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THE USE OF MAGNETOMETER SENSORS IN PHYSICS EXPERIMENTS: THE MOTION OF OBJECTS WITH CONSTANT VELOCITY AND CONSTANT ACCELERATION

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Abstract

This article explains how the magnetometer sensor determines the velocity and acceleration of objects moving in a straight line. Data retrieval using experimental devices consisting of tracks, magnetic stones, DC motors, smartphones, Phyphox software, trolleys, and rulers. The magnetometer sensor measures the magnetic field strength at every point the object passes. Measurements were repeated five times to obtain more accurate data. Data analysis was performed using Microsoft Office Excel. The results indicated the magnetometer sensor with Phyphox software could accurately measure the magnetic field along the track, enabling the results to be used as a reference for determining the exact position and time.

Keywords: Acceleration, Magnetometer, Phyphox, Sensor, Velocity.

1. Introduction

Practicum-based learning is required to provide opportunities for students to find and apply concepts by observation [1]. Practicum prepares students to face real-world conditions in the industrial world [2-5], especially in the current Industrial Revolution 4.0 [6, 7]. Thus, it is necessary to create a curriculum for practicums that aligns with the student's needs [8-11]. Many reports have been on using technology in practicums [12-18].

In straight motion practicum, several difficulties generally arise, such as measuring the position of objects with high accuracy, measuring the time accurately, or objects used to move at always changing and difficult to control. Thus, calculating the average velocity or acceleration will be more complicated. One alternative that can help overcome this problem is to use technology [19], such as the virtual laboratory [20]. Many papers regarding this matter have been reported [21-28]. Although a virtual laboratory can present more accurate measurement results and help students understand physics concepts, this virtual laboratory still has limitations, especially in supporting the development of students' physical skills [29, 30]. A practicum design is needed and can be practiced in real terms. Accurate measurement of position and time in straight motion practicum can be done using a sensor. This measurement is important and has been one of the important subjects [31-33]. One of the sensors is the magnetometer sensor contained in the smartphone. Every smartphone has been designed to run sensors in various experiments, especially physics experiments [34]. Smartphones are powerful gadgets offering many possibilities for school use [35], especially in physics teaching; they can be seen as a multiple measurement tool, disposable every time and everywhere [36, 37].

One of the smartphone applications as a magnetometer sensor is Phyphox [38] which can accurately measure various physical parameters such as acceleration, angular acceleration, magnetic field, light intensity, sound, etc. It is also an effective tool for practical experiments to enhance students' interest [39]. This sensor can automatically set the time. The measurement results can be visualized in the form of curves, graphs, or tables. Therefore, it provides a solution to address accuracy issues in measuring time and position, especially in straight-line motion experiments. The concept of a magnetometer has been well-documented [40-42]. Subsequently, to address the issue of controlling the movement of difficult-to-manage objects, a DC motor is employed. This DC motor is designed to produce a constant rotation to pull objects, enabling them to move at a constant velocity. Thus, it is necessary to test the use of the magnetometer sensor using the Phyphox application to measure the magnetic field through which objects pass. The magnetic field measurement results accurately determine objects' position and time, confirming the velocity and acceleration of objects moving in a straight line. This study aims to determine the velocity of an object moving in a straight line and the acceleration of an object moving in a straight line changes regularly.

2. Methods

This physics experiment used tools and materials like tracks, rulers, smartphones, trolleys, DC motors, magnets, and Phyphox software as magnetometer sensors. The tools and materials are assembled (see Fig. 1). The experiment was carried out in two activities: 1) object motion at a constant velocity and 2) object motion at a constant velocity. This experiment considered an object in a smartphone.

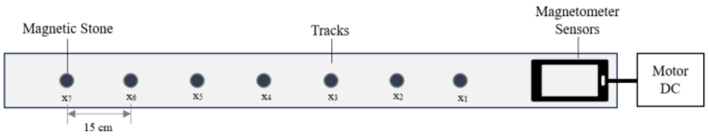

Fig 1. Schematic of experimental tools.

This smartphone functions as a magnetometer sensor. The magnetometer sensor uses Phyphox software. The smartphone is mounted on a trolley connected to a DC motor via a rope. DC motor regulates objects' velocity of motion (smartphones). When the trolley is moved, the object will pass through the track paired with a magnetic stone. The magnetic stone is installed at positions x_1, x_2, x_3, x_4, x_5, x_6, and x_7 (see Fig. 1). The magnetometer sensor on the smartphone will enumerate the magnitude of the magnetic field at any time along the trajectory traversed. The distance between the magnetic stones is 15 cm. Data collection on each activity is carried out repeatedly five times. In measuring the motion of objects at a constant velocity, the DC motor is turned on to control. Thus, the object's velocity is constant. At the same time, measurements in the motion of objects with constant acceleration do not use DC motors. To move the trolley, the track is tilted 15 degrees. The track length used is about 100 cm. The measurement data from the magnetometer sensor in text files was analysed using MS Office Excel. The results of the analysis are displayed in the form of tables, curves, or graphs. The results are used to interpret the motion of objects with constant velocity and objects with constant acceleration.

3. Results and Discussion

Experiments were conducted to determine the velocity of an object moving straight regularly and the acceleration of objects moving straight changes regularly using a magnetometer sensor with a Phyphox application. Compared to conventional methods, the sensor is more thorough in measuring time. The magnetometer sensor can record up to 50 data/s. The results of measuring the strength of the magnetic field at any time in the motion of objects with a constant velocity are given in Fig. 2. In contrast, the motion of objects with constant acceleration is given in Fig. 3. Figures 2 and 3 depict the relationship between the magnetic field (B) and time (t). At times t_1, t_2, t_3, t_4, t_5, t_6, *and* t_7, the sensor counts the maximum value of the magnetic field.

3.1. The motion of objects at a constant velocity

The results of magnetic field measurements using the magnetometer sensor are then used to determine the position of x_1, x_2, x_3, x_4, x_5, x_6, x_7, and time t_1, t_2, t_3, t_4, t_5, t_6, and t_7. The tabulated results are given in Table 1. The relationship between position and time based on Table 1 is shown in Fig. 4. The relationship between position and time is directly proportional to the equation of $Y = 17.62X - 168.73$ with $R^2 = 0.9997$. Because the variable on the x-axis is time t, and the y-axis is position x, the line equation becomes $x = 17.62t - 168.73$, with x (cm) and t (seconds). The $x = 17.62t - 168.73$ is identical to the $x = x_0 + vt$ equation. The equation $x = x_0 + vt$ is an equation of motion with a constant velocity v. The slope of the line of the linear equation on the position-to-time relationship is the velocity of a constant-valued body. Thus, based on the equation $x = 17.62t - 168.73$, the velocity v is 17.62 cm/s. This velocity v is constant, or the object moves at a constant velocity. Objects moving at a constant velocity are called regular straight-moving objects.

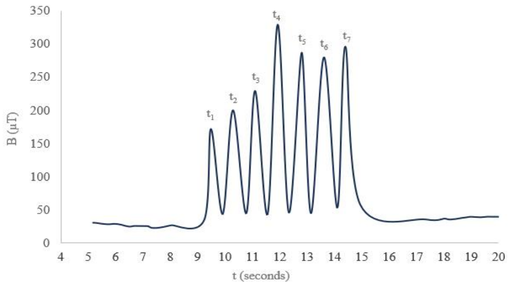

Fig. 2. The magnetic field vs. time for an object moving at a constant velocity.

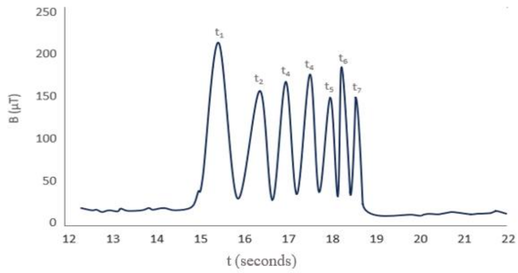

Fig. 3. The magnetic field vs. time for an object at a constant acceleration.

Table 1. Magnetic field, time, and position of objects at a constant velocity.

No.	Time (s)	Magnetic field (μT)	Position (cm)
1	$t_1 = 9.62$	175.24	$x_1 = 0$
2	$t_2 = 10.41$	202.56	$x_2 = 15$
3	$t_3 = 11.23$	226.34	$x_3 = 30$
4	$t_4 = 12.15$	327.82	$x_4 = 45$
5	$t_5 = 12.97$	280.34	$x_5 = 60$
6	$t_6 = 13.82$	276.21	$x_6 = 75$
7	$t_7 = 14.71$	290.23	$x_7 = 90$

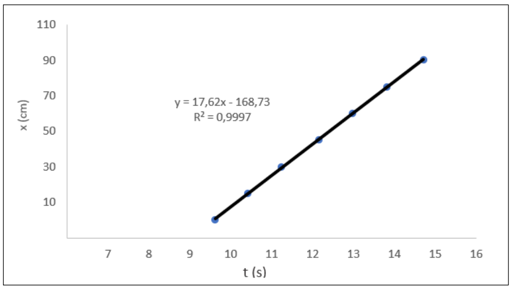

Fig. 4. Position vs. time when velocity is a constant.

Magnetic field strength measurements in this experiment were repeated five times to obtain more accurate data. The results of these measurements are then analysed, and each measurement's velocity is obtained, as in Table 2. The object's average velocity is |17.64 ± 0.04| cm/s with a relative uncertainty of 0.22%, indicating the accuracy of measuring the determination of the velocity of objects is very high. Thus, using magnetometer sensors with Phyphox software is feasible for straight-motion experiments with constant velocity.

Table 2. The results of the velocity analysis on each measurement.

Measurement	Velocity (cm/s)	δ	R^2
1	17.62	0.02	0.9997
2	17.68	0.04	0.9754
3	17.65	0.01	0.9991
4	17.68	0.04	0.9834
5	17.61	0.03	0.9732
Average	17.64	-	-

3.2. The motion of objects with constant acceleration

The results of magnetic field measurements using the magnetometer sensor are then used to determine the position of x_1, x_2, x_3, x_4, x_5, x_6, x_7, and time t_1, t_2, t_3, t_4, t_5, t_6, and t_7. The tabulated results are given in Table 3. The relationship between position and time based on Table 3 is given in Fig. 5.

The relationship between position and time in a curve is in line with $y = 6.6296x^2 - 196.15x + 1449.1$ and $R^2 = 0.9988$. Because the variable on the x-axis is time t, and the y-axis is position x, the line equation becomes $x = 6.6296t^2 - 196.15t + 1449.1$, x (cm) and t (seconds). The equation $x = 6.6296t^2 - 196.15t + 1449.1$ is identical to the equation $x = x_0 + v_0t + 1/2\ at^2$.

The equation $x = x_0 + v_0t + 1/2\ at^2$ is an equation of motion with a constant acceleration a. Figure 5 is a straight motion curve with a constant acceleration. Thus, according to equation $x = 6.6296t^2 - 196.15t + 1449.1$, acceleration a is 13.26 cm/s^2. Because the acceleration of an object is constant, the velocity of the object changes regularly.

The motion of an object in a straight line with constant acceleration is uniformly accelerated rectilinear motion. This method of analysis requires interpretive skills. The ability to interpret curves is an important skill in many fields, especially academia, business, science, and media [43].

Curve interpretation involves understanding and conveying information presented in specific forms, such as bar, pie, and line charts [44]. Therefore, this ability needs to be trained in learning through practicum activities in the laboratory [45]. Magnetic field strength measurements in this experiment were repeated 5 times to obtain more accurate data.

The results of these measurements are then analysed, and each measurement's acceleration is obtained as in Table 4. The average acceleration of the object is |13.14 ± 0.17| cm/s^2 with a relative uncertainty of 1.29%, indicating the accuracy of measurements using magnetometer sensors to determine the acceleration of objects is very high. Thus, a magnetometer sensor with Phyphox is suitable for straight-motion experiments.

Table 3. Magnetic field, time, and position of objects at a constant acceleration.

No	Time (s)	Magnetic field (μT)	Position (cm)
1	$t_1 = 15.32$	213.14	$x_1 = 0$
2	$t_2 = 16.41$	152.63	$x_2 = 15$
3	$t_3 = 16.97$	165.23	$x_3 = 30$
4	$t_4 = 17.48$	176.32	$x_4 = 45$
5	$t_5 = 17.90$	140.71	$x_5 = 60$
6	$t_6 = 18.23$	181.04	$x_6 = 75$
7	$t_7 = 18.49$	145.57	$x_7 = 90$

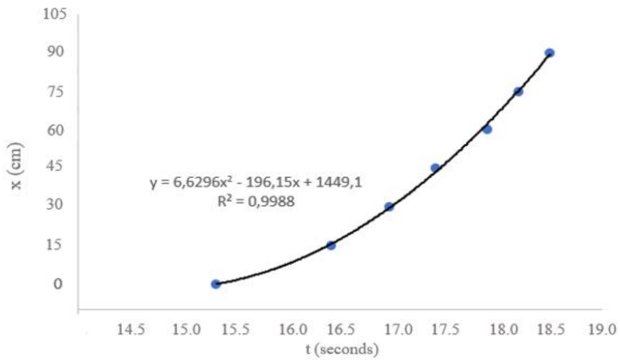

Fig. 5. Distance vs. time when acceleration is a constant.

Table 4. The results of the acceleration analysis on each measurement.

Measurement	Acceleration (cm/s^2)	δ	R^2
1	13.26	0.12	0.9988
2	13.17	0.03	0.9956
3	13.02	0.12	0.9921
4	12.97	0.17	0.9827
5	13.29	0.15	0.9936
Average	13.14	-	-

4. Conclusion

The results indicated the magnetometer sensor with Phyphox accurately measured the magnetic field along the track, enabling the results to be used to determine the exact position and time. The object moves straight at a constant velocity of |17.64 ± 0.04| cm/s and a constant acceleration of |13.14 ± 0.17| cm/s^2.

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