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# The Utilization of Sensors on Smartphone to Determine the Coefficient of Kinetic Friction with the Inclined Plane in Supporting Physics Learning

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### *Abstract*

*This study aimed to determine the coefficient of kinetic friction with the inclined plane of some materials using sensors on smartphones that can support learning media. Determination of the kinetic friction coefficient on the inclined plane using a sensor on a smartphone by utilizing a Phyphox application connected to a PC / Laptop as remote access. The student can calculate the kinetic friction coefficient on several surfaces of objects such as wood on wood, glass on glass, and acrylic on acrylic. The acceleration value of an object when moving on an inclined plane is the basis. Also, the angle used affects the value of the kinetic friction coefficient on each material. The results of the analysis were carried out on Ms. Excel. The kinetic friction coefficient values obtained on the surface of the wooden block on wood for (0.25 ± 0.01), glass block on glass for (0.36 ± 0.03), and acrylic block on acrylic for (0.38 ± 0.01). The use of smartphones as sensors to identify physical quantities is very supportive in learning, especially experimental activities. An in-depth understanding of the theory is certainly supported by real evidence to make learning more meaningful.*

***Keywords:*** *smartphone sensor, kinetic friction coefficient, inclined plane, physics learning*

## 1. Introduction

Learning activities related to science education, particularly physics, have encountered particular challenges in complicated teaching materials. The development of more sophisticated technology can be a new, better breakthrough and utilized to implement methods and approaches in teaching physics to be more efficient [1]. Physics learning requires exactly concept delivering and real evidence that supports the concept. Experimental activities carried out can give meaningful learning experiences for students. Furthermore, direct experiences in experimental activities are expected to strengthen the concept given by the teacher [2]. Several kinds of research explain the weakness of conventional learning, such as weakness in knowledge, skills, competency, and learning outcomes. Students have no chance to actively participate in the learning process, except the teacher asks them to finish tasks or give questions. The knowledge presented by the teacher usually could not be opposed, and students should accept it [3].

Applying creative and innovative learning is necessary if teaching and learning activities focus on the process, particularly the scientific process skills of students in learning [4]. However, one of the problems in the experimental activities in the physics laboratory is the slow data collection method [5]. The utilization of technology in the experimental activities in the laboratories can shorten the time duration for data collection and graphical representation [6][7]. It turns out that teachers and students at school have technology such as smartphones with sensors. This sensor feature can help them in measuring physical scales required for learning in the classroom or laboratories [8].

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The force of friction is an essential element in motion dynamics. It is essential to teach this topic in physics learning [9]. However, explaining the forces requires exact approaches [10], and students find it challenging to understand the force of friction and related phenomena [11]. Previous research discussed the difficulties faced by students in understanding the force of friction between solid objects.

The force of friction is known as the opposite movement of a solid object towards another solid object [10. The force of friction has a value called the coefficient of friction. There are two different friction coefficients, which are static and kinetic. The static friction coefficient can be determined when an object will move or before moving. In contrast, the kinetic friction coefficient can be determined when the object has moved. The coefficient of friction can be determined with various methods and techniques in the experiment [12]. Determining the coefficient of friction can be done through electrical resistance measurement [13]. Besides, determining the static friction coefficient can be done through the circular motion on the object [14]. The presentation of a simple experiment with computers to find out the law on the friction coefficient determination is also done by examining the dependency probability of the friction coefficient on the various parameters such as types of materials of the object, normal force, the area of the object contacted with friction plane and the  [15]. According to the number of research, the effect of acceleration on the constant force when the sliding object can be used to calculate the kinetic friction coefficient. By using more accurate experimental tools such as technology-based motion sensors, students can measure motion on an object for quite a short time interval [16]. In this research, the smartphone sensor is optimally utilized in physics learning to determine the kinetic friction coefficient on the inclined plane. The plane materials were varied and are easy to be used and to be found, such as wood, glass, and acrylic.

## 2. Materials and Methods

This research carried out an experiment on determining the kinetic friction coefficient of an object on an inclined plane by using sensors on a smartphone. The tools used in this research were an inclined plane, smartphone, PC/laptop, wooden, glass, and acrylic blocks, as shown in Figure 1.

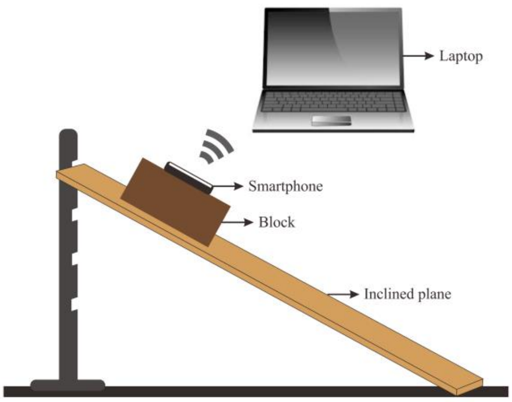


**Figure 1. The Design of the Experiment**

Angles used on the inclined plane that was 32$^{o}$. The sliding block can identify the speed scale so that it can be measured through the motion sensor. Then the speed is plotted as the function of time [16]. However, the amount of acceleration of block that sliding on the inclined plane can be identified and measured through the motion sensor.

Smartphones as media provide motion sensors to detect physical scale on an object. Smartphones require applications as presenters of data sensors. Therefore, to obtain data in this research, it needs to install the Phyphox application from Google Play Store for Android users. The acceleration measurements consist of three sensors divided into three dimensions on smartphones. These sensors are placed orthogonally each other, and the dimensions determined are acceleration on the x-axis acceleration on the y-axis and acceleration on the z-axis [17]. Figure 2 shows the sensor configuration on smartphones.

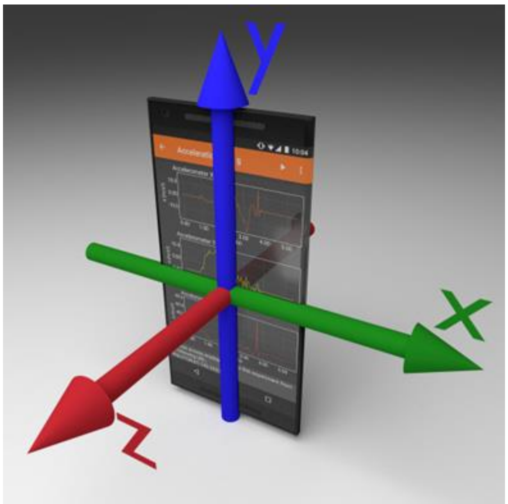


**Figure 2. Smartphone Configuration**

On figure 2, the x-axis points to the right when holding the device in the standard smartphone position. The position means when the screen is on the portrait (vertical) orientation. The y-axis points to the upright direction and is along with the standard smartphone position. The z-axis points to the perpendicular direction towards the screen.

The Phyphox application provides IP address to connect with PC/laptop so remote access can be activated through the same network between smartphones and PC/laptop. The smartphone that is connected to the PC/Laptop is then placed on the block to slide. Next, the user is set through the feature available on the Phyphox application. The sensor feature used on the Phyphox application is acceleration with g. This sensor detects the acceleration of a moving block. The first block is a wooden block. The second is glass, and the third is acrylic, while the inclined plane is adjusted to the sliding block. In this research, the interactions are between wood with wood, wood with glass, and wood with acrylic. PC/Laptop as remote access can easily be used to give the command to start or stop the sensor in detecting acceleration on the block.

The block is set on an inclined plane so the block can continuously slide with changing speed. The angle used must be broad enough, so the gravity along the inclined plane surface is more significant than the kinetic friction force to upright along the inclined plane. Therefore, the total force equation on the block is,

$$F = w \sin\theta - f_k \tag{1}$$

with kinetic friction force

$$f_k = \mu_k N = \mu_k w \cos\theta \quad (2)$$

Through the second Newton law, the object acceleration can be obtained [18]

$$a = \frac{F}{m} \quad (3)$$

So, on the inclined plane, the kinetic friction coefficient of the object can be obtained,

$$\mu_k = \tan\theta - \frac{a}{g\cos\theta} \quad (4)$$

where θ is the angle used on the inclined plane [16].

When the block is sliding on the inclined plane, the PC/Laptop is set to record acceleration data on the moving block. Then, after the block stopped, the PC/Laptop is also set to stop the data recording. On the available features on PC/Laptop, acceleration data as a function of time obtained is then exported to a spreadsheet application such as Ms. Excel to be analyzed [17]. Data obtained on Ms. Excel covers block acceleration data on the x-axis, block acceleration on the y-axis, and block acceleration on the z-axis. However, this research only used the block acceleration on the x-axis because the position of the smartphone when sliding with the block is horizontal. Therefore, only the direction of the x-axis that follows the direction of the block when sliding on the inclined plane.

The method used was a linear weighted equation with five-time data collection, then finding the average of the block acceleration. After obtaining the block acceleration, the kinetic friction coefficient can be calculated by using equation (4). The difference of the value of the kinetic friction coefficient can be determined on each block interaction of wood with wood, glass with glass, acrylic with acrylic. Table 1 explains the friction coefficient on the various materials.

**Table 1. Friction Coefficient**

| Surface | $\mu_s$ | $\mu_k$ |
|---|---|---|
| Steel with steel | 0,74 | 0,57 |
| Aluminium with steel | 0,61 | 0,47 |
| Copper with steel | 0,53 | 0,36 |
| Rubber with concrete | 1,0 | 0,8 |
| Wood with wood | 0,25-0,5 | 0,2 |
| Glass with glass | 0,94 | 0,4 |
| Waxy wood with wet snow | 0,14 | 0,1 |
| Waxy wood with dry snow | - | 0,04 |
| Metal with metal (lubricated) | 0,15 | 0,06 |
| Ice to ice | 0,1 | 0,03 |
| Teflon with Teflon | 0,04 | 0,04 |
| Synovial joints with human beings | 0,01 | 0,003 |

## 3. Results and Discussion

Sensor Acceleration with g has identified the block acceleration sliding on the inclined plane. Figure 3 shows the result of the acceleration graph towards the function of time. The result of the graph is one example of the result of data collection with wooden materials.

Sensor acceleration on smartphones is a microsystem that processes information mechanically and electrically, which is called micro-electro-mechanical systems (MEMS). Therefore, figure 3 shows the difference in the graph on each x-axis, y-axis, and z-axis. Accelerometer x explains the graph of acceleration on the x-axis towards time. Accelerometer y explains the graph of acceleration on the y-axis towards time.

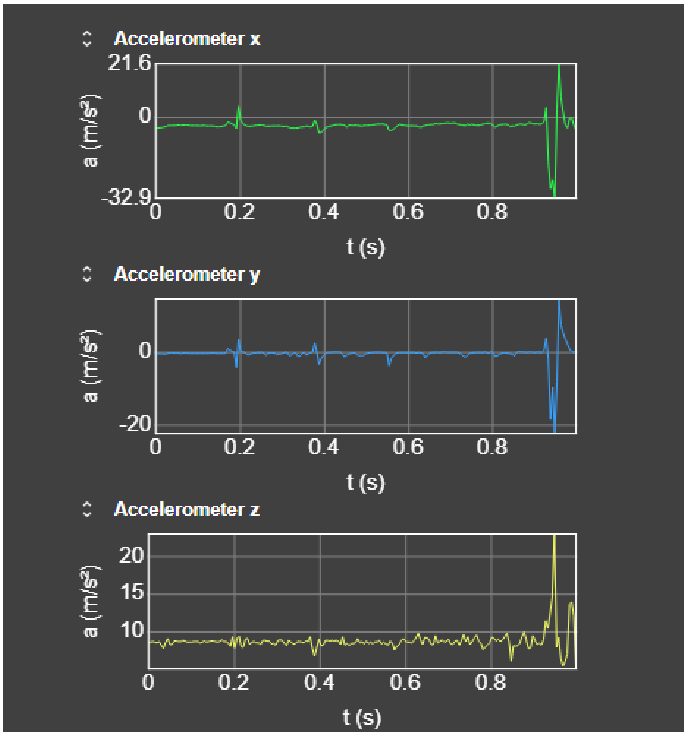


**Figure 3. The Graph of Acceleration Towards Time Obtained from Phyphox Application**

Since the position of the smartphone when sliding with the block is in the horizontal position, only the x-axis that follows the direction of the block movement when sliding on the inclined plane. Figure 4 shows the function of acceleration on the x-axis ($a_x$) towards time on each material. It shows the recoil acceleration. It happens on almost all graphs. Especially the graph showing material wood with wood and acrylic with acrylic has acceleration values are fluctuating. Starting from an early time, then the acceleration value suddenly increases significantly. In the research conducted before, the graphs of speed towards time and acceleration towards time explain the effects of the recoil acceleration. The first second shows the significant increase of acceleration value when releasing the block on the inclined plane. Based on the early review, the recoil acceleration appears to release a more significant static friction coefficient. This phenomenon can be analogized as a rope that starts to bluff during the tug of war race. So far, based on the literature, the effects are related to the pre-sliding displacement phenomenon [16]. Pre-sliding displacement can cause a difference in friction coefficient value [18]. This reason is why phenomenological approaches are considerably used to explain the friction phenomena [9].

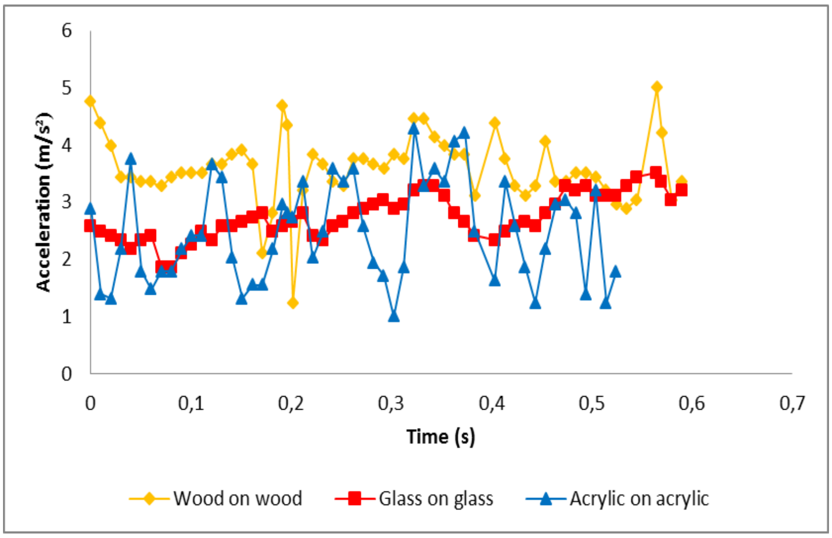


**Figure 4. The Graph of Acceleration towards time on Various Materials**

Data of acceleration towards time in Figure 4 explains different speeds. It shows that the friction coefficient depends on the speed [15]. Through the speed change, acceleration can be identified. Therefore, it becomes interesting to learn and discuss with students the aspects affecting the friction coefficient on an object.

The calculation result of acceleration on the block is done by taking the average of data exported to Ms. Excel. Besides, the angle measurement on the inclined plane is 32°. Based on data of average acceleration, the kinetic friction coefficient can be obtained by using equation (4) as shown in Table 2.

**Table 2. Friction Coefficient on the Inclined Plane**

| Surfaces | $\mu_k$ | $\delta\mu_k$ |
|---|---|---|
| Wood on Wood | 0,25 | 0,01 |
| Glass on Glass | 0,36 | 0,03 |
| Acrylic on Acrylic | 0,38 | 0,01 |

Based on Table 2, the result data of the kinetic friction coefficient can be compared to previous research. Wood on the wood surface has a kinetic friction coefficient of 0.2, glass on glass has 0.4 [19][20]. Compared to the result in table 1, the value of the kinetic friction coefficient of the wooden surface on wood is (0,25 ± 0,01); glass on glass is (0,36 ± 0,03). There is a slight difference between the kinetic friction coefficient and that of previous research. It occurred because of the use of different types of materials of wood and glass. The use of acrylic in this research has a kinetic friction coefficient value of (0,38 ± 0,01). The use of various materials that are easily found can ease learning the experimental activities particularly. Besides, smartphones as the facilities in collecting data can be directly used without any complicated stages.

The use of sensors on smartphones can be a reference for learning media, particularly in the experimental activities in the classroom. In this research, the kinetic friction coefficient between two surfaces can be determined through the acceleration sensor by utilizing the Phyphox application. It is simple, and the devices can be easily found. This experiment is immensely practical, so the teacher and students can carry it out in the classroom without requiring a laboratory [21]. Besides, several materials can be easily found and used to determine the kinetic friction coefficient of those materials.

Data that can be quickly obtained and directly analyzed makes the time for learning becomes efficient. Besides, the data result that is raw data is felicitous for students to teach data reading and analysis [22].

The smartphone-based experiment can motivate students so that students can explore learning materials with their own devices. The exploration activities can help students to build and develop self-knowledge [23]. Learning through experiments can also support students to think scientifically into the learning process that is strong, innovative, and logical between concepts and phenomena [24]. Furthermore, students can develop their skills in the scientific process in exploring every stage of the experimental activities. Therefore, with well-designed activities, students can find out the concept based on the phenomenon they found [25]. The skills of the scientific process also function to improve the students' participation in learning and develop students' curiosity [26].

## 4. Conclusions

The utilization of sensors on smartphones with the Phyphox application is effective for learning, particularly for experimental and demonstrative activities in the classroom. It is helpful when learning has limited time, but this kind of experimental activities can save time. Besides, this learning also gives opportunities for students to be active and directly participate in understanding materials and proving it with real evidence. Through the block acceleration value obtained on the inclined plane by using various materials, the kinetic friction coefficient on each material can be determined. The kinetic friction coefficient on the block interaction of wooden surface on wood is (0,25 ± 0,01), glass on glass is (0,36 ± 0,03) and acrylic on acrylic is (0,38 ± 0,01).

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