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COVER LETTER

Gary Williams, July 23, 2018

Editor-in-Chief of *Physics Education*,

Institute of Physics, UK

Dear Gary Williams:

I wish to submit an original article for publication in *Physics Education*, titled "***Constant Speed Motion Analysis using Smartphone Magnetometer***". The paper was authored by Ade Yeti Nuryantini and Bebeh Wahid Nuryadin.

This study demonstrated that the constant average speed of the dynamic car could be measured and calculated using the smartphone magnetometer. The apparatus setup was build using a dynamic car, a linear track up to 1.50 m, a bunch of strong magnets, and a smartphone magnetometer application. The smartphone magnetometer application, "Physics Toolbox Suite", was used free for the experiment. The strong magnet and a smartphone magnetometer were attached on a linear track and dynamic car, respectively. When the dynamic car was moving in car track, the smartphone magnetometer will measure the magnetic field value vs. time relation. The magnetic field value was fluctuated, increasing when close to a magnet or decreased when a distance to a magnet. The magnetic field properties (peaks time) vs. magnet distance position were analyzed using linear fitting, and get an average speed of the dynamic car. We hope that this magnetometer experiment will be valuably used in general physics laboratories. Further, this manuscript should be of interest to the readers of the *Physics Education*.

This manuscript has not been published or presented elsewhere in part or in entirety and is not under consideration by another journal. All study participants provided informed consent, and the study design was approved by the appropriate ethics review board. We have read and understood your journal's policies, and we believe that neither the manuscript nor the study violates any of these. There are no conflicts of interest to declare.

Thank you for your consideration. I look forward to hearing from you.

Sincerely,

Bebeh Wahid Nuryadin, Dr.

Department of Physics, UIN Sunan Gunung Djati Bandung

Jl. A.H. Nasution 105, Bandung 40614, Indonesia

Email: bebehwahid102@uinsg.ac.id

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Physics Education

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Thank you for your submission

Submitted to	Physics Education
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Title	Constant Speed Motion Analysis using Smartphone Magnetometer
Authors	Nuryantini, Ade Nuryadin, Bebeh
Date Submitted	23-Jul-2018

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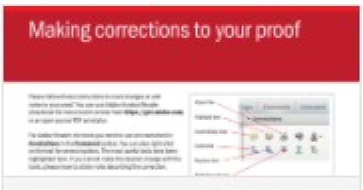

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Response to Reviewers' Comments on the Manuscript Entitled "Constant Speed Motion Analysis using Smartphone Magnetometer" by Nuryantini, Ade; Nuryadin, Bebeh Article reference: PED-101546

We would like to extend our sincere gratitute to the reviewers for evaluating our manuscript and for their valuable suggestions. We have included the following revisions that are highlighted in blue in response to your comments and suggestions concerning our manuscript.

Referee: 1

Comments:

Page 1 Line 25 - what type of magnets have been used? This should be stated.

Authors' response:

Thank you for your correction. We have revised the explanation about the type of magnets
Type of magnets is ***Alnico*** *(*aloi A*luminium (Al), Nickel (Ni), Cobalt (Co))* magnet.
Dimension:
Long : 7 cm
Width : 2 cm
Thickness : 0,5 cm

Experimental overview, page 3, paragraph 2

Comments:

Page 2 Line 6 "…which pairs.." not sure what this means.

Authors' response:

Thank you for your suggestion. We have revised the lack of clarity of the language by a native English speaker, using the recently launched IOPP English-language editing service Editage at http://iopeditingservices.editage.com/.

Comments:

Fig 1a(b) is confusing, poorly explained and of no relevance to the practical.

Authors' response:

Thank you for your suggestion. We have removed Fig 1 (a) and (b).

Comments:

Page 2,49 to Page 3,5 should be replaced (not appropriate for the scholastic level of the procedure) with something like " The physics toolbox app is used to measure magnetic filed strength."

Authors' response:

Thank you for your suggestion. We have revised the lack of clarity of the language by a native English speaker, using the recently launched IOPP English-language editing service Editage at http://iopeditingservices.editage.com/.

Comments:

The data are fine BUT…. The value of the peak magnetic fields play no part at all in the analysis. This looks like its being made over complicated. The paper should have pointed out that you have shortened the total distance used as you moved the magnets closer together.

Authors' response:

Comments:

(Page 5,35) There is no need to speculate about battery power…. Do you mean the battery power of the dynamics cart?.

Authors' response:

Comments:

Finally…how do you get the cart to go at constant speed?

Comments:

The conclusion is mainly a repeat of the overview… could be significantly reduced.

Authors' response:

Response to Reviewers' Comments on the Manuscript Entitled "Constant Speed Motion Analysis using Smartphone Magnetometer" by Nuryantini, Ade; Nuryadin, Bebeh Article reference: PED-101546

We would like to extend our sincere gratitute to the reviewers for evaluating our manuscript and for their valuable suggestions. We have included the following revisions that are highlighted in blue in response to your comments and suggestions concerning our manuscript.

1. **Reviewers' Comment**:

Page 1 Line 25 - what type of magnets have been used? This should be stated.

Authors' response:

We thank you for the correction. We have revised the manuscript and added more specific of the magnets at sentence page 2 line 21 in Experimental Overview.

Page 2 line 21
a strong magnet of Alnico (aloi Aluminium (Al), Nickel (Ni), Cobalt (Co)) with dimension 7 x 2 x 0.5 cm,

2. **Reviewers' Comment**:

Page 2 Line 6 "…which pairs.." not sure what this means.

Authors' response:

We thank you for the corection. We have revised the sentence to make it clearer.

Page 2 line 2

Motion data and analysis is obtained by detecting the maximum magnetic field of the magnet is placed in a row along the linear track.

3. **Reviewers' Comment**:

Fig 1a(b) is confusing, poorly explained and of no relevance to the practical.

Authors' response:

We thank you for the suggestion. We have revised the manuscript and removed Fig 1.

4. **Reviewers' Comment**:

Page 2,49 to Page 3,5 should be replaced (not appropriate for the scholastic level of the procedure) with something like "The physics toolbox app is used to measure magnetic filed strength."

Authors' response:

We thank you for the suggestion. We have replaced the sentence to follow your suggestion.

Page 2 line 8

In this study, the Android based smartphone and the physics toolbox app is used to measure magnetic filed strength.

5. **Reviewers' Comment**:

The data are fine BUT…. The value of the peak magnetic fields play no part at all in the analysis. This looks like its being made over complicated. The paper should have pointed out that you have shortened the total distance used as you moved the magnets closer together. (ieu teh maksadna Makalah ini seharusnya menunjukkan bahwa Anda telah memperpendek jarak total yang digunakan saat jarak antar magnet diperkecil. Ini gtw harus gmn, jd disajikan aja weh tabelnya kaya yg dimakalah yg indonesia)

Authors' response:

We thank you for the suggestion. We have revised the data to follow your suggestion

6. **Reviewers' Comment**:

(Page 5,35) There is no need to speculate about battery power…. Do you mean the battery power of the dynamics cart?.

Authors' response:

We thank you for the suggestion. The battery power at sentences (page 5,35) is battery power of the dynamic car. We have revised the manuscript to follow your suggestion.

Page 5 line 7

A small difference in average speed results may be caused by considerable a linear track resistance, magnet position, and magnetometer sensor accuracy

7. **Reviewers' Comment**:

Finally…how do you get the cart to go at constant speed?

Authors' response:

We thank you for the question. The dynamics car had a DC electric motor with gear transmission system and control switches for control of car speed.

8. **Reviewers' Comment**:

The conclusion is mainly a repeat of the overview… could be significantly reduced.

Authors' response:

We thank you for the suggestion. We have revised the conclusion to follow your suggestion.

Page 5 line 12

We have successfully studied the use of magnetometer sensors to determine the constant average speed of a dynamic car using the smartphone magnetometer sensor and the Physics Toolbox application to record the magnetic field as a function of time. We have obtained the dynamic car speed for variation magnet distance position (δL) has a constant speed. The experiments show that smartphone devices offering sufficient measurement accuracy and can be being everyday tools to measure physical quantities. distance position were analyzed using linear fitting, and get the average speed of the dynamic car.

Constant Speed Motion Analysis using Smartphone Magnetometer

Ade Yeti Nuryantini,[1] Asti Sawitri[2], Bebeh Wahid Nuryadin[2]

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Abstract

This study demonstrated that the constant average speed of the dynamic car could be measured and calculated using the smartphone magnetometer. The apparatus setup was build using a dynamic car, a linear track up to 1.50 m, a bunch of strong magnets, and a smartphone magnetometer application. The smartphone magnetometer application, "Physics Toolbox Suite”, was used free for the experiment. The strong magnet and a smartphone magnetometer were attached on a linear track and dynamic car, respectively. When the dynamic car was moving in car track, the smartphone magnetometer will measure the magnetic field value vs. time relation. The magnetic field value was fluctuated, increasing when close to a magnet or decreased when a distance to a magnet. The magnetic field properties (peaks time) vs. magnet distance position were analyzed using linear fitting, and get an average speed of the dynamic car. We hope that this magnetometer experiment will be valuably used in general physics laboratories.

Keywords: motion analysis, constant speed, smartphone magnetometer, magnetic field

Introduction

Research on the sensor smartphones as learning and experiment apparatus, especially in the physics laboratory, is exciting and still increase [1, 2]. The sensors on commons smartphone are an accelerometer, gyroscope, light sensor, and magnetic sensor. Accelerometer (and gyroscope) sensors have been widely used to analyze free fall objects [1], rolling motion [3], free and damped oscillations, and simple pendulum [4]. In 2017, Kapucu group has been developed a method of measuring the object's velocity using a smartphone light sensor [5]. Also, magnetometer sensors have been used to measure the magnitude of the static magnetic field [6], and the magnetic field on the straight cable and the loop [7]. The use of magnetometer sensors is quite exciting and potential because of the high sensor precision and low interference of the external (earth) magnetic field.

Therefore, this study reports the use of magnetometer sensors to determine the constant average speed of a dynamic car. Motion data and analysis is obtained by detecting the maximum magnetic field of the magnet is placed in a row along the linear track. This research is expected to be a guide for teachers and students in conducting physics experiments using magnetometer sensors.

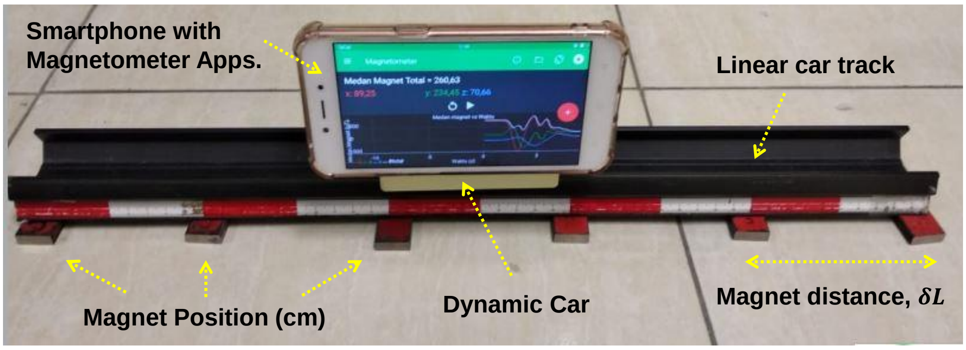

Figure 1 The schematic of the constant speed motion analysis using smartphone magnetometer

Experimental Overview

In this study, the Android based smartphone and the physics toolbox app is used to measure magnetic field strength. The magnetic field data used is the total magnetic field measured by the magnetometer sensor. The magnetic field due to a dipole, expressed by [6, 8]:

$$B = \frac{\mu_0 2m}{4\pi r^3} = \left(\frac{2\mu_0 m}{4\pi}\right)\left(\frac{1}{r^3}\right) \tag{1}$$

where B, μ_0, m and r are the magnetic field (T), the magnetic permeability of the free space ($4\pi \times^{-7}$ Wb/A.m), magnetic momen (J/T), and radius (m). Next, the average speed of the dynamics car was calculated by [5]:

$$v_x = \frac{\Delta x}{\Delta t} \approx \frac{dx}{\mathrm{dt}} \tag{2}$$

where v_x, Δx, and Δt are the average speed, magnet position (m) and peak time span (s), respectively.

The schematic of the constant speed motion analysis using smartphone magnetometer setup is shown in Figure 1. The apparatus setup was build using a dynamic car with constant speed, a linear car track up to 2.00 m, a strong magnet of AlNiCo (Aluminum (Al), Nickel (Ni), Cobalt (Co)) alloy) with dimension 7 x 2 x 0.5 cm, and a smartphone magnetometer application. The strong magnet was attached on a car track on parallel position, with distance position at 10 cm, 15 cm and 20 cm for the different experiment. The smartphone magnetometer was attached to the dynamic car, and move horizontally at linear car track. When the car with constant speed was running in linear car track, the smartphone magnetometer would measure the magnetic field value vs. time relation. The magnetic field value was fluctuated, increasing when close to a magnet or decreased when the distance to the magnet as shown at **Eq. 1**. To get the magnetic field properties were analyzing the magnetic peak value and peak time of the measurement data. The magnetic peak value describes the magnet position on a linear car track. Thus, from the magnetic field data were getting the relation of the peak time and magnet positions. The relation of the peaks time and magnet position were analyze using linear fitting using **Eq. 2**, and get the average speed of smartphone magnetometer on the dynamic car.

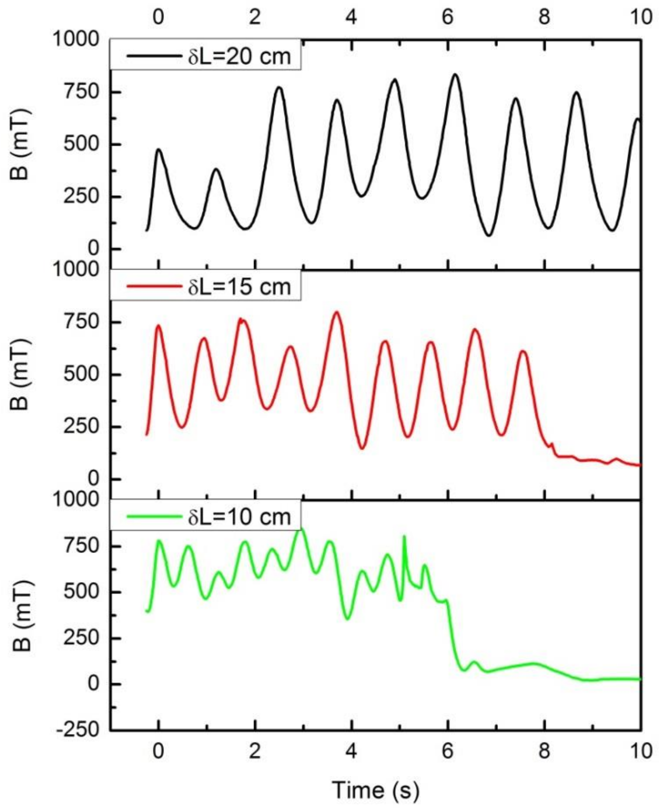

Figure 2 Magnetic field measurement using a car with constant speed and smartphone magnetometer for magnet distance position (δL) at 10 cm, 15 cm, and 20 cm

Trials and Results

In the following experiment, the dynamic car and the smartphone are moved to the x-axes (1D motion analysis). The mass of the dynamic car and the smartphone together is 0.350 ± 0.001 kg. The 1D motion of a dynamic car on the linear track, the smartphone starts measured magnetic field value (100 Hz) for different of magnet distance position at 10 cm, 15 cm and 20 cm (see **Figure 2**). For easy analysis, the initial time of the magnetic experiment was applied (selected) at first-peak time of the magnetic field data. The magnetic field properties (peak periods) were analysis directly from the magnetic field, as shown in **Table 1**. The results show that the magnetic field value was fluctuated, increasing when close to a magnet or decreased when the distance to magnet [6]. The relative of the peak time span for magnet distance position (δL) at 10cm, 15cm, and 20cm are 0.6s, 0.9s, and 1.2s, respectively. The peaks time span indicates that the dynamic car is moving at a constant speed at 1D motion (see **Eq. 2**).

Table 1 Magnetic field properties for magnet distance position (δL) at 10 cm, 15 cm, and 20 cm

	δL = 10 cm		δL = 15 cm		δL = 20 cm	
Peak	Peak Time (s)	Magnet Position (cm)	Peak Time (s)	Magnet Position (cm)	Peak Time (s)	Magnet Position (cm)
1	0	0	0	0	0	0
2	0.610	10	0.946	15	1.184	20
3	1.246	20	1.698	30	2.483	40
4	1.808	30	2.735	45	3.691	60
5	2.352	40	3.691	60	4.899	80
7	2.936	50	4.718	75	6.149	100
8	3.531	60	5.665	90	7.398	120
9	4.225	70	6.552	105	8.666	140
10	4.748	80	7.538	120	9.925	160
11	5.091	90				
12	5.515	100				
13	5.957	110				

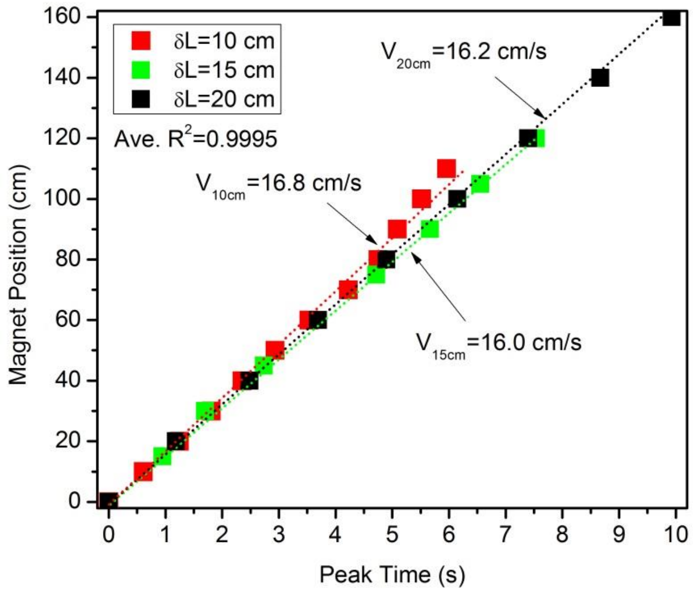

Figure 3 Peak time vs. magnet position relation, and constant speed linear fitting for magnet distance (δL) at 10cm, 15cm and 20cm

For measure speed of the dynamic car, the relation of the peak time vs. magnet position was analyzed using linear fitting (see **Eq. 2**) as shown in **Figure 3**. The dynamic car speed for magnet distance position (δL) at 10cm, 15cm and 20cm are 16.8 cm/s, 16 cm/s and 16.2 cm/s, respectively. These results show that dynamic car has a constant speed, with average R^2 is about 0.9995. A small difference in average speed results may be caused by considerable a linear track resistance, magnet position, and magnetometer sensor accuracy. We hope that this magnetometer experiment will be valuably used in general physics laboratories.

Conclusions

We have successfully studied the use of magnetometer sensors to determine the constant average speed of a dynamic car using the smartphone magnetometer sensor and the Physics Toolbox application to record the magnetic field as a function of time. We have obtained the dynamic car speed for variation magnet distance position (δL) has a constant speed. The experiments show that smartphone devices offering sufficient measurement accuracy and can be being everyday tools to measure physical quantities. distance position were analyzed using linear fitting, and get the average speed of the dynamic car.

Reference

[1] J. Kuhn and P. Vogt, "Analyzing free fall with a smartphone acceleration sensor," *The Physics Teacher*, vol. 50, March 2012.

[2] J. A. Sans, F. J. Manjón, A. L. J. Pereira, J. A. Gomez-Tejedor and J. A. Monsoriu, "Oscillations studied with the smartphone ambient light sensor," *European Journal Physics*, vol. 34, p. 1349–1354, 2013.

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[4] T. Pierratos and H. M. Polatoglou, "Study of the conservation of mechanical energy in the motion of a pendulum using a smartphone," *Physics Education*, vol. 53, p. 015021, 2018.

[5] S. Kapucu, "Finding the average speed of a light-emitting toy car with a smartphone light sensor," *Physics Education*, vol. 52, p. 045001, 2017.

[6] E. Arribas, I. Escobar, C. P. Suarez, A. Najera and A. Beléndez, "Measurement of the magnetic field of small magnets with a smartphone: a very economical laboratory practice for introductory physics courses," *European Journal of Physics*, vol. 36, p. 065002 , 2015.

[7] R. D. Septianto, D. Suhendra and F. Iskandar, "Utilisation of the magnetic sensor in a smartphone for facile magnetostatics experiment: magnetic field due to electrical," *Physics Education*, vol. 52, p. 015015, 2017.

[8] B. Setiawan, R. D. Septianto, D. Suhendra and F. Iskandar, "Measurement of 3-axis magnetic fields induced by current wires using a smartphone in magnetostatics experiments," *Physics Education*, vol. 52, p. 065011 , 2017.

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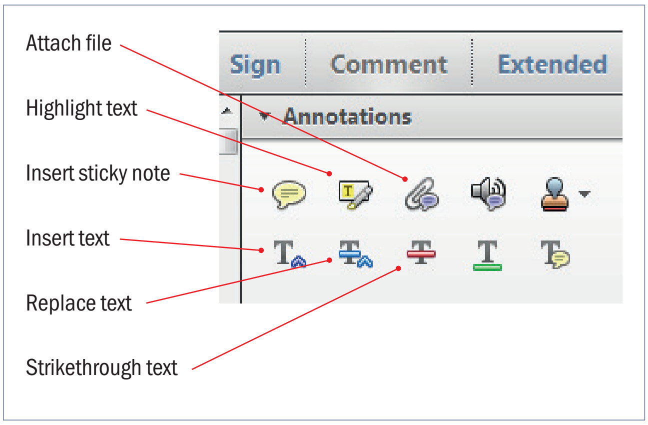

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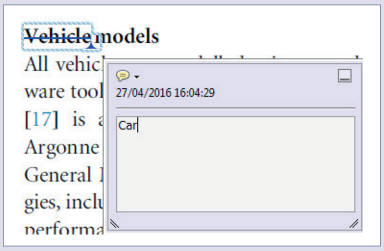

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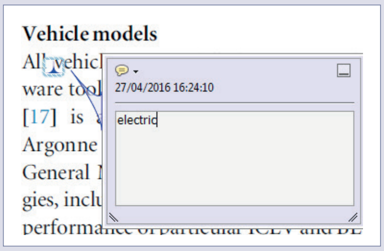

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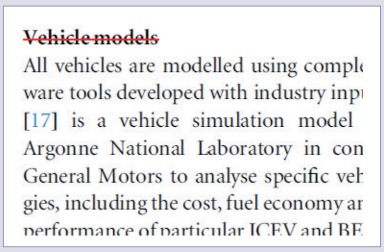

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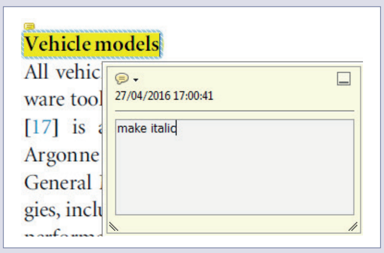

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PAPER

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Constant speed motion analysis using a smartphone magnetometer

Ade Yeti Nuryantini[1], Asti Sawitri[2] and Bebeh Wahid Nuryadin[2]

[1] Department of Physics Education, UIN Sunan Gunung Djati Bandung, Jl. A H Nasution No. 105, Bandung 40614, Indonesia

[2] Department of Physics, UIN Sunan Gunung Djati Bandung, Jl. A H Nasution No. 105, AQ1 Bandung 40614, Indonesia

E-mail: ade.yeti@uinsgd.ac.id and bebehwahid102@uinsgd.ac.id

Abstract

This study demonstrated that the constant average speed of a dynamic car could be measured and calculated using the smartphone magnetometer. The apparatus setup was built using a dynamic car, a linear track up to 1.50 m, a bunch of magnets, and a smartphone magnetometer application. The smartphone magnetometer application, 'Physics Toolbox Suite', was free for the experiment. The magnet and smartphone magnetometer were attached on a linear track and dynamic car, respectively. When the dynamic car are moving on the car track, the smartphone magnetometer will measure the magnetic field value versus the time relation. The magnetic field value will fluctuate, increasing when close to the magnet or decrease when the distance from the magnet increases. The magnetic field properties (peaks time) versus the magnet distance position were analyzed using linear fitting, and we find the average speed of the dynamic car. We hope that this magnetometer experiment will be valuably used in general physics laboratories. AQ2

Introduction

Research on smartphones sensors as a learning and experimental apparatus, especially in the physics laboratory, is exciting and still increasing [1, 2]. The sensors on common smartphones are an accelerometer, gyroscope, light sensor, and magnetic sensor. Accelerometer (and gyroscope) sensors have been widely used to analyze objects in free fall [1], rolling motion [3], free and damped oscillations, and a simple pendulum [4]. In 2017, the Kapucu group developed a method of measuring an object's velocity using a smartphone light sensor [5]. Also, magnetometer sensors have been used to measure the magnitude of the static magnetic field [6], and the magnetic field on the straight cable and the loop [7]. The use of magnetometer sensors is quite exciting and has much potential because of the high sensor precision and low interference of the external (Earth) magnetic field.

Therefore, this study reports the use of magnetometer sensors to determine the constant average speed of a dynamic car. Motion data and analysis is obtained by detecting the maximum magnetic field of the magnet placed in a row along the linear track. This research is expected to be a guide for teachers and students in conducting physics experiments using magnetometer sensors.

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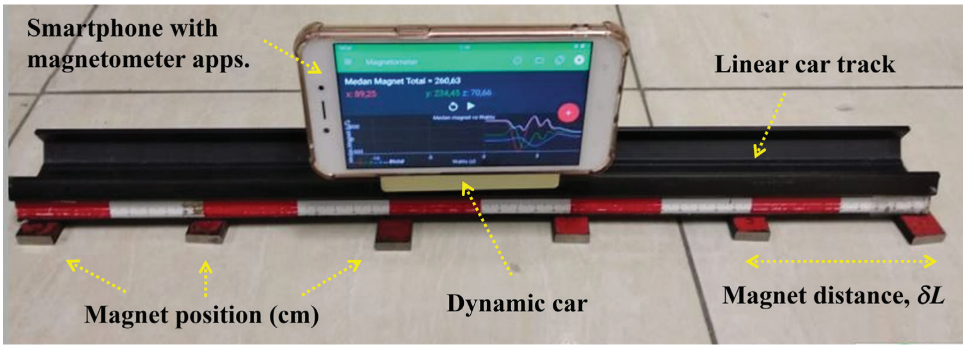

Figure 1. The schematic of the constant speed motion analysis using a smartphone magnetometer.

Experimental overview

In this study, the Android based smartphone and the Physics Toolbox app is used to measure the magnetic field strength. The magnetic field data used is the total magnetic field measured by the magnetometer sensor. The average speed of the dynamic car was calculated by [5]:

$$v_x = \frac{\Delta x}{\Delta t} \approx \frac{\mathrm{d}x}{\mathrm{d}t}, \quad (1)$$

where v_x, Δx, and Δt are the average speed, magnet position (m) and peak time span (s), respectively.

The schematic of the constant speed motion analysis using the smartphone magnetometer setup is shown in figure 1. The apparatus setup was built using a dynamic car with a constant speed, a linear car track up to 2.00 m, strong magnets of AlNiCo (Aluminum (Al), Nickel (Ni), Cobalt (Co)) alloy) with dimension $7 \times 2 \times 0.5$ cm, and a smartphone magnetometer application. The magnets were attached on a car track in a parallel position, with a distance position at 10 cm, 15 cm and 20 cm for the different experiments. The smartphone magnetometer was attached to the dynamic car and moved horizontally on the linear car track. When a car with constant speed was running on the linear car track, the smartphone magnetometer would measure the magnetic field value versus the time relation. The magnetic field value fluctuated, increasing when close to a magnet or decreasing the further from the magnet [6]. To find the magnetic field properties we analyzed the magnetic peak value and peak time of the measurement data. The magnetic peak value describes the magnet position on the linear car track. Thus, from the magnetic field data we find the relation of the peak time and magnet positions. The relation of the peak time and magnet position were analyzed using the linear fitting in using equation (1), and we find the average speed of a smartphone magnetometer of the dynamic car.

Trials and results

In the following experiment, the dynamic car and the smartphone are moved to the x-axes (1D motion analysis). The 1D motion of a dynamic car on the linear track, the smartphone starts measuring the magnetic field value (100 Hz) for different magnet distance positions at 10 cm, 15 cm and 20 cm (see figure 2). For easy analysis, the initial time of the magnetic experiment was applied (selected) at the first-peak time of the magnetic field data. The magnetic field properties (peak periods) were analyzed directly from the magnetic field, as shown in table 1. The resultant graphs show that the magnetic field value fluctuated, increasing when close to a magnet or decreasing when the distance to magnet increases [6]. The relative of the peak time span for ther magnet distance position (δL) at 10 cm, 15 cm, and 20 cm were 0.6 s, 0.9 s, and 1.2 s, respectively. The peak time span indicates that the dynamic car is moving at a constant speed at 1D motion (see equation (2)). AQ3

To measure the speed of the dynamic car, the relation of the peak time versus the magnet position was analyzed using linear fitting (see equation (2)) as shown in figure 3. The dynamic car speed for the magnet distance position (δL) at 10 cm, 15 cm and 20 cm were 16.8 cm s^{-1}, 16 cm

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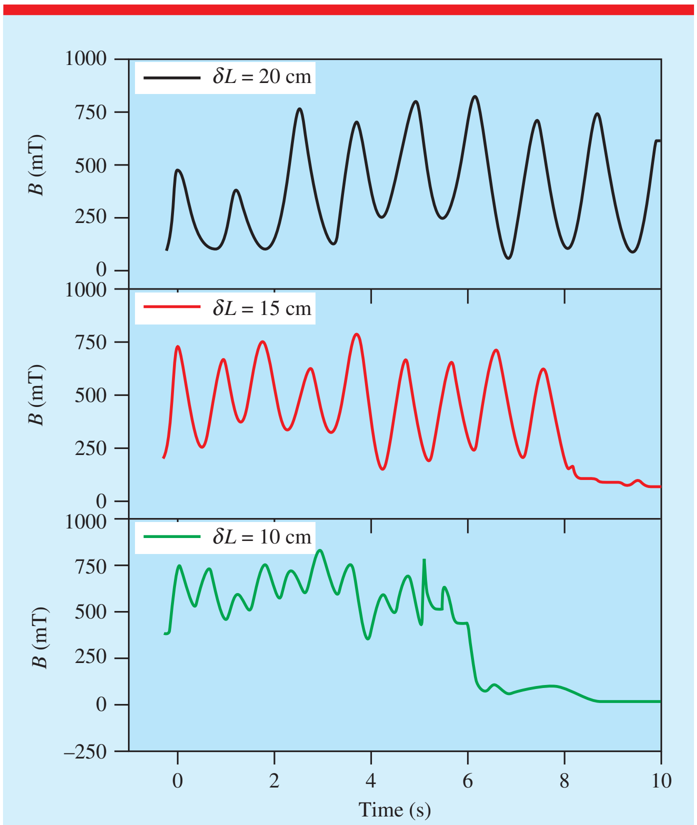

Figure 2. Magnetic field measurement using a car with constant speed and smartphone magnetometer for magnet distance position (δL) at 10 cm, 15 cm, and 20 cm.

Table 1. Magnetic field properties for magnet distance position (δL) at 10 cm, 15 cm, and 20 cm.

	$\delta L = 10$ cm		$\delta L = 15$ cm		$\delta L = 20$ cm	
Peak	Peak time (s)	Magnet position (cm)	Peak time (s)	Magnet position (cm)	Peak time (s)	Magnet position (cm)
1	0	0	0	0	0	0
2	0.610	10	0.946	15	1.184	20
3	1.246	20	1.698	30	2.483	40
4	1.808	30	2.735	45	3.691	60
5	2.352	40	3.691	60	4.899	80
7	2.936	50	4.718	75	6.149	100
8	3.531	60	5.665	90	7.398	120
9	4.225	70	6.552	105	8.666	140
10	4.748	80	7.538	120	9.925	160
11	5.091	90				
12	5.515	100				
13	5.957	110				

s^{-1} and 16.2 cm s^{-1}, respectively. These results show that dynamic car has a constant speed, with average R^2 about 0.9995. A small difference in average speed results may be caused by a considerable linear track resistance, magnet position, and magnetometer sensor accuracy. We hope that this magnetometer experiment will be used in general physics laboratories.

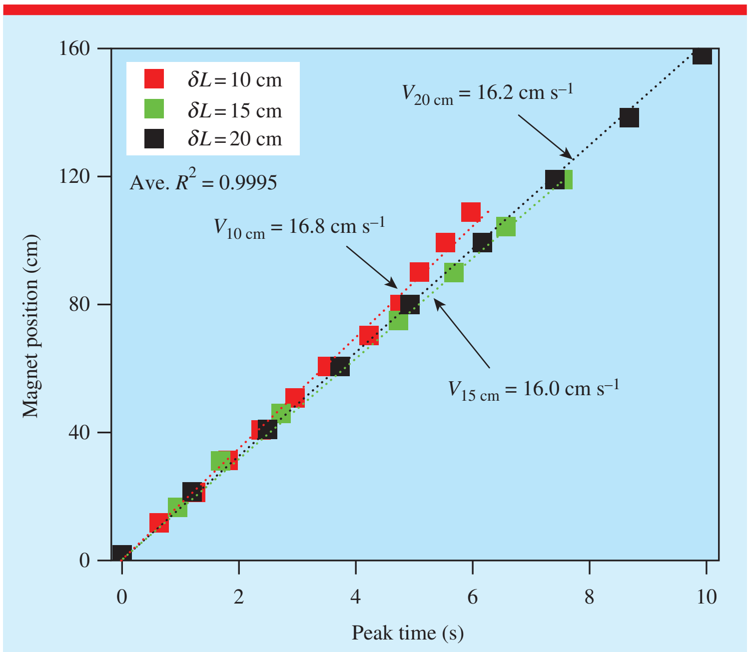

Figure 3. Peak time versus magnet position relation, and constant speed linear fitting for magnet distance (δL) at 10 cm, 15 cm and 20 cm.

Conclusions

We have successfully studied the use of magnetometer sensors to determine the constant average speed of a dynamic car using the smartphone magnetometer sensor and the Physics Toolbox application to record the magnetic field as a function of time. We have shown the dynamic car speed for various magnet distance position (δL) has a constant speed. The experiments show that smartphone devices offer sufficient measurement accuracy and can be used as everyday tools to measure physical quantities. Distance positions were analyzed using linear fitting and to find the
AQ4 average speed of the dynamic car.

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Equation (2) is cited in text but has not been provided. Please remove citation or provide details.
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$$B = \frac{\mu_0 2m}{4\pi r^3} = \left(\frac{2\mu_0 m}{4\pi}\right)\left(\frac{1}{r^3}\right) \qquad (2)$$

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