e-ISSN: 2549-8258
p-ISSN:2721-2718

VIDEO TRACKING BASED GRAVITY ACCELERATION ANALYSIS ON PENDULUM SWING

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ABSTRACT

This study aims to determine the acceleration of gravity on the pendulum swing with video tracking method. The research was conducted through video on a simple pendulum swing experiment. The recorded video is imported into the Tracker app to get the period and frequency for each trial with different rope lengths. The rope length and mass data were measured manually, and the period and frequency data were obtained through video tracking analysis. The research results are shown in tables and graphs. Data analysis used a linear regression equation between the square of the period and the length of the pendulum. The magnitude of the acceleration due to gravity is obtained through the gradient of the quadratic equation and the length of the rope. The results show that the acceleration of gravity through video tracking analysis is 9.735 m/s² .

Keywords: pendulum swing, video tracking, acceletiation of gravity

INTRODUCTION

Physics has a very important role in human life because various events or daily events involve physics concepts both consciously and unconsciously. The development of technology today is because many have succeeded in applying basic science, especially physics, into various technologies such as analyzing the acceleration of gravity on pendulum swings using tracker applications. So as to facilitate the implementation of contextual physics learning, because contextual media will study real physics events in everyday life. One of them is the incident on the pendulum swing. A pendulum is an object that is tied to a rope and can swing freely and repeatedly. (Tirtasari et al., 2015).

Physics concepts are always related to natural order. Many relationships between concepts in physics are related to the acceleration of the Earth's gravity. The acceleration of the Earth's gravity has been observed since the time of Galileo-Galilei (Tate, 1968). The value of gravitational acceleration on the earth's surface varies due to differences in force, the earth is not round, the position on the earth's surface and also the density of the earth's surface (Artawan, 2013). (Artawan, 2013). The magnitude of the acceleration of gravity has been widely stated that the magnitude of 9.8 m / s ^{2}(Brown, n.d.); (Walker et al., 2014).

Physics concepts related to gravitational acceleration are free fall motion (Walker et al., 2014), parabolic motion (*motion in a parabola*) (Benenson et al., 2000), *mathematical pendulum* swing (Benenson et al., 2000) (Benenson et al., 2000).

In the theory of free fall motion for the gravitational acceleration equation $F = G\frac{Mm}{R^2}$ so $g = G\frac{M}{R^2}$. With F is the force of gravity (N), G is the gravitational constant, m is the mass being tested (which produces the gravitational force), M is the mass of the earth, R is the distance of the point to the center of the earth, and g is the acceleration of gravity. (Nurhayati, Reski Dewi Ayu A, 2021). In the theory of inclined plane, if the forces in the inclined plane are decomposed into x and y components, the equation is obtained. $w \sin\theta - F_g = m.a$. in this case, $\sum F_y = 0$, F_g ignored (smooth surface) and w is the weight of the object, so the equation becomes $a = g\sin\theta$(Astuti, 2016).

Research on the magnitude of g *is* done by determining the distance traveled by an object as long as the object moves t seconds from the starting place using the concept of free fall motion. (Ristiawan, 2018). The results of previous studies in determining the acceleration of gravity there are various ways such as in research (Artawan, 2013), where in his research the value of gravitational acceleration in each place is different. At the Equator the acceleration of gravity is about 9.78 m/s^2 , while in the polar region 9.83 m/s^2 . In addition, there is also research (Nurhayati, Reski Dewi Ayu A, 2021)The value of gravitational acceleration depends on the altitude position of a place. In his research through experiments, the value of gravitational acceleration is 9.831302275 m/s^2 . In experiments that have been carried out by (Agustina & Astuti, 2018) on a *Microcomputer-based* inclined plane, the value of the acceleration of gravity is 9.895 m/s . ^{2}

In this study, the methods used to investigate the local acceleration of gravity in Chumphon province, latitude 10° 24' 0" N and longitude 99° 4' 0" E, are by free fall motion, simple pendulum, physical pendulum and atwood force. In Thailand, the earth's gravitational acceleration (g) was measured near Songkhla province, southern Thailand by the National Institute of Metrology at 9.78120 m/s 2 (Suwanpayak et al., 2018)..

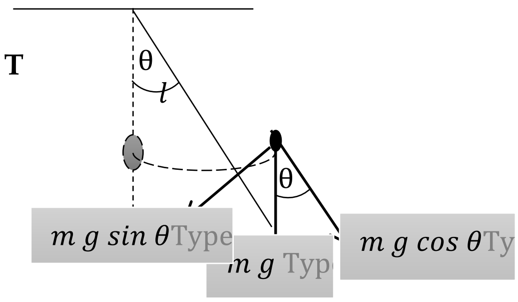
The acceleration of gravity in theory and for the free fall motion of objects obtained an average acceleration of (9.63 ± 0.33) m / s2 (Ristiawan, 2018).

Gravity is the relationship between mass objects in the form of attractive forces, the magnitude of the gravitational force is influenced by the mass of the object and its distance, the relationship between the two is the multiplication of the two masses is directly proportional while the distance is inversely proportional to the magnitude of the gravitational force. (Setyadin et al., 2016).

Changes in gravity can also calculate the period of the pendulum swing event using Newton's gravity equation. The pendulum swing event is closely related to gravity, where objects will move from one side to the other due to the gravitational pull of the earth. In addition, the longer the pendulum swing movement, the slower the swing because of the dampening force (air resistance).

Judging from the facts that exist and are often found in the world of education, in measuring pendulum swings, a lot is still done manually both by students and exemplified by the teacher. So that students feel bored to learn because the graph drawn is less interesting and the work process is long. However, measuring manually will be better understood and remembered because the way to do it is sequential.

With the tracker application, students' interest in learning increases because it is easy to measure without having to calculate manually and the results are easier to read and the measurement process is fast. However, the tracker application also has weaknesses in measuring because when we do the swing experiment it must be clear, use a good camera and try not to shake the camera so that the resulting video will be read clearly by the tracker. (Iii & Soepomo, 2013).



Pendulum swing

An object is suspended at a fixed point by a rope that is considered massless, then the rope is deviated by an angle $\boldsymbol{\theta}$ to the vertical line then the recovering force is (Chusni, 2017):

$$\boldsymbol{F_t = m.a_t}$$

$$\boldsymbol{m.g\ sin\ \theta = m\frac{d^2\ S}{dt^2}} \quad \text{......... press. (1)}$$

For angles $\boldsymbol{\theta}$ negative sign indicates the direction of the force is recovered opposite to the angle of deviation $\boldsymbol{\theta}$ which is small, so sin $\boldsymbol{\theta = S = L.\theta,}$ where S is the arc of the object's trajectory and L is the length of the string. The pendulum is pulled and then released from its equilibrium point by giving a small angle of deviation. $\boldsymbol{\theta}$ a small angle of deviation.

$$F = -\frac{mg}{L}S \quad \text{press. (2)}$$

If the friction force against the air and the twisting force on the rope are ignored, equation (1) becomes:

$$\boldsymbol{\frac{d^2\ S}{dt^2} = -g\ sin\ \theta}$$

$$\boldsymbol{\frac{d^2\ (L.\theta)}{dt^2} = -g\ sin\ \theta}$$

$$\boldsymbol{L\frac{d^2.\theta}{dt^2} = -g\ sin\ \theta}$$

$$\boldsymbol{\frac{d^2\ .\theta}{dt^2} = -\frac{g}{L}\ \theta}$$

$$\boldsymbol{\theta = \theta_{max}.\omega t}$$

$$\boldsymbol{\frac{d^2.\theta}{dt^2} = -\omega^2\ \theta = -\frac{g}{L}\theta}$$

$$\boldsymbol{\omega^2 = \frac{g}{L}} \quad \text{Press. (3)}$$

Substitute $\boldsymbol{\omega = 2\pi f,}$ then obtained:

$$\boldsymbol{(2\pi f)^2 = \frac{g}{L}}$$

$$\boldsymbol{g = 4\pi^2 f^2 L}$$

$$\boldsymbol{g = 4\pi^2 \left(\frac{1}{T}\right)^2 .L}$$

$$\boldsymbol{g = 4\pi^2 \frac{1}{T^2}.L}$$

$T^2 = \frac{4\pi^2}{g} L$ Press. (4)

From equation (4), the equation for gravitational acceleration becomes:

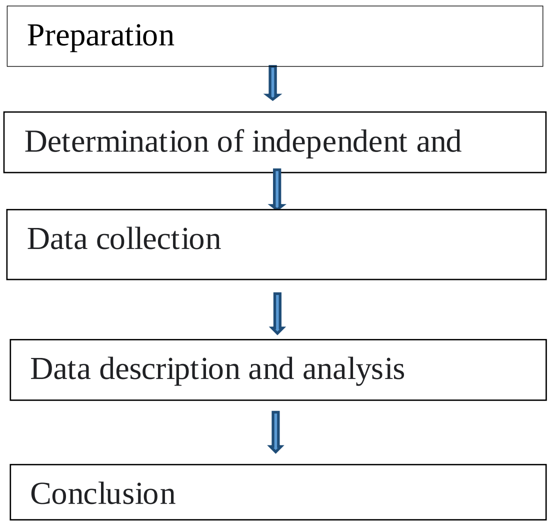
$g = \frac{4\pi^2 L}{T^2}$ Press. (5)

The purpose of this research is to determine the acceleration of gravity with the video tracking method.

METHODS

The research method used in this practicum is the experimental method. This practicum is carried out to analyze the acceleration of gravity based on video tracking on pendulum swings by utilizing the tracker application. The experiment was recorded using a smartphone and then analyzed the video using the tracker application to see the pendulum movement. (Erdamansyah, 2013). This practicum was conducted at the Physics Laboratory of the University of Flores. Experimental research includes preparation, determination of independent variables and dependent variables, data collection, analysis and conclusion. (Khoirina et al., 2018).. The following is a picture of the experimental research structure.

Figure 2: Research structure chart



In the preparation stage, the things that are prepared are a rope with a length of 160 cm, a laptop that has installed the tracker application, a ruler, a stative, a longitude, a load, a tripot, and a camera. In the second stage is to determine the independent variable and the dependent variable. The independent variable is the length of the rope hanging from the end of the stative, while the dependent variable is the period, time, and position. In the third stage is collecting data. In data collection, the rope is hung on the end of the stative and hung with a load, then measure the length of the rope from various lengths in each experiment. Next, make a video recording using a smartphone camera when the hanging load is pulled and measure the deviation by 10^0 , then released. The camera is turned off after the swing rotates 10 times and then enter it into the laptop.

The next step is data description and analysis. Enter the recorded video during data collection into the tracker application, calibration stick, then coordinate the axes test, point mass, auto tracker, copy data to excel, plot time and x position, then calculate the acceleration of earth's gravity. Finally, draw conclusions based on the data.

RESULT & DISCUSSION

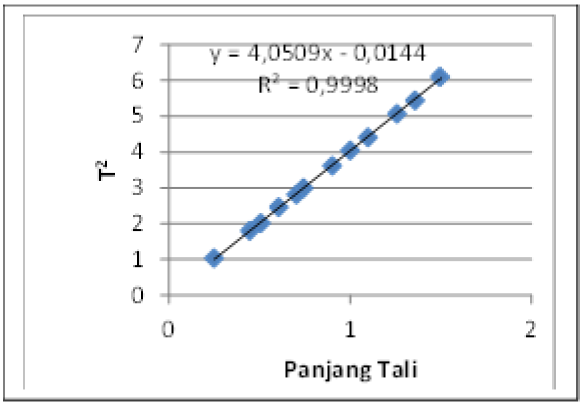
Analysis of gravitational acceleration using video tracking on a pendulum swing, with the help of *tracker software*. This analysis is done to facilitate the calculation of the acceleration of gravity on the pendulum swing.

Table 1. Experimental Data and Results

No.	L	T	T*T	g
1	0,25	1,013	1,026	9,608
2	0,45	1,339	1,793	9,899
3	0,50	1,418	2,011	9,807
4	0,60	1,566	2,452	9,649
5	0,70	1,676	2,809	9,828
6	0,75	1,730	2,993	9,883
7	0,90	1,902	3,618	9,812
8	1,00	2,010	4,040	9,762
9	1,10	2,099	4,406	9,847
10	1,25	2,251	5,067	9,729
11	1,35	2,333	5,443	9,782
12	1,50	2,469	6,096	9,704

The relationship between the length of the rope (L) and the period squared (T^2) can be seen in the following graph.

Figure 3: Graph of Relationship between Rope Length and Squared Period



Based on the graph of the relationship between the length of the rope (L) and the period squared (T^2) above, the gradient or a value of 4.0509 is obtained. Showing equation (4) where $\boldsymbol{T^2} = \frac{\boldsymbol{4\pi^2.L}}{\boldsymbol{g}}$, equivalent to $y = ax + b$, where $a = \frac{4\pi^2}{g}$, so that $g = \frac{4\pi^2}{a} = 9{,}735\ {}^{m}/_{s}{}^{2}$.

e-ISSN: 2549-8258
p-ISSN:2721-2718

Gravitational acceleration is affected by the length of the rope and the period, so the acceleration of each region is almost the same. With the efforts to conduct experiments to determine the acceleration of Earth's gravity, some are done manually and using digital with the help of computers. (Yanti et al., 2020).

With this tracking, it can facilitate the analysis of gravitational acceleration on pendulum swings. In this tracking display is very interesting can make users, especially students who become more comfortable and not impressed the same. Tracking can be used as a learning medium and as a tool to analyze the acceleration of gravity on a pendulum swing without having to calculate manually.

The use of this treacker produces more accurate data, namely (9.8 m/s^2). It does not take a long time to analyze it compared to manual experiments. By using this device, one of the new innovations in physics experiments so that it can facilitate students or students in carrying out practicum does not require a long time. (Agustina & Astuti, 2018).

CONCLUSION

The practicum results show that the value of gravitational acceleration calculated based on the data is 9.735 m/s^2 . With the mass of the object ignored and the angle of deviation 10^0 . So it is concluded that, based on the analysis that has been done, the video tracking technique using the tracker application to measure the acceleration of gravity in the pendulum swing practicum can be said to be valid.

The researcher suggests that future researchers should re-analyze the value of gravitational acceleration, and analyze the factors that affect the difference in more depth so that in future studies more thorough data can be obtained which can later be developed as a basis for initial analysis to determine the acceleration of gravity.

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