First name .... Date..

Last name .... Degree program name...

Exercise B58

INVESTIGATION OF THE SMARTPHONE’S MAGNETIC FIELD

Magnetic field strength (in Gauss) above the smartphone

		Width [cm]										
Length [cm]		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
	1											
	2											
	3											
	4											
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	18											

Measurement Station (description for the photo below):

1. Computer with software
2. Smartphone overlay
3. USB flash drive (brought by the student)
4. Smartphone (brought by the student)
5. Magnetic field sensor
6. Stand for mounting the magnetic field sensor

Fig. 1) Measurement station

Theoretical Introduction

A magnetic field is one of the fundamental components of the electromagnetic field, defined as **the space in which moving electric charges and magnetic materials experience forces**. This field can be either static or time-varying. Its sources include permanent magnets and electrical conductors through which electric current flows.

In mobile technology, electromagnetic fields generated by smartphones are particularly significant. The emitted fields cover a broad range of frequencies, from **Radio Frequencies (RF)** used for wireless communication, through **Extremely Low Frequency (ELF)** fields associated with electronic circuits, to the less-studied **Static Magnetic Fields (SMF).**

Static magnetic fields primarily arise due to the flow of direct current through conductors, resulting from the motion of electric charges. In addition, a crucial source of SMF is permanent magnets, such as commonly used neodymium magnets, which exhibit high field strength in a small form factor.

When electric charges accelerate or decelerate, they generate time-varying magnetic fields that propagate as electromagnetic waves. Such fields are essential to all wireless technologies, especially cellular telephony.

A magnetic field is a vector quantity, meaning it is described by both its magnitude and direction. Two fundamental physical quantities are used to describe it:

- Magnetic flux density, also referred to as magnetic induction (in SI units of tesla), denoted by $\vec{B}$
- Magnetic field strength, denoted by $\vec{H}$ (measured in A/m—ampere per meter)

There is a mathematical relationship between these two quantities:

$$\boldsymbol{\vec{B} = \mu\vec{H},}$$

where μ is the magnetic permeability of the medium, measured in henrys per meter (H/m). Magnetic flux density is often expressed in smaller units known as gauss (abbreviated G or Gs), which is a unit in the CGS system. The conversion is:

$$\boldsymbol{1T = 10^4\ G}$$

Because smartphones are so widespread, there has been intensive research into the potential health risks of exposure to electromagnetic fields. Studies on RF EMF point to possible effects on the nervous system, reproductive processes, and an increased risk of certain tumors, such as glioma. A correlation has been found between frequent phone use and a higher risk of glioma, particularly on the side of the head where the phone is regularly held. Research on other tumors, such as salivary gland tumors, is inconclusive, although some studies suggest a slight increase in risk.

Research also indicates that RF EMF at a frequency of 1788 MHz and a specific SAR level (0.405 W/kg) can affect the functioning of the human autonomic nervous system, for example by influencing heart rate variability.

Static magnetic fields generated by smartphones have also attracted scientific interest because they may affect biological cells—**potentially causing genotoxicity, altering cancer and**

healthy cell proliferation, influencing antioxidant mechanisms (modulating reactive oxygen species, ROS), and impacting enzymes responsible for DNA repair.

Another important issue is the **interaction of magnetic fields with medical devices**, particularly implants such as pacemakers or defibrillators. These devices have a built-in "magnetic mode" that allows them to be safely deactivated by a magnetic field. The presence of strong magnetic fields in a patient's environment can lead to unexpected interactions, which is why continued research is necessary to understand and mitigate these risks.

Historically, large magnets (e.g., from speakers) posed problems, but modern smartphones contain small magnets that produce strong fields close to the device, introducing new challenges.

Specific Absorption Rate (SAR) measures how much electromagnetic radiation energy body tissues absorb per unit mass. It is expressed in watts per kilogram (W/kg). SAR is primarily used to assess the safety of devices that emit electromagnetic radiation, such as mobile phones, to determine how much RF (radio frequency) energy the body can safely absorb. SAR standards are established to limit potential health effects from radiation exposure. Most mobile devices' maximum permissible SAR values are typically around **1.6 W/kg (in the US) and 2 W/kg (in the European Union)**, measured for the head or body during the device's maximum power output.

International Guidelines (ICNIRP/WHO) The most widely applied guidelines are those of the ICNIRP (International Commission on Non-Ionizing Radiation Protection), supported by the WHO (World Health Organization) within the framework of the International EMF Project. ICNIRP sets basic restrictions and corresponding reference levels for magnetic and electromagnetic fields, separately for occupational (controlled) exposure and for the general public.

- **Static fields (0 Hz):** ICNIRP recommends that workers should not be exposed to magnetic fields exceeding 2 T (teslas) for the head and torso (limbs may be exposed up to 8 T). The limit is 0.4 T (400 mT) for the general public. *Note:* Because of the attraction of ferromagnetic materials and effects on medical devices, ICNIRP highlights the need for much lower practical limits—on the order of 0.5 mT (5 gauss)—in the vicinity of electronic implants and ferromagnetic objects.
- **Extremely Low Frequency (ELF, e.g., 50/60 Hz):** ICNIRP's limits primarily protect against nerve stimulation. For a 50 Hz mains frequency, the general public should not be exposed to magnetic fields above about 100 µT (0.1 mT). In contrast, the limit for workers is 500 µT (the fivefold higher limit reflects permissible occupational exposure). This corresponds to EU recommendations—specifically Union Directive 2013/35/EU—where 100 µT at 50 Hz is the reference level for public exposure. ICNIRP has somewhat revised these values (differentiating effects on the central and peripheral nervous systems), for example raising the allowable 50 Hz field for the general population to around 200 µT. However, many countries (including those in the EU) still conservatively apply the earlier 100 µT as a precautionary level for the public.
- **Higher frequencies (RF fields, above ~100 kHz):** The main limitation is tissue heating. ICNIRP defines limits by providing SAR values. The basic SAR limit is 0.08 W/kg (whole body) for the general public and 0.4 W/kg for workers, with local (e.g. head, torso) limits up to 2 W/kg for the general public and 10 W/kg for occupational exposure. By way of illustration, these values restrict the power density of an electromagnetic wave to 2 W/m² for the public and 10 W/m² for occupational exposure in the 10–400 MHz band. At higher frequencies (GHz), the limit levels increase—for example, above 2 GHz, the public limit is 10 W/m² (1 mW/cm²) and the controlled-exposure limit is 50 W/m². ICNIRP limits—endorsed by the WHO—are considered

to protect against established health effects **(nerve stimulation at low frequencies and overheating at high frequencies).**

In this exercise, we will investigate the static magnetic fields (SMFs) emitted by smartphones. We will map the SMF at a distance of 0.5 cm from the smartphone's surface to better understand the nature of these fields and their potential impact on the surroundings. Understanding the distribution of the magnetic field around smartphones is crucial for insights into their operation and assessing possible biological risks. This knowledge is particularly important in view of growing concerns about the potential health effects of long-term exposure to magnetic and electromagnetic fields emitted by modern mobile devices and their impact on implanted medical devices.

Magnetic Field Sensor

The sensor provides the magnetic flux density (i.e., magnetic induction) in gauss. The arrangement of the X, Y, and Z components is indicated on the top part of the sensor housing. It can also measure the total magnetic field in terms of magnitude (the quantity we will use for this exercise), although this forfeits information about the direction. The sensor used in this exercise is designed for measuring static fields.

In the CGS system, the unit of magnetic induction is 1 Gauss [G or Gs], while in the SI system it is 1 Tesla [T]. One Tesla equals 10,000 Gauss = 10 kG.

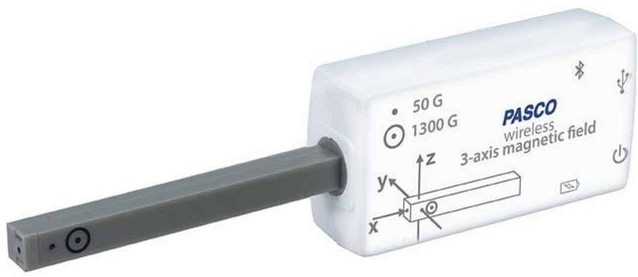

Fig. 2) The magnetic field sensor used in the experiment.

Objective of the Exercise

The goal of the exercise is to map the magnetic field generated by a smartphone.

Experiment Procedure

Preparation of the Station and Materials:

1. Turn on the station's power by turning the red knob under the table to the right, and then turning the key. A green LED on the power strip should light up.
2. Connect the magnetic field sensor to the computer using the USB cable.
3. Turn on the computer and log in (or switch user) to the B58 account.
4. Open the data acquisition program "B58 – Pomiar pola magnetycznego smartfona" located on the computer desktop.

Performing the Measurements:

1. Place the overlay (Figure 3) over your smartphone. The overlay is marked with centimeters along its length and width. The length is numbered in green and placed at the top of the grid on the left side. The width is numbered in red and is placed at the bottom of the grid on the right side. Each grid cell measures exactly 1 cm × 1 cm. Always align the overlay so that its length and width match the smartphone's length and width.

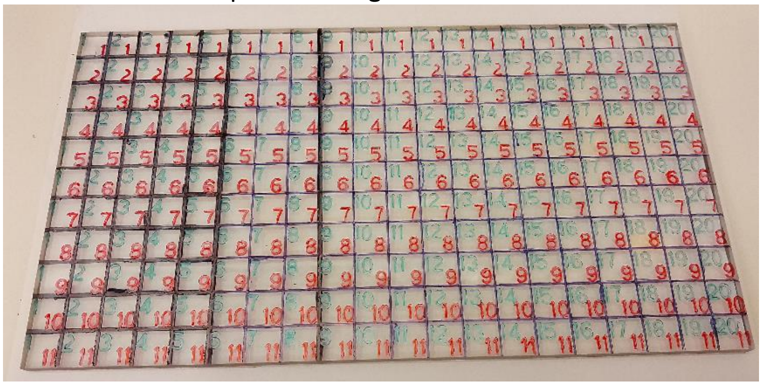

Fig. 3) Smartphone overlay.

2. Place the smartphone with the attachment under the magnetic field sensor – Fig. 4.

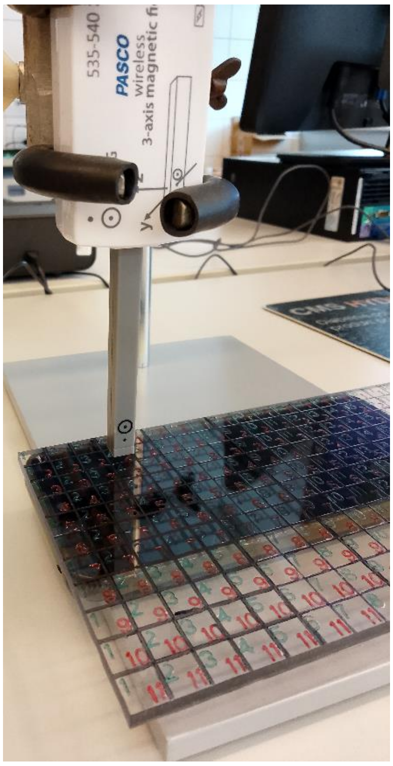

Fig. 4) Diagram showing the position of the smartphone, overlay and field sensor.

3. Move the smartphone with the overlay from one area of the overlay to the next, ensuring that the sensor is always in the centre of the respective area. The sensor should be positioned 1-2 mm above the overlay.
4. Enter the magnetic field strength measured in Gauss into the measurement table.

Conducting the Analysis:

1. There is a file named "Tabela.txt" on the desktop. Click on it to open it. (If the file is missing, log out and then log back in to the B58 account in Windows).

2. Enter your measurement table data into the file in the proper format, namely:
   - In the first column, provide the length coordinate of the smartphone in centimetres,
   - In the second column, provide the width coordinate of the smartphone in centimeters,
   - In the third column, provide the measured magnetic field value in gauss.

   Example of what the file should look like:

   1 1 2.14
   1 2 3.18
   1 3 4.17
   1 4 5.16

   2 1 2.17
   2 2 3.15
   2 3 4.17
   2 4 5.11

   3 1 1.19
   3 2 2.18
   3 3 4.11
   3 4 5.11
   Etc.

   Remember that the measurement data should be recorded as three numbers separated by spaces: length, width, and field value. Each new measurement is placed on a new line. Separate measurement groups (for different lengths) with an empty line (as in the example). This data entry format is important for the graphical processing later performed by "Gnuplot." End the file with an empty line as well.

3. After entering the data into the file, save it (for example, using the Ctrl + S shortcut).

4. Next, click the "Zrób wykres" (Make a plot) icon on the desktop. The program will reformat the entered data and run Gnuplot, generating a plot and saving it on the desktop.

5. The resulting plot shows the distribution of the static magnetic field generated by our smartphone. Copy the file to external storage, print it, and attach it to the report.

Additional Questions for Discussion in the Conclusions:

1. What actions should be taken if dangerous magnetic field levels are detected?

2. What medical risks can arise from being in a constant magnetic field? (Reference No. 3)

3.

4. What magnetic field values are sufficient to activate the magnet mode in medical devices? (Reference No. 3)

References

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2) Seth J. Seidman, Joshua Guag, Brian Beard, Zane Arp, Static magnetic field measurements of smart phones and watches and applicability to triggering magnet modes in implantable pacemakers and implantable cardioverter-defibrillators, *Heart Rhythm* **18** (10), 1741 - 1744 (2021). https://doi.org/10.1016/j.hrthm.2021.06.1203.
3) FDA, Magnets in Cell Phones and Smart Watches May Affect Pacemakers and Other Implanted Medical Devices. https://www.fda.gov/radiation-emitting-products/cell-phones/magnets-cell-phones-and-smart-watches-may-affect-pacemakers-and-other-implanted-medical-devices
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