Development of Static and Kinetic Friction Coefficient Experiment Device Based on Arduino Uno

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Abstract. The concept of friction makes physics more realistic. Based on research, physics education students are still experiencing misconceptions or do not understand the concept of the friction coefficient. Experimental tools commonly used in practicum have not been able to measure the coefficient of friction properly. The purpose of this research is to design a static and kinetic friction coefficient experiment that can be used in basic physics practicum. This study uses the ADDIE model which is carried out to the stage of develop or media development. The experiment was developed using the principle of sliding beams in an inclined plane by using an Arduino Uno microcontroller and sensors as a time and angle measurement device. The experiments designed to observe the effect of differences in mass and surface roughness on the friction coefficient. this device can measure the value of \( \mu_s \) and \( \mu_k \) simultaneously. The time measurement precision value of the tool is 93% and the angle measurement precision is 98.0%. The experiment succeeded in proving that \( \mu_s > \mu_k \), surface roughness affects the value of the coefficient of friction and the mass does not affect the value of the coefficient of friction.

1. Introduction
Science education in 21st century is oriented to the develop strategies and solutions to answer various problems that occur in everyday life [1]. Friction is a phenomenon that can not be separated from human daily activities. The coefficient of friction between two solid objects is an important coefficient in physics learning about the dynamics of motion of objects. Studying the concept of friction in physics minimizes the notion that physics is abstract and does not match reality [2]. Research shows that there are still a lot of misunderstanding and even misconceptions among physics education students about the concept of friction [3][4]. This finding needs attention because physics education students are prospective teachers who will teach at school. Therefore, physics education students must have a good understanding of concepts.

Physics learning, like other science learning, requires proof and physical understanding [5]. The physics curriculum covers natural phenomena, and uses a process consisting of observation, measurement, analysis, and conclusions [6]. Therefore, one effective method for learning physics is to use practicum methods. Therefore, the problem of understanding this concept can be overcome by applying practical learning [3][4][7]. The use of instructional media in practical learning makes physics concepts more easily for students to understand [8][9].

The experimental procedure most often used in measuring friction coefficients is using a pulley system, spring balance and inclined plane. Although experiments using the pulley system and spring balance can be used to calculate the friction coefficient, the precision and accuracy of these measurements are still very low [10]. These limitations can make it difficult for students to understand...
concepts correctly [11]. The minimum equipment needed to be able to measure the coefficient of friction correctly is the inclined plane, a stopwatch and a protractor [10].

The development of the friction coefficient experiment device in this study was designed using the method of launching the test beam on an incline. This method is the simplest method and has the best measurement [10]. This experimental device is designed to obtain the two minimum data needed to calculate the coefficient of static and kinetic friction, the angle and time. The work of this device is controlled by an Arduino Uno microcontroller. Gliding time measuring is done using a time sensor that is photodiode and laser diode. While the slope of the sliding plane will be read by the angle tilt sensor, the MPU6050 sensor.

2. Methodology

This study uses the ADDIE model. The ADDIE stages that will be carried out in this research are the Analyze, Design and Develop stages. Based on the results of the analysis it was found that the development of friction coefficient practicum tools was needed to overcome student misconceptions. The design of the device consists of electronic circuit design and tool frame. The electronic circuit design needed for the device is shown in Figure 1.

![Figure 1. Schematic design of an electronic device circuit](image1)

The main components of this tool are Arduino Uno, photodiode sensor and laser diode and MPU6050 sensor. The dc motor is used to rotate the inclined plane automatically whose movement is regulated by pressing the up / down button. The measurement results of the device will be displayed on the LCD in the form of an angle and time value. Figure 2 is the design of the experimental tool frame.

![Figure 2. The design of the experimental tool frame.](image2)
The device is designed to start operating when the up button is pressed. The motor will spin and lift the beam's track board. When the board rises until it reaches a certain slope, the beam will start sliding down the board from its rest position. When the beam starts moving and passes laser 1, the motor rotation will stop and the gliding time calculation starts. The tilt sensor measures the inclination of the plane when the beam is sliding. Recording time stops when the beam passes through the laser 2. Output will be displayed via the LCD in the form of time and tilt angle. After completing data retrieval, the board can be lowered back to its original position by pressing the down button.

3. Result and Discussion

Experimental device was built based on a design that had been made before. Figure 3 is a display of the friction coefficient experiment device.

![Figure 3. The friction coefficient experiment device.](image)

Experiment device that has been completed is then programmed in accordance with the desired work function. After the device is finished, a functioning test is performed. This test serves to determine whether the device is able to find the concept of the friction coefficient in accordance with the theory. This functionality test aims to calculate the level of precision of time and angle measurements on the experiment device. There are 2 types of experiments that are designed on this tool. The first experiment aims to compare the values of the static and kinetic coefficient of friction on the beam with smooth, medium and rough surfaces. The second experiment aims to compare the values of the static and kinetic coefficient of friction on similar beams with different masses. Table 1 is the result of measurement and calculation of the precision value and the coefficient of friction value of each block in the first experiment.

| beam type          | Distance (m) | Average of time measurement (s) | Precision of time measurement (%) | Average of angle measurement (°) | Precision of angle measurement (%) | The average value of the coefficient of friction $\mu_s$, $\mu_k$ |
|--------------------|--------------|---------------------------------|-----------------------------------|----------------------------------|-----------------------------------|------------------------------------------|
| 150 gram (rough/sand paper) | 0.394        | 1.012                           | 98%                               | 33.362                           | 99%                               | 0.658, 0.562                             |
| 150 gram (medium/plywood)    | 0.394        | 0.634                           | 92%                               | 27.270                           | 97%                               | 0.516, 0.293                             |
| 150 gram                 | 0.394        | 0.632                           | 91%                               | 25.390                           | 99%                               | 0.474, 0.251                             |
Based on the data obtained it can be concluded that the more rough the surface of objects, the time of the object gliding the incline plane will be slower, the friction angle and the coefficient of friction between surfaces will be even greater. From these experiments also proved that the value of the static friction coefficient of the object is greater than the value of the kinetic friction coefficient of the object. Next, the results of the second experiment are shown in Table 2.

### Table 2. Measurement results and calculations of the second experiment.

| beam type           | Distance (m) | Average of time measurement (s) | Precision of time measurement | Average of angle measurement (°) | Precision of angle measurement | The average value of the coefficient of friction |
|---------------------|--------------|--------------------------------|-------------------------------|---------------------------------|--------------------------------|-----------------------------------------------|
| 200 gram (plywood)  | 0.394        | 0.676                          | 93%                           | 27,990                          | 98%                            | 0.531                                         |
| 150 gram (plywood)  | 0.394        | 0.634                          | 92%                           | 27,270                          | 97%                            | 0.516                                         |
| 100 gram (plywood)  | 0.394        | 0.652                          | 91%                           | 29,032                          | 98%                            | 0.555                                         |
| Average             |              | 93%                            | 98%                           |                                 |                                |                                               |

The average precision of time measurement is 93% and the average angle measurement precision is 98%. Based on the experimental data in Table 2, the results show that mass variation does not affect the value of the static and kinetic friction coefficient between surfaces.

### 4. Result and Discussion

This experiment tool succeeded in measuring the value of the static and kinetic friction coefficient of objects. Through this tool it can also be proven that surface roughness influences the value of the coefficient of friction, whereas mass does not affect the value of the coefficient of friction.

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