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# Measurement of Magnetic Field U (MaFiU) Utilizing Smartphone: A Practice Experiment for High School Students

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## Abstract

In this study, we offer a low-cost laboratory practice for an introductory physics class laboratory for students of any grade level in science and engineering. This practice, in which a mobile phone (iOS, Android, or Windows) is used in conjunction with mini magnets (similar to what's found on refrigerator doors), a rule, paper, and a free application (app) which has to be downloaded and installed to measure magnetic fields by using smartphone's magnetic field sensor or magnetometer, was very well received by our pupils. This practice is completely free. The major aim of the exercise is for students to discover the influence of component x of the magnetic field produced by various magnets. We discover that the magnetic field's dependence on distance takes the form $\boldsymbol{x^{-6}}$, which is perfectly compatible with the theoretical analysis. The second purpose is to compute the magnetic field found in various types of household electronic devices.

**Keywords:** Measurement of magnetic field u (MaFiU), smartphone, practice experiment, physics toolbox suite

## INTRODUCTION

Physics instruction train students to proof the concept which have found by scientist through a measurement [1-3]. Measurement is a process in employ a particular tool to verified or proof the hypothesis [4-6]. One of essential measurement for senior high school is magnetic fields. Mostly student maintained that magnetic field topic is too implicit [7-9]. While concept of magnetic field frequently finds in real life [10], for instance, laptop, smartphone, speaker, fun, refrigerator etc. Teacher can utilise experiment method to engage student more active and obtain learning application [11-13]. Therefore, teacher would assist student to do experiment for improve student understanding concept.

Student will be interest to learn as they understand the concept [14-16]. Many ways investigated to increase student understanding concept [17-18]. Firstly, the teacher guide student to solve some problem in individuals or groups [19-20]. Secondly, the teacher provides an appropriate model such as discovery, inquiry, project based and problem-based learning [21]. Lastly, teacher assist student to experiment in the laboratory [22-23] [7]. However, some school does not facilitate with complete tools in laboratory [24-26]. Moreover, during pandemic covid-19, student only learn from home [27-29], no interaction [30], no active [31], no collaboration with other student [32-34]. This problem must be finding alternative solution for example use virtual lab by smartphone.

Nowadays, smartphone becomes primarily need by humans around the world. Almost all student has smartphone since post covid-19 because of they need to access material from internet [35-37]. It obviously evidence that smartphone have a role in education [38-40]. Smartphone can complete with many tools include education tools like calculator, dictionary, PhET simulation and so on. Technology developer and scientist cooperate to build some tools which can utilise in learning process [41-43]. One of their popular works is virtual lab. Virtual lab provides student and teacher to do experiment in everywhere and anywhere [44-45]. In this research, we employed physics toolbox suite to collect the data.

Physics toolbox suite is a free and low-cost application who developed by Vieyra Software. user can open this app by computer or PC and smartphone. Their goals are to attach the power of smartphone sensors, improve science education and assist research and industrial use. This application provide at least eight group parts include kinematics (g-force meter, linear accelerometer, Gyroscope, inclinometer, protractor), acoustics (sound meter, tone meter, tone generator, oscilloscope, spectrum analyser, spectrogram), light (light meter, colour detector, colour generator, proximeter, stroboscope), magnetism (compass, magnetometer, magna-AR), other (barometer, ruler, GPS, System temperature), combination (multi record, dual record, roller coaster), plotting (manual data plot), and game. In this paper, we employed magnetism component exactly magnetometer. Unfortunately, android cannot access menu for example barometer can open by IOS.

**Basic Theory**

The x component of the magnetic field produced by a magnet of length d and the magnetic moment with the module m at a point located at a distance x along the magnetic axis (which coincides with the direction of the magnetic moment) is shown in equation 1 as follows.

$$B = \frac{\mu_0 m x}{2\pi(x^2 - d^2/4)^2}$$

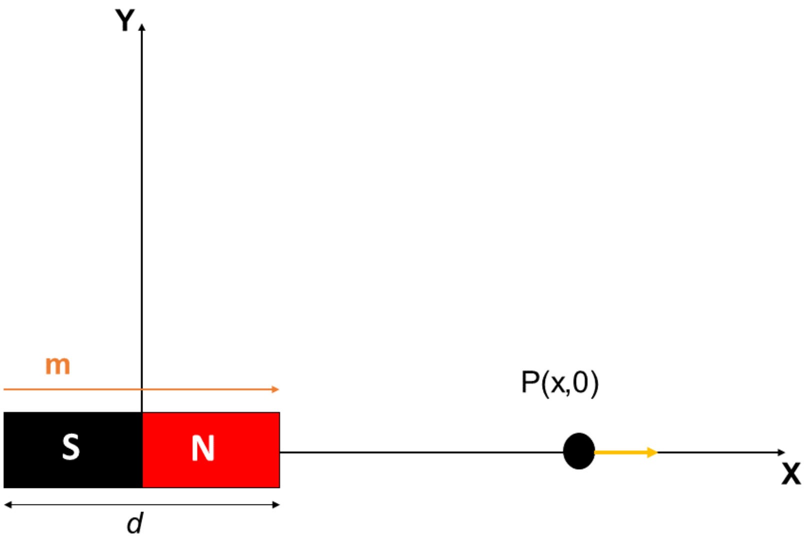


**Figure 1.** The x component of the magnetic field is located at a point P on the x axis, and the bar magnet has a length d and a magnetic moment with module m.

Where $\mu_0$ is the magnetic permeability in vacuum $\left(\mu_0 = 4\pi.10^{-7} N.A^{-2}\ atau \frac{H}{m}\right)$. In SI, the unit of magnetic moment of a magnet $(m)$ is $A.m^2\ or\ J/T$. If this magnetic field is measured at a distance $x$, greater than the length of the field $(d)$, so it can be simplified from the previous equation, assuming the value $x \gg d$, then equation 1 above will become equation 2 as follows.

$$B = \frac{\mu_0 m}{2\pi x^3}$$

In this way, the magnitude of the magnetic field is proportional to $x^{-3}$ and $\frac{\mu_0 m}{2\pi}$ is constant. From equation 2, the magnitude of the magnetic field can be measured as a function of the distance to the center of the magnet using the Magnetometer tool in the Physics Toolbox Suite Application.

## MATERIALS AND METHODS

To conduct this laboratory experiment, we ought to download an app on our phone that measures the magnetic field. It is critical to install an application capable of determining the three spatial components of the magnetic field, not only its module since the module is only insufficient. There are several programs accessible via the web that allow one to take these measures. The Magnetometer app comes highly recommended. Figure 2 is a snapshot of this app running on phones using the Android operating system [46]. Magnetometer Metal Detector and Physics Toolbox Magnetometer are two more intriguing apps that can be utilized on iPhone running the IOS operating system [47].

These programs frequently contain a settings screen where the refresh frequency reading, which is generally between 2-10 Hz, is displayed. Because the app collects data from the sensor every tenth of a second, it is difficult to interpret the decimal component for high numbers because it fluctuates extremely fast. When we change the frequency to 2 Hz, it gathers data every half-second, making it easy to type down both the entire component and the initial decimal digit. Further accuracy is not required; if we take three measures (or more), we compute the arithmetic average, which would be better than any measurement device.

The Earth, as we all realize, is a magnet. Its geographical North Pole is quite near to its magnetic South Pole, which is why a compass needle points to the Earth's geographical North Pole. We additionally know that the magnetic field of the Earth is on the scale of $50\mu T$. The magnetic field generated by laboratory magnets is in the range $\mu T - mT$, based on the distance of both the detector and magnet. We may deduce from this data that the Earth's magnetic field will impact our observations since it has comparable or superior orders of magnitude. To prevent having a foreground magnetic field from the terrestrial magnetic field, we merely really ought to point our smartphone in a certain direction when collecting data. We will spin the smartphone gently until we find a place where the value of the magnetic field component $x$ is almost zero. If we are unable to show the value 0, we must input the smallest value (the average of three observations), which we shall refer to as $B_{x0}$. Ultimately, according on whether it is positive or negative, we will have to deduct or add from our measures. If we examine this location, we observe that the smartphone has simply remained aligned in the N-S direction, which means that the $x$-axis is perpendicular to this direction, depicted in figure 3.

When we have accomplished all of these basic changes, we may begin the practice's experimental assembly, which is fairly straightforward (as shown in Figure 5). We position our phone in the appropriate orientation on a DIN A4 sheet of paper and draw the correct $x$ -axis of the phone that does indeed pass through the sensor. Then, at various distances, we install a magnet and record the value of the x component of the magnetic field delivered by the application. It should be noted, with reference to Figure 4, that we have to provide the position from the coordinate origin to which the magnetometer is positioned because this sensor is placed within the phone.

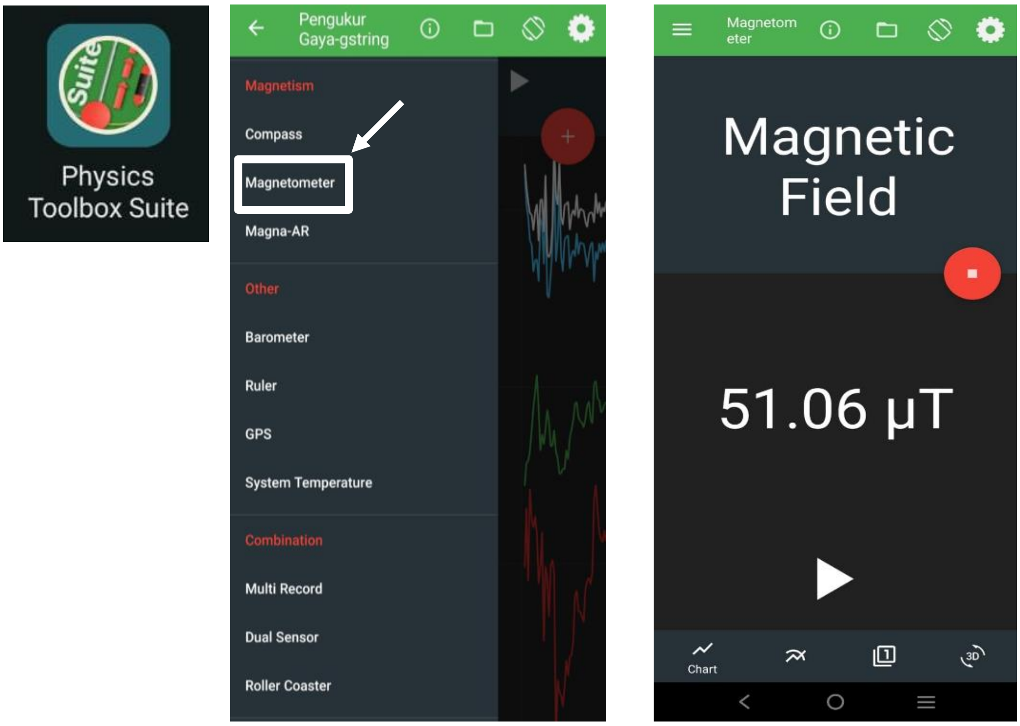


**Figure 2.** First setting to measure the magnetic field by smartphone

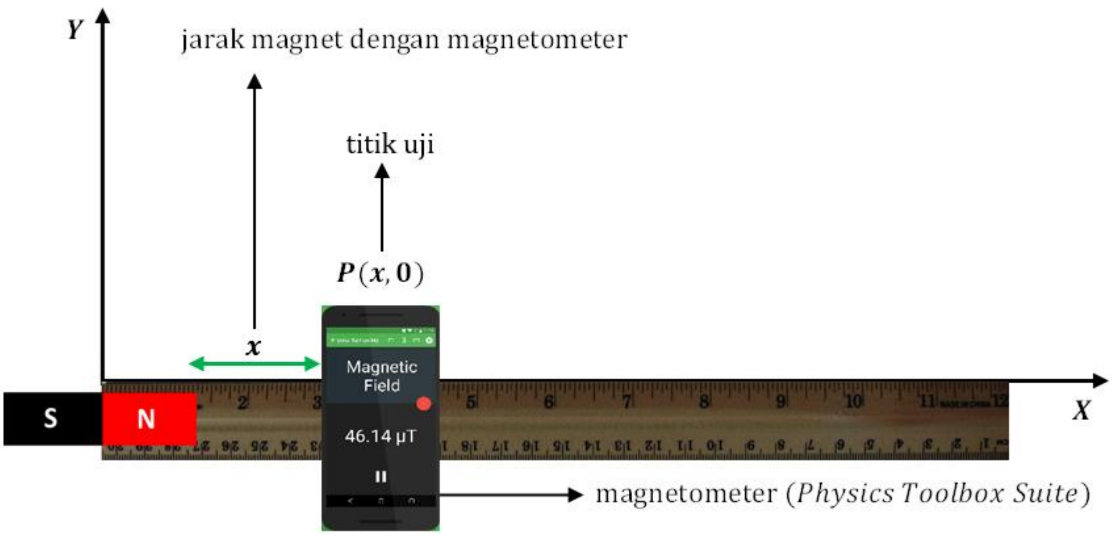


**Figure 3**. Position of the magnetic sensor in the interior of a phone.

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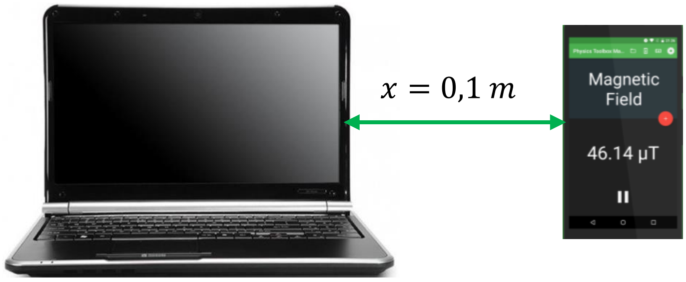


**Figure 4**. Measurement of magnetic field from 0,1 m distance from device

## RESULTS AND DISCUSSION

Next, we will examine the data collected using various versions of cellphones and magnets that have varied shapes and magnetic moments.

**Table 1** Result of measurement the magnetic field for 10 data

| No | x (m) | B ($\mu T$) |
|---|---|---|
| 1 | 0,01 | 98,60 |
| 2 | 0,02 | 89,85 |
| 3 | 0,03 | 81,76 |
| 4 | 0,04 | 74,63 |
| 5 | 0,05 | 67,22 |
| 6 | 0,06 | 61,93 |
| 7 | 0,07 | 56,43 |
| 8 | 0,08 | 52,32 |
| 9 | 0,09 | 48,54 |
| 10 | 0,10 | 45,08 |

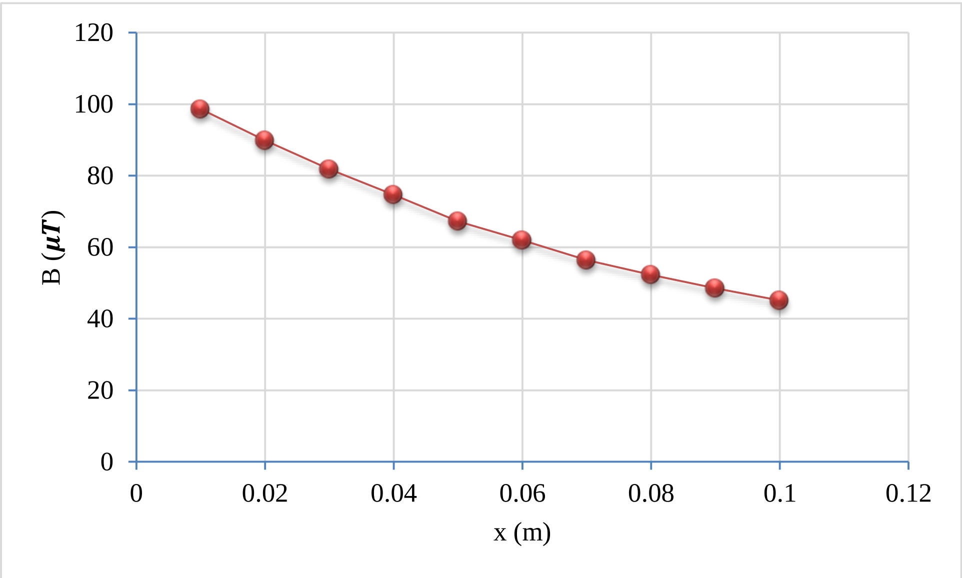


**Figure 5.** Magnetic field measurement results for 10 measurements

Figure 7 depicts a visual representation of the data captured with the magnetic sensor of the mobile phone for the component x of the magnetic field B in the component of the x distance, for the such situation involving the two less strong magnetic fields, the typical ones which are firmly related to refrigerator doors as ornaments. This graphic additionally demonstrates the setup of the experimental data with Microsoft excel.

Table 2 likewise depicts measurements of the magnetic field observed in numerous electronic devices that are commonly utilized constantly. According to the intended use of the electronic device, these gadgets utilize various forms of magnetic fields.

**Table 2** Results of magnetic field measurements from various types of electronic devices

| No | Devices | B ($\mu T$) |
|---|---|---|
| 1 | Laptop | 51, 06 |
| 2 | Smartphone | 44,76 |
| 3 | Speaker | 61,58 |
| 4 | Fan | 26,33 |
| 5 | Refrigerator | 32,18 |

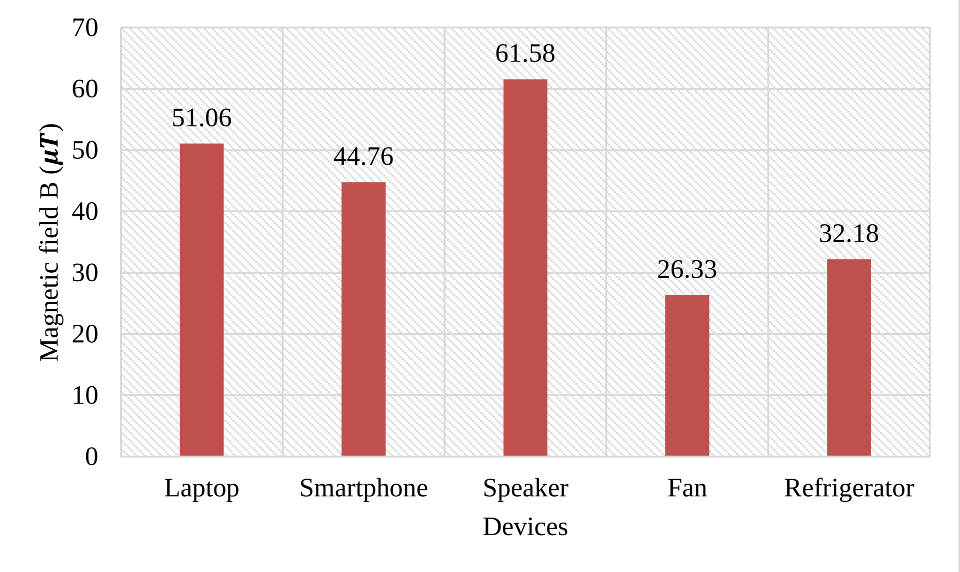


**Figure 6**. Differences in magnetic fields on laptops, cell phones, speakers, fans and refrigerators.

The magnetic field of five distinct types of electrical equipment are depicted in table 2 and figure 3. The distance between the magnetometer and the item in these measurements is always the same for all electrical equipment. The speaker appears to have the strongest magnetic field strength, which is $61.58 \times 10^{-6}T$. Then a laptop with a magnetic field strength of $51.06 \times 10^{-6}T$ followed. Meanwhile, the magnetic field of the fan is quite powerful. The smallest magnetic field measured is $26.33 \times 10^{-6}T$. Remarkably, the magnetic field strengths of the five instruments are not significantly different.

## CONCLUSION

A low-cost laboratory activity has been devised for the laboratory of an intro physics class for any grade level of science and engineering education. Students might determine the dependence of the magnetic field generated by various magnets by employing a phone magnetic sensor and appropriate software. Students can also create a visualization and deduce from the empirical observations in a reasonably straightforward way that the magnetic field is inversely proportional to the distance to the cube. Furthermore, by using a least squares correction, the magnetic moment of any magnet may be computed with extreme accuracy.

The magnetic sensor in cellphones can be utilized to assess how the magnetic field of tiny magnets varies with location. Master students carried out the experiment. Prior to carrying out the experiment, theories and concepts about the magnetic field created by a magnet were researched. The experiment taught the students the relevance of location in measuring the magnetic field and made them more familiar with experimental methods. As previously proven, the data are entirely in line with the conceptual assumption. Lastly, we believe that cellphones, with the assistance of a proper app, might be utilized to carry out laboratory procedures in other domains of physics.

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