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Magnetic field

Instructor version

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Overview

- Topic: magnetic field, data analysis, experimental process
- Target group: 1st year physics and non-physics students, high school students
- Timeframe: 1h30min for the experimental task

In this task, you will use the *PhyPhox* application to measure the Earth's magnetic field as well as the magnetic field of a permanent magnet and determine how the magnetic field depends on the distance from the permanent magnet.

Required equipment

- Smartphone with *PhyPhox* installed (available for both *Android* and *Apple* devices).
- Computer with a software for data analysis (e.g. *Excel*).
- Permanent magnets.
- Graph paper.
- Ruler

Orienting questions during the experiment

Recommended questions to ask students during the experimental task:

- When there is no magnet in the vicinity of the smartphone, what magnetic field do we measure?
- Do you know where north is?
- Where does the measured Earth's magnetic field point to?
- What are x, y i z directions of the smartphone sensors?
- If there was no direct reading of the resultant magnetic field, how would you find it?
- How did you find the position of the sensor in your smartphone?
- Why is it not recommended to place the permanent magnet on top of your smartphone?
- Does the orientation of the magnet matter when conducting the experiment?
- Can you determine how the magnetic field of a permanent magnet depends on the distance from the permanent magnet from the $B - x$ graph?
- Why do we need to modify the experimental data when analyzing it?

Testing the equipment

Each smartphone has the magnetometer sensor in a different position. We moved the magnet around and above the smartphone until we got the maximal reading. If the sensor is not close to the edge of the smartphone, measure (approximately) the distance from the edge and take it into consideration when making measurements.

We tested the experiment with fridge magnets, and it worked fine. Make sure students do not damage any equipment during the experiment. In our lab, one student placed the permanent magnet on top of the sensor in the smartphone and it damaged it (measurements were completely different from other smartphones).

The sensor in the smartphone is quite sensitive. Other devices or items that can influence the measurement of the magnetic field should be placed aside when conducting the experiment.

Data collection

Students must find the approximate location of the sensor in their smartphone first. Once they have an idea where the sensor is, students can start collecting experimental data by placing the permanent magnet some distance away from the sensor and noting the distance from the magnet to the sensor with a ruler and the magnitude of the magnetic field measured by the *PhyPhox* application. Data collection can be done on paper or directly in the data analysis software of choice.

Data analysis and representation

Before students start drawing graphs, discuss with them why the $B - x$ graph is not suitable to draw conclusions from, and why is the linearization from $B - x$ graph to $\log(B) - \log(x)$ graph needed. It is important for students to understand the basic ideas behind linearization and the least squares method since they will use them often during their studies.

After students obtain the $\log(B) - \log(x)$ ask how the magnetic field of a permanent magnet depends on the distance from the permanent magnet and what is the meaning of the negative sign of the slope.

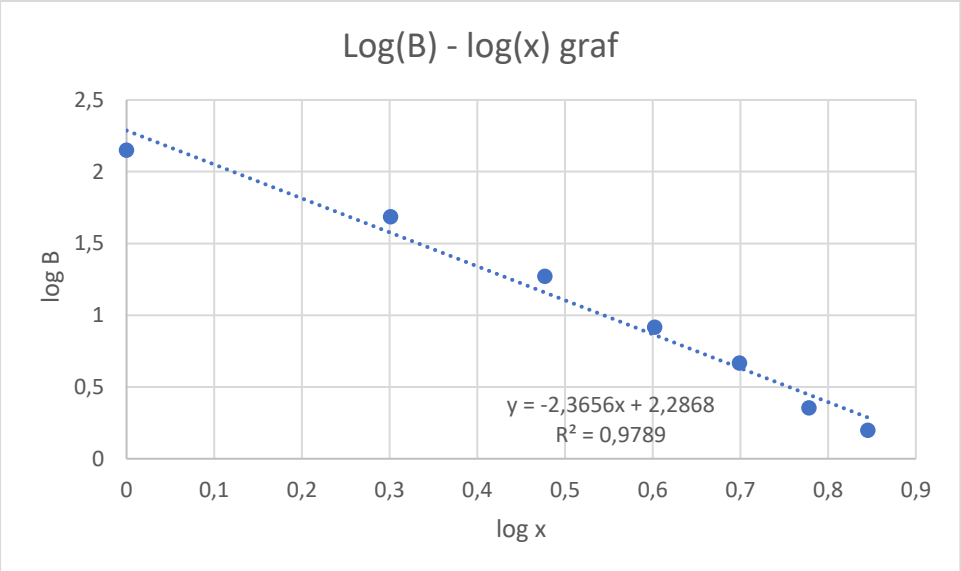

Figure 1: Example graph of student's measurement of the magnetic field of a permanent magnet.

Reporting

Students answer questions from the task instructions and send the word/PDF file to the instructor. Note to students to attach all the graphs, tables, and explanations in the file they send. First year students usually give short answers so ask them questions while they are conducting the experimental task.

From our lab

Students enjoyed the group photo and it helped them with their engagement in the experimental task.

Most students had minor issues with data analysis in *Excel* since they did not use the program prior to this lab. Some thought that $\log(\mathrm{B}) - \log(x)$ graph means the difference of $\log(\mathrm{B})$ and $\log(\mathrm{x})$.

One group tried to answer the additional question. The problem they had was manipulating equations with logarithms and SI units of the result.

Possible modifications

Some students have never used *Excel* before this lab. The instructions on how to use *Excel* were sufficient to guide students through data analysis, but it took some time for students to learn how to use the program. It might be a good idea to give them pre-lab exercise so that students can have more confidence in using *Excel* when they start doing the experimental task.

For more advanced students, the experiment can be modified. Students can measure the magnetic field of a wire which carries electric current.