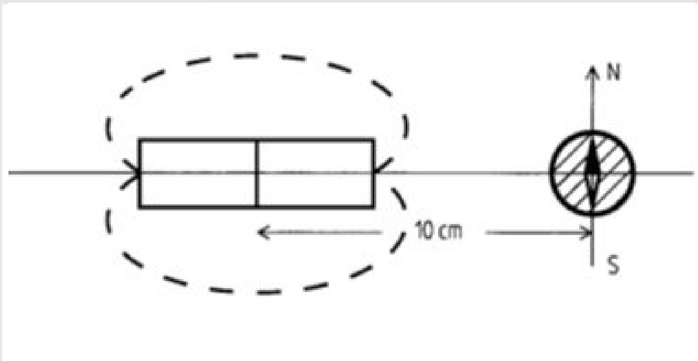


Set-up (2/2)

PHYWE

Draw two perpendicular lines on the sheet of paper and place the compass on it so that the pivot of the magnetic needle is above the intersection of the lines. Turn the sheet of paper until the magnetic needle runs in the direction of the shorter path and mark the ends of these paths with N and S. Now place the bar magnet on the sheet of paper at a distance of about 10 cm from the magnetic needle and mark two field lines on the sheet.





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Procedure (1/6)

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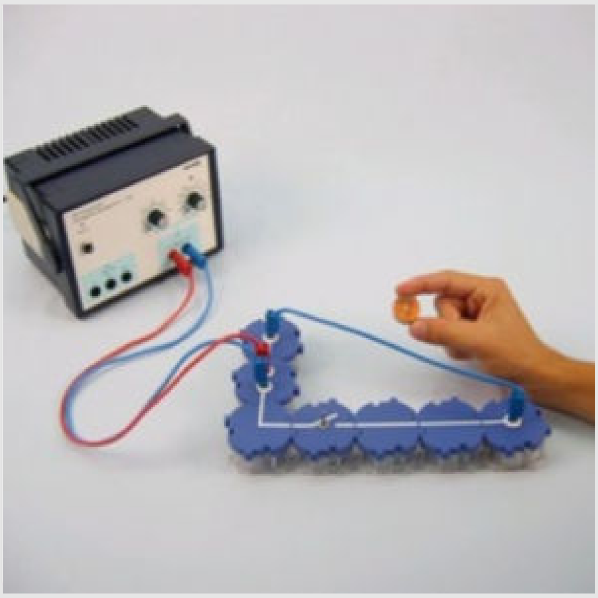
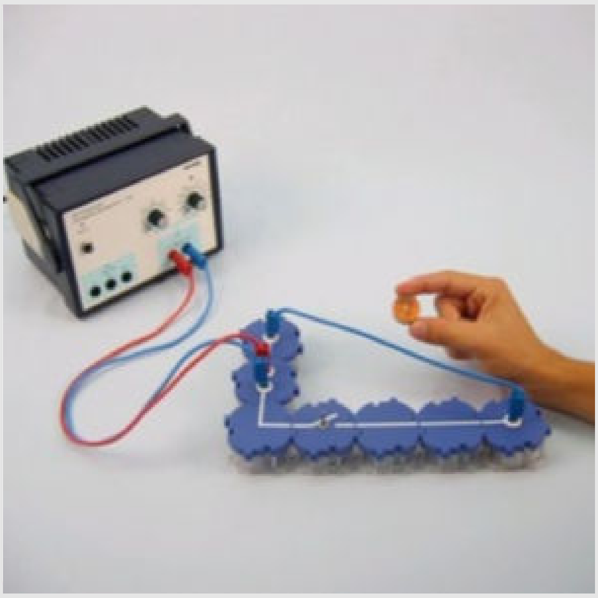


Take the compass and observe the magnetic needle for all the actions listed below:

- Hold the compass directly **at** the conductor section running in a north-south direction. Close and open the switch a few times in succession. Make a sketch with the conductor (+ / -) and the magnetic needle.
- Hold the compass directly **via** the conductor piece (see illustration). Close and open the switch again a few times. Also sketch the current mutual position of conductor and magnetic needle.

Procedure (2/6)

PHYWE



- Close the switch:
- Lift the compass higher and higher above the ladder.
- Then hold the compass directly under the ladder and lower it further and further.
- Hold the compass directly next to the ladder piece and slowly remove it horizontally from the ladder.
- Finally, hold the compass under the ladder again. Open the switch and reverse the polarity of the connections on the power supply unit and, if necessary, on the measuring instrument. Close the switch and watch the magnetic needle again.
- Set the power supply unit to 0 V and switch it off.

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Procedure (3/6)

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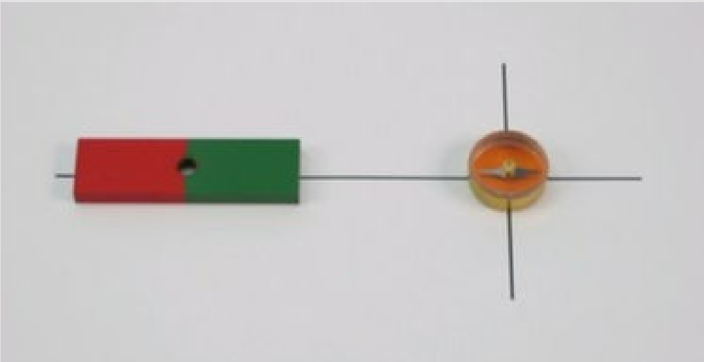
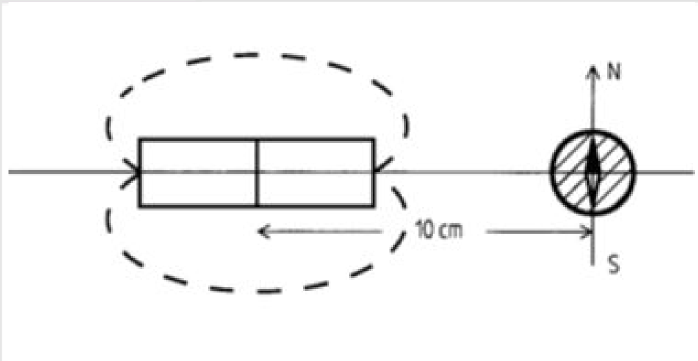
- Move the compass along the field lines slowly once around the bar magnet.
- Always observe the position of the magnetic needle.





Procedure (4/6)

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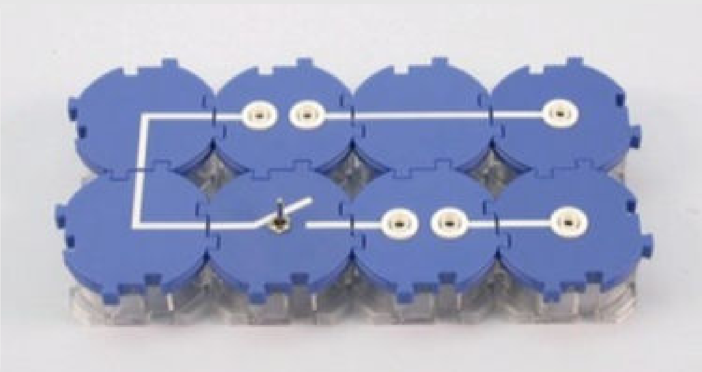
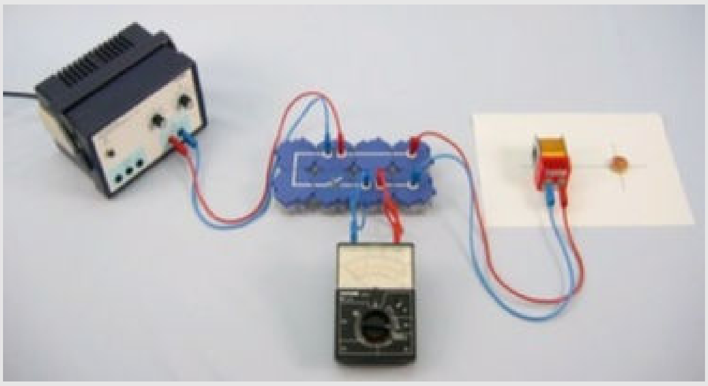
Modify the experiment from the figures below. The switch is now initially open. Connect a coil with 1600 turns to the two long connecting leads and select a current measuring range of about 300 mA. Place the coil on the sheet instead of the bar magnet. Place the compass back in its original position (above the intersection of the lines).





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Procedure (5/6)

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- Switch on the power supply unit and close the switch. Increase the voltage until the ammeter reads 250 mA.

Observe the position of the magnetic needle for the following actions:

- Slowly approach the compass to the coil and then move the compass around the coil along the drawn field lines as before.
- Place the compass back in its original position and observe the deflection of the magnetic needle when the currents are 250 mA, 150 mA and 50 mA in succession. Note the positions of the magnetic needle on your sheet.
- Open the switch, replace the 1600-turn coil with the 400-turn coil and repeat the above measurements.

Procedure (6/6)

PHYWE

- Push the I-shaped iron core into the coil.
- Compare the deflection of the magnetic needle before and after the insertion of the iron core.
- Place nails or paper clips on the sheet and bring the coil with the core near the parts.
- Set the power supply unit to 0 V and switch it off.

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Report

Task 1

What conclusion must be drawn from the observations you made in the first part of the experiment with the current-carrying conductor? Drag the words to the right places.

Every ______ conductor is surrounded by a ______.
The direction of the ______ depends on the direction of the ______

Not used: ______ (adjective), ______ (noun)

- gravitational field
- field lines
- magnetic flow
- magnetic field
- current
- current

Check

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Task 2

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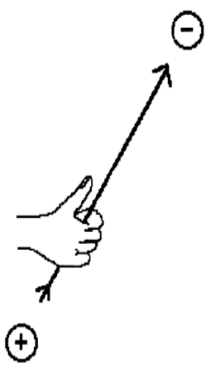
From the observations in the first part of the experiment, one can conclude the shape of the magnetic field that apparently surrounds the conductor when the current flows through it. Which shape best describes the magnetic field (the magnetic field lines)?

- circular
- elliptical
- spiral-shaped
- rectangular

Check

Task 3

PHYWE



On the left is shown how to determine the course of the field lines around a current-carrying conductor with the "right-hand rule". Try to formulate this rule.

If you grasp the conductor with your ____ hand so that the ____ points to the negative pole, the ____ indicate the direction of the magnetic ____ : ____ (adjective), ____ (noun)

fingers | index finger | right | field lines | thumb | left

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Task 4

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What follows from the observations in the second part of the experiment regarding the effect of a current carrying coil?

- [ ] A coil through which current flows acts like a bar magnet (permanent magnet).
- [ ] A current carrying coil, has no magnetic field.
- [ ] A current carrying coil, has a magnetic field, but this field is randomly directed.
- [ ] A current carrying coil has a magnetic field whose direction depends on the electrical polarity.

Check

Task 5

PHYWE

What is the strength of the magnetic field of a current carrying coil dependent on? Which of the following statements are correct?

- [ ] The lower the current strength, the stronger the magnetic field for the same number of turns of the coil.
- [ ] The higher the number of turns of the coil, the stronger the magnetic field at the same current strength.
- [ ] The higher the current, the stronger the magnetic field for the same number of turns of the coil.
- [ ] The smaller the number of turns of the coil, the stronger the magnetic field is at the same current strength.

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Task 6

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What can be concluded from the observation when the iron core was in the coil?

- [ ] Due to the inserted iron core more current flows through the coil.
- [ ] An iron core considerably increases the magnetic field.
- [ ] The material of the coil core influences the magnetic field.

Check

Task 7

PHYWE

A current carrying coil is called an electromagnet. Compile the advantages and possible disadvantages that an electromagnet has compared to a permanent magnet.

Advantages of the electromagnet: It can be ______ and its ______ can be reversed by switching. Its strength can be varied by the ______ and can be much greater than that of a permanent magnet due to a large ______ and current.

Disadvantages of the electromagnet It requires continuous ______.

- switched off
- poles
- current
- number of turns
- electrical energy

Check

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Slide	Score / Total
Slide 20: Current carrying conductor / magnetic field	0/6
Slide 21: Form of the magnetic field	0/1
Slide 22: Right Hand Rule	0/6
Slide 23: Coil = Permanent magnet	0/2
Slide 24: Dependencies of the magnetic field strength	0/2
Slide 25: Iron core in coil	0/2
Slide 26: Electromagnet vs. permanent magnet	0/5

Total amount 0 / 24

Solutions Repeat

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