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Constant speed motion analysis using a smartphone magnetometer

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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.

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, 8]. 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.

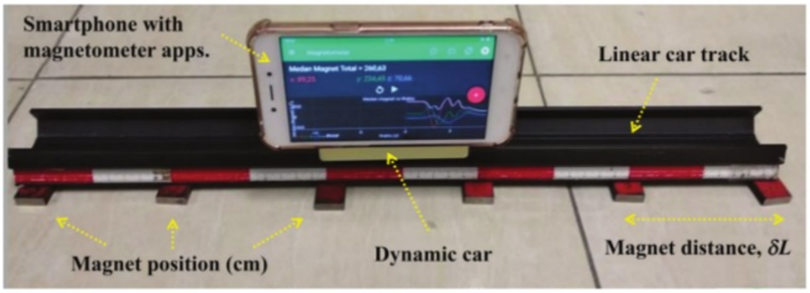

Figure 1. The schematic of the constant speed motion analysis using a smartphone magnetometer.

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]:

$$v_x = \frac{\Delta x}{\Delta t} \approx \frac{\mathrm{d}x}{\mathrm{d}t}, \tag{1}$$

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 dimensions $7 \times 2 \times 0.5$ 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 the 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.

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 (1)) 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 s^{-1} and 16.2 cm s^{-1}, respectively. These results show that dynamic car has a constant

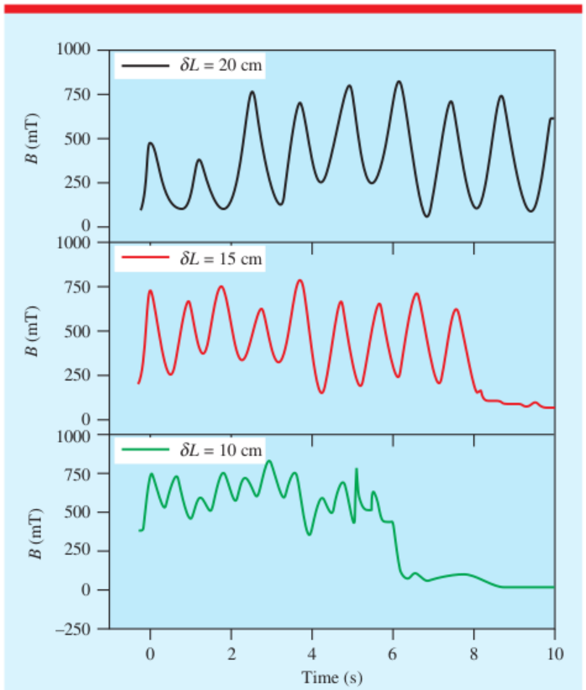

Figure 2. Magnetic field measurement using a car with constant speed and smartphone magnetometer for magnet distance position (δL) at 10 cm, 15 cm, and 20 cm.

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				

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.

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

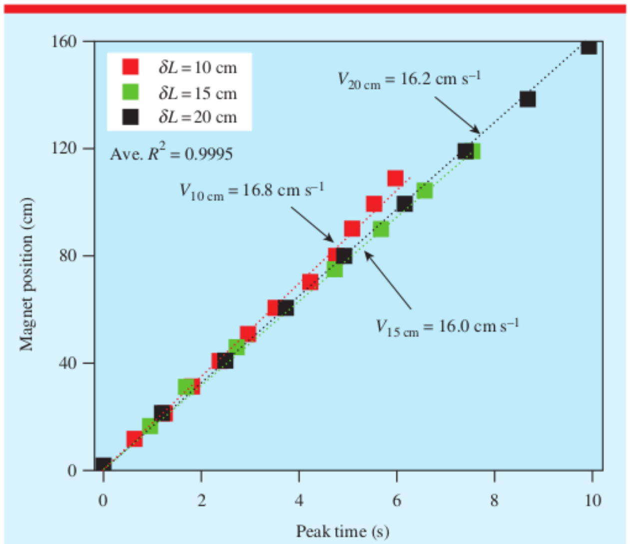

Figure 3. Peak time versus magnet position relation, and constant speed linear fitting for magnet distance (δL) at 10 cm, 15 cm and 20 cm.

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 average speed of the dynamic car.

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Ade Yeti Nuryantini has a doctoral degree in physics, specializing in nanomaterials (or nanofibers). She is associate professor in physics education at the UIN Sunan Gunung Djati Bandung, Indonesia. Her current research interests focus on synthesis and functionalization of nanomaterial (or nanofiber) and focus on using smartphones /mobile computers as experimental and simulation tools in physics education in teaching and learning in school labs and university courses. Moreover, she is trying to develop a Mobile Science Laboratory for Madrasah/School Improvement (MOSLM Lab's), especially using smartphones and open source applications.

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