Asian Journal of Science Education
Vol. 6. No. 2, (October 2024) 95-101

e- ISSN 2715- 5641
DOI: doi.org/10.24815/ajse.v6i2.40578

Asian Journal of Science Education

Journal homepage: https://jurnal.usk.ac.id/AJSE

Calculation of Gravitational Acceleration Using the Method of Objects Oscillating at the End of a Spring and Swinging a Pendulum

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ARTICLE HISTORY

Submited : 09 August 2024
Revised : 20 November 2024
Accepted : 22 November 2024
Publication : 28 November 2024
Avaible *Online* : 28 November 2024

KEYS WORDS
Truth or dare, argumentation skills, buffer solution

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ABSTRACT

In buffer solution material, many students still do not complete it. This is due to the lack of variation in learning media. One of the right media is the truth or dare game. This media can help students to ask, answer questions, and share their ideas, so that it can help train students' argumentation skills which are still relatively low. This study aims to describe the effectiveness of the truth or dare game media to train students' argumentation skills on the buffer solution material. The research design used a pre-experimental design, namely One Group Pretest-Posttest Design. Implementation was carried out on 32 grade XI high school students. The instruments used were argumentation skills test sheets and knowledge learning results test. The data collection method used the test method. Data were analyzed using paired t-tests, N-Gain, along individual and classical completeness tests. The results of the study indicate that the truth or dare game media is effective in training argumentation skills and students complete individually and classically.

INTRODUCTION

The 21st century, which was marked by the Industrial Revolution 4.0 or the Fourth World Industrial Revolution, has become an era of quite tight competition, namely competition for the quality of human resources (HR) to have the ability to think critically and be competent in solving problems (Prihartini et al., 2017; Setyawan, 2019). The quality of a nation's human resources is determined by improving the quality of education, starting with improving the quality of learning (Widyaiswara, 2019; Rahmawati & Sutopo, 2020). In the context of understanding periodic motion, human ability to observe and analyze recurring movement patterns is one of the most fundamental intellectual achievements in the history of science. Every recurring motion pattern essentially contains complex information about energy interactions, forces, and displacement, which are not limited to mechanical phenomena, but also encompass broader aspects of life and the universe.

In everyday life, we cannot be separated from physics, starting from what exists within ourselves, such as the movements we make every moment, the energy we use every day, and something that is outside of ourselves (Susilo & Herawati, 2018; Hartono et al., 2019). In physics, motion that occurs repeatedly in the same time interval is called periodic motion (Ferdiana et al., 2020; Kusuma et al., 2021). Because this movement occurs regularly, it is also called harmonic/harmonious movement (Hermanto & Suryani, 2018; Kurniawan & Sumarno, 2021). If a particle performs periodic motion on the same path, the motion is called oscillation/vibration motion (Widyaiswara, 2019; Pratama et al., 2018). The simplest form of periodic motion is an object oscillating at the end of a spring and a pendulum swinging (Susilo & Herawati, 2018; Irwansyah & Hidayat, 2019). A deeper understanding of periodic motion is not merely explaining physical mechanisms, but also opening a window to understand the complexity of dynamic systems in nature. Each oscillation has a unique characteristic that reflects the fundamental interaction between potential and kinetic energy, which can be used as a model to understand more complex phenomena in science and life.

A vibration is a form of object movement that is often encountered in everyday life, for example, the vibrations that occur when a load is attached to or hung from a spring (Ferdiana et al., 2020; Nugroho & Wahyuni, 2018). Other examples are the pendulum of a clock that swings right and left, a small boat that swings up and down, the disc in an alarm clock that twists, the oscillation of air molecules in sound waves, and the strings of a plucked musical instrument (Hermanto & Suryani, 2018; Wibowo & Nugroho, 2020). Based on this example, it can be seen that vibrations can occur if a system is disturbed from its stable equilibrium position (Widyaiswara, 2019; Putri et al., 2020). This vibration will occur continuously and repeatedly as long as the system experiences force (Susilo & Herawati, 2018; Santoso et al., 2020). The vibratory motion of objects that repeats itself over a fixed time is usually referred to as periodic motion (Ferdiana et al., 2020; Rachman et al., 2021). In a more philosophical context, vibrations and periodic motion can be viewed as a fundamental manifestation of universal balance and dynamics, where every movement has the potential to generate complex energy information and transformation.

Through the oscillating object at the end of the spring and the swing of the pendulum, we can calculate the vibration period, namely the time interval required for the load to carry out a complete vibration (Hermanto & Suryani, 2018; Irwansyah & Hidayat, 2019). Basically, this experiment with a pendulum cannot be separated from vibration, where the meaning of vibration itself is periodic back-and-forth movement through the equilibrium point (Widyaiswara, 2019; Nugroho & Wahyuni, 2018). Vibrations can be simple and can be complex (Susilo & Herawati, 2018; Putri et al., 2020). In this experiment, we will use two methods to calculate the period of vibration, namely through objects that are isolated at the end of the spring and the swing of the pendulum. The results of the vibration period calculation will be compared and analyzed using the two methods. It will be seen which method is more accurate in calculating the spring period (Ferdiana et al., 2020; Rachman et al., 2021).

The object that oscillates at the end of the spring and the pendulum swing used is a swing made in such a way that the weight is a physical pendulum (Hermanto & Suryani, 2018; Wibowo & Nugroho, 2020). The vibration discussed is simple harmonic vibration, namely a vibration where the resultant force acting at an arbitrary point always leads to the equilibrium point, and the magnitude of the resultant force is proportional to the distance of the arbitrary point to the equilibrium point (Widyaiswara, 2019; Kurniawan & Sumarno, 2021).

RESEARCH METHODS

Research Approach

This research uses this type of research experiments with a quantitative approach. Study Experimentation is the research method used to look for the effect of a particular treatment towards others under certain conditions

Research Participants

The object of the research carried out was using a pendulum placed on a static rod and then carrying out an experiment by deviating the pendulum ball from its balanced duck, with a relatively small deviation angle ($\leq 10^0$), to obtain harmonic vibrations in the pendulum ball and no turbulence occurred and Practice calculating the length of time for a number of swings, for example 50 swings, to obtain a period with high accuracy.

Research Instruments

In this experiment, two methods will be used to calculate the vibration period, namely through an insulated object at the end of the spring and the swing of the pendulum. The results of the vibration period calculation will be compared and analyzed using the two methods and it will be determined which method is more accurate in calculating the spring period.

Data Collection

Data collection in this experiment was carried out by carrying out 2 trials in each experiment by varying the length of the rope (l) for the experiment using the Pendulum Swing Method and varying the deviation (y) in the Spring Method of Measurement.

Data Analysis

A. Pendulum Swing Method Measurement Data

Measurement of the vibration period is obtained using the following formula:

$$T = \frac{t}{n}$$

Calculate gravitational acceleration with the following formula:

$$g = \frac{4\pi^2 \ell}{T^2}$$

Data analysis can be obtained after carrying out several experiments with different deviations for each experiment and the final results are calculated using the equation:

$$g = \frac{g_1+g_2+g_3+g_4+g_5+g_6+g_7+g_8+g_9+g_{10}}{10}.$$

B. Spring Method Measurement Data

Measurement of the vibration period is obtained using the following formula:

$$T = \frac{t}{n}$$

Calculation of spring constant using the following formula:

$$g = \frac{4\pi^2 m}{T^2}$$

Data analysis can be obtained after carrying out several experiments with different deviations for each experiment and the final results are calculated using the equation:

$$g = \frac{g_1+g_2+g_3+g_4+g_5+g_6+g_7+g_8+g_9+g_{10}}{10}.$$

RESULTS AND DISCUSSION

Results of the First Research Objectives

Pendulum Swing Method Measurement Data

Based on the results of the measurements carried out, the following data was obtained:

Table 1. Pendulum Swing Experiment Data

No.	l(m)	n	t_1(s)	t_2(s)	t_3(s)	t_4(s)	t_5(s)	t_6(s)	t_7(s)	t_8(s)	t_9(s)	t_{10}(s)
1	0,2	10	8,62	8,91	8,87	8,54	8,64	8,95	8,45	8,76	8,75	8,69
2	0,3		11,63	11,25	11,33	11,27	11,10	11,60	11,13	11,08	11,02	11,20

Information:

• Vibrations are carried out 10 times (n=10).
• Measurements were repeated 10 times ($t_{1\text{-}10}$)
• Do variations twice, namely l = 0.2 m and l = 0.3 m.

Results of the Second Research Objectives
Spring Method Measurement Data
Based on the results of the measurements carried out, the following data was obtained:

Table 2. Spring Observation Table

No.	Displacement (m)	Mass (kg)	Time (s)									
			1	2	3	4	5	6	7	8	9	10
1	0.02	0.05	4.46	4.22	4.11	4.25	4.46	4.5	4.41	4.1	4.4	4.05
2	0.03		4.48	4.49	4.3	4.55	4.5	4.43	4.32	4.36	4.18	4.13

Information:
• Vibrations are carried out 10 times (n=10).
• Deviation variations were carried out in 2 variations, namely y=0.02 m and y=0.03 m
• The mass of the load is 0.05 kg
• Measurements are repeated 10 times ($t_{1\text{-}10}$)

Discussion
1. Pendulum Swing Method Measurement Data
Measurement of the vibration period is obtained using the following formula:

$$T = \frac{t}{n}$$

So obtained,

Table 3. Pendulum Swing Method Measurement Data

No.	l(m)	T_1(s)	T_2(s)	T_3(s)	T_4(s)	T_5(s)	T_6(s)	T_7(s)	T_8(s)	T_9(s)	T_{10}(s)
1	0,2	0,862	0,891	0,887	0,854	0,864	0,895	0,845	0,876	0,875	0,869
2	0,3	1,163	1,125	1,133	1,127	1,110	1,160	1,113	1,108	1,102	1,120

Calculate gravitational acceleration with the following formula:

$$g = \frac{4\pi^2 \ell}{T^2}$$

Information:
g : Gravitational acceleration ($^m/_{s^2}$)
ℓ : Rope length (m)
T : Period (Hz)
π : 22/7 or 3,14

The result of the calculation using the formula above,

Table 4. Calculation of Gravitational Acceleration

No.	l(m)	g(m/s²)										
		1	2	3	4	5	6	7	8	9	10	g
1	0,2	9,74	9,93	9,79	9,70	9,74	9,97	9,68	9,76	9,76	9,74	9,781

2	0,3	8,74	9,34	9,22	9,32	9,60	8,79	9,55	9,64	9,74	9,43	9,337

From the results of the observations that have been made and based on the theoretical basis, it was found that the length of the rope or thread used will be proportional to the magnitude of the gravitational acceleration, so the longer the rope used, the greater the gravitational acceleration. Conversely, the shorter the rope or thread used, the greater the gravitational acceleration. From this statement, the value of gravitational acceleration on a mathematical pendulum is in accordance with existing theory. Meanwhile, the period is inversely proportional to the magnitude of the gravitational acceleration, so the smaller the gravitational acceleration value, the greater the resulting period. Conversely, the greater the gravitational acceleration value, the smaller the resulting period.

1. Spring Method Measurement Data

Measurement of the vibration period is obtained using the following formula:

$$T = \frac{t}{n}$$

So it is obtained,

Table 5. Spring Method Measurement Data

No.	y (m)	m (kg)	Periode(T (s)) 1	2	3	4	5	6	7	8	9	10
1	0.02	0.05	0,446	0,422	0,411	0,425	0,446	0,45	0,441	0,41	0,44	0,405
2	0.03		0,448	0,449	0,43	0,455	0,45	0,443	0,432	0,436	0,418	0,413

Calculation of spring constant using the following formula:

$$g = \frac{4\pi^2 m}{T^2}$$

Therefore, we obtain:

Table 5. Calculation of Spring Constant

No.	y (m)	m (kg)	g(m/s²) 1	2	3	4	5	6	7	8	9	10	g
1	0.02	0.05	9,90	10,06	10,6	10,09	9,90	9,2	9,55	10,7	9,55	10,43	9,998
2	0.03		9,82	9,77	10,6	9,52	9,73	10,03	10,5	10,4	10,74	10,78	10,159

In this experiment, we then used a spring. As with using a rope or thread, the extension of the spring is proportional to the magnitude of the gravitational acceleration. So the greater the extension of the spring produced, the greater the value of the gravitational acceleration. Conversely, the smaller the extension of the spring produced, the smaller the gravitational acceleration because the extension of the spring is the same as the length of the rope or thread used.

Based on the data obtained from observations, it can be concluded that from the two methods used, determining gravitational acceleration using a pendulum swing is more accurate. This is seen from the average value of gravitational acceleration (g), where we obtain the following values: Judging from the average value obtained, the results are obtained $\check{g}$ pendulum =9.559 m⁄s^2 and Judging from the average value obtained, the results are obtained $\check{g}$ pegas = 10,007 m/s^2. These two values show that the g value of the pendulum swing is closer to the general gravitational acceleration value, namely 9.81 m⁄s^2.

CONCLUSION

Based on the data obtained from observations, it can be concluded that from the two methods used, determining gravitational acceleration using a pendulum swing is more accurate. This is seen from the average value of gravitational acceleration (g), where we obtain the following values: the average value of g ˇ pendulum is 9.559 m/s^2 and average value of g ˇ spring is 10.07 m/s^2. These two values indicate that the g value of the pendulum swing is closer to the general gravitational acceleration value, namely 9.81 m/s^2. Errors that may occur from differences in acceleration values are as follows: errors in measuring the length of the rope or thread, errors in measuring the extension of the spring, and errors in calculating the time used during a certain period. There are several limitations in this research, namely that there are still errors in calculating the time used during a certain period when using a stopwatch, which can affect the final results of the research. This can be anticipated by not rushing to continue the experiment to the next variation, in other words, increasing the duration of the pause after turning off the stopwatch and really looking carefully at the measurement results obtained.

Acknowledgment

The author would like to thank all parties who have helped carry out this research and also helped write this journal so that it was complete.

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