

Analysis of Free Fall Motion Using the Double-Switch Laboratory Method with Iron Balls

Mikael Namas*^{ORCID}, Felisianus Efrem Jelahun, Mutiara Meldisari Mnahonim

Politeknik Negeri Kupang, Adisucipto St., Kupang, East Nusa Tenggara, 85258, Indonesia

*Corresponding author, email: mikaelnamas18@gmail.com

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Abstract

The purpose of this research is to determine the magnitude of the acceleration of gravity on the free fall motion and in analyzing this research is to determine the magnitude of the acceleration of a free fall object which depends on the magnitude of the force that affects the object by varying the distance the object will be dropped. Data collection in this research uses an experimental method. The subject of this research is the magnitude of the acceleration of the free fall object, in the falling motion, variations in the height of the object's fall will be carried out, 75 cm and 90 cm with the mass of the object ignored, the data needed is the free fall object by analyzing the iron ball that will be dropped at different heights. To be able to find out the magnitude of the acceleration of an object in free fall motion, an analysis will be carried out using the formula in the theory, and the time required in this research is six months. Based on the analysis that has been used, the value of the acceleration of the object's motion for a large iron ball and for a small iron ball, the average value is $(4.84 \text{ ms}^{-2} \pm 4.54) \text{ ms}^{-2}$ and the magnitude of the object's velocity falling at a height of 75 cm for a large iron ball and for a small iron ball, the average value is $(2.6544 \text{ ms}^{-1} \pm 2.8302) \text{ ms}^{-1}$ and for a height of 90 cm, the average value of the velocity is $(2.6544 \pm 2.8302) \text{ ms}^{-1}$.

1. Introduction

There are two reasons for studying physics: first, physics is one of the most fundamental sciences, and scientists from various disciplines utilize ideas from physics, from chemists studying molecular structure to those who are fundamental to all engineering and technology. With the development and advancement of Science and Technology, which plays a crucial role in today's education, science and technology play an effective role in supporting the development and improvement of human resources in the educational field. Education is an effort to develop knowledge, attitudes, and skills.

The study and application of simulation in education continues to evolve along with advances in computer science and software, and various conditions and technological changes, particularly in computational physics methods. Physics is considered a difficult subject, making it difficult for students to grasp the concepts, which are often abstract. This can be done through skill training and experience about physical phenomena that occur in everyday life and to utilize the development of science and technology in the learning process, it is necessary to develop practices so that the implementation of learning activities can provide direct and meaningful experiences compared to abstract learning and Physics is one of the branches of natural science that studies natural phenomena. Natural phenomena that occur in physics can be reviewed theoretically and experimentally. The motion material in the sub-material of free fall motion and uniform straight motion is one of the natural phenomena studied in physics. Motion is a change in the position of an object to a reference point, the reference point can be defined as the starting point or the point where the observer is. Motion is also relative, meaning the motion of an object depends on its reference point.

Based on acceleration, motion is divided into two types: uniform linear motion and uniformly accelerated linear motion. Uniform linear motion is the motion of an object along a straight path with constant acceleration, while uniformly accelerated linear motion is the motion of an object along a straight path with acceleration. Free fall also includes the linear motion of an object dropped without initial velocity.

According to Young (2002), the motion of falling objects has been studied with a high degree of precision since then. If the effects of air can be ignored, Galileo was correct; all objects falling from a certain point will have the same downward acceleration, regardless of their size or weight. If the distance of the fall is shorter than the radius of the Earth, the acceleration is constant.

According to Jati and Bambang (2013), free fall is the motion of an object falling due to its own weight. The term "fall" means the object is released with no initial velocity, and the term "no initial velocity" means it is initially at rest or has zero velocity.

Free fall motion is the falling motion of an object without initial velocity, in this case it means that when an object falls it is not affected by other forces such as friction, then any object that falls without initial velocity and is not affected by other forces will produce the same gravitational acceleration, in other words if an object is dropped at a certain height without initial velocity and is not affected by other forces such as friction it will produce a constant gravitational acceleration.

According to Prihatin (2017) states that: Uniformly Accelerated Linear Motion is the motion of particles on a straight-line path with a constant direction of motion that covers a distance that changes regularly every unit of time and Uniformly Accelerated Linear Motion can also be known as one-dimensional motion with Constant Acceleration.

In this study, the materials used were in normal condition and the results of this study have never been published in a journal, so we tried to take this research title.

2. Method

The method used in this research is the experimental method, an experiment that is systematic and planned to prove the truth of a theory by preparing tools and materials and testing to find out the falling ball produced from holding magnets and the results of this research will be used as data.

The beginning for further research on the application of falling object technology in the field of mechanics and this research was carried out for 6 months in the physics laboratory of the Kupang State Polytechnic, and the method used in this research is the experimental method using large iron balls and small iron balls dropped at different heights, namely 90 cm and 75 cm through holding magnets. And the tools used in this research are: (1) Large iron ball, (2) Small iron ball, (3) Holding magnet, (4) Statip, (5) Sufficient cable, (6) 100 cm long ruler (7) Digital Counter, (8) Large contact plate, (9) Main supply unit Capacitor 5 Farad - 2 μ F, (10) Double pole switch.

Experimental research is a quantitative method that aims to test cause-and-effect relationships by manipulating one or more independent variables (treatments) and controlling external variables to determine their impact on the dependent variable. This method is characterized by the presence of experimental and control groups, randomization, and strict controls to ensure the validity of the results. Important aspects of experimental research include:

Understanding the impact of a specific treatment on a subject compared to a group without treatment and being able to control external variables so they do not affect the dependent variable.

True Experimental: Has a control group and full randomization and is often conducted in a laboratory. Quasi-Experimental: Similar to a true experiment but without strict randomization, often used for social/educational research.

Experimental research is very useful for predicting research outcomes and systematically testing hypotheses. Free fall is the motion of an object falling from a certain height without any initial velocity ($v_0 = 0$). An example in everyday life is when an apple falls from a tree. The fruit falls without any initial velocity.

Applications of free fall in everyday life. Measuring Building Height To measure the height of a building, you don't need to use a tape measure like you would to measure the length of a piece of wood, or to throw rocks or other objects from the top.

the building. Then, calculate how long it takes the object to reach the ground. Once you know the time, you can plug that time into the equation for height (h) for free fall. Measuring Pool Depth If you want to find the depth of a pool but don't have a tape measure, try using the principle of free fall. Throw a rock from the surface of the pool and record the time it takes for the rock to reach the bottom. The formula used in this study is

$$t = \sqrt{2gh} \text{ or } g = \frac{2h}{t^2} \text{ and}$$

$$v = \sqrt{2gh}$$

t = time (second)

h = high (cm, meters)
 v = speed (ms⁻¹)
 g = gravitational acceleration (ms⁻²)

In this study, data can be taken at heights of 75 cm, 90 cm, 95 cm and 98 cm. Each time the height changes, place a small iron ball on the holding magnet, then press the contact plate, then the ball falls and read the scale on the stopwatch to obtain time data (t). Likewise, for a large iron ball with the same height, it will obtain time data (t). So, at different heights, the time will be different according to each height.

3. Results and Discussion

If an object is dropped from a certain height without initial velocity, the object will fall to the surface of the earth, the object is said to be in free fall. So the falling motion is a vertical motion around the earth's surface that is only influenced by the earth's gravitational force by ignoring other forces such as air friction, this study aims to determine the acceleration of a free-falling object and the speed of movement of an object falling from different heights and also to determine the magnitude of the force acting on the object.

Experimental data on free-fall motion can be obtained from different heights, namely, heights at 75 cm and 90 cm from these varying heights, a large iron ball and a small iron ball are dropped, and the time also varies according to each height.

From the experimental data on the free-fall motion of the data model, there are two different objects, namely a Small Iron Ball and a Large Iron Ball, after analysis, the value of the Earth's gravitational acceleration varies and after averaging the value of the gravitational acceleration at a height of 75 cm. for a small iron ball 6.290 ms⁻² and for a large iron ball 4.1381 ms⁻².

At a height of 90 cm, the acceleration due to gravity also varies, and after being averaged for the small iron ball, the value is 5.4225 ms⁻² and for the large iron ball, the value is 4.5547 ms⁻². The calculation of the speed of motion of an object with a height of 75 cm varies, and after being averaged, the value is 2.771 ms⁻¹ for the small iron ball and for the large iron ball, after being averaged, the value is 2.787 ms⁻¹.

Table 1. Time Data for Altitude 75 cm

small iron ball		big iron ball	
t ₁	0.73 second	t ₁	0.50 second
t ₂	0.71 second	t ₂	0.48 second
t ₃	0.53 second	t ₃	0.70 second
t ₄	0.55 second	t ₄	0.71 second
t ₅	0.43 second	t ₅	0.60 second
t ₆	0.44 second	t ₆	0.56 second
t ₇	0.42 second	t ₇	0.61 second
t ₈	0.45 second	t ₈	0.70 second
t ₉	0.46 second	t ₉	0.68 second
t ₁₀	0.57 second	t ₁₀	0.65 second

Table 2. Time Data for Altitude 90 cm

Small iron ball		Big iron ball	
t ₁	0.73 Second	t ₁	0.50 Second
t ₂	0.71 Second	t ₂	0.48 Second
t ₃	0.53 Second	t ₃	0.70 Second
t ₄	0.55 Second	t ₄	0.71 Second
t ₅	0.43 Second	t ₅	0.60 Second
t ₆	0.49 Second	t ₆	0.69 Second
t ₇	0.42 Second	t ₇	0.64 Second
t ₈	0.53 Second	t ₈	0.72 Second
t ₉	0.57 Second	t ₉	0.73 Second
t ₁₀	0.67 Second	t ₁₀	0.65 Second

Table 3. Time data for altitude 95 cm

Small Iron Ball		Big Iron Ball	
t ₁	0.70 Second	t ₁	0.51 Second
t ₂	0.72 Second	t ₂	0.53 Second
t ₃	0.69 Second	t ₃	0.47 Second
t ₄	0.59 Second	t ₄	0.69 Second
t ₅	0.56 Second	t ₅	0.68 Second

Small Iron Ball		Big Iron Ball	
t ₆	0.52 Second	t ₆	0.50 Second
t ₇	0.60 Second	t ₇	0.48 Second
t ₈	0.63 Second	t ₈	0.55 Second
t ₉	0.55 Second	t ₉	0.49 Second
t ₁₀	0.58 Second	t ₁₀	0.63 Second

Table 4. Time Data for Altitude 98 cm

Small Iron Ball		Big Iron Ball	
t ₁	0.80 Second	t ₁	0.49 Second
t ₂	0.79 Second	t ₂	0.50 Second
t ₃	0.81 Second	t ₃	0.52 Second
t ₄	0.82 Second	t ₄	0.47 Second
t ₅	0.78 Second	t ₅	0.57 Second
t ₆	0.74 Second	t ₆	0.48 Second
t ₇	0.71 Second	t ₇	0.62 Second
t ₈	0.69 Second	t ₈	0.65 Second
t ₉	0.75 Second	t ₉	0.56 Second
t ₁₀	0.77 Second	t ₁₀	0.60 Second

Table 5. Calculation of Gravity Value at height 75 cm (0.75 meters)

Small Iron Ball		Big Iron Ball	
¹	$g_1 = \frac{2h}{t^2} = \frac{2 \times 0,75}{(0,73)^2} = \frac{1,5}{0,5329} = 2,815ms^{-2}$	¹	$g_1 = \frac{2h}{t^2} = \frac{2 \times 0,75}{(0,50)^2} = \frac{1,5}{0,25} = 6,0ms^{-2}$
²	$g_2 = \frac{2h}{t^2} = \frac{2 \times 0,75}{(0,71)^2} = \frac{1,5}{0,5041} = 2,976ms^{-2}$	²	$g_2 = \frac{2h}{t^2} = \frac{2 \times 0,75}{(0,48)^2} = \frac{1,5}{0,2304} = 6,5104ms^{-2}$
³	$g_3 = \frac{2h}{t^2} = \frac{2 \times 0,75}{(0,53)^2} = \frac{1,5}{0,2809} = 5,340ms^{-2}$	³	$g_3 = \frac{2h}{t^2} = \frac{2 \times 0,75}{(0,70)^2} = \frac{1,5}{0,49} = 3,0612ms^{-2}$
⁴	$g_4 = \frac{2h}{t^2} = \frac{2 \times 0,75}{(0,55)^2} = \frac{1,5}{0,3025} = 4,959ms^{-2}$	⁴	$g_4 = \frac{2h}{t^2} = \frac{2 \times 0,75}{(0,71)^2} = \frac{1,5}{0,5041} = 2,975ms^{-2}$
⁵	$g_5 = \frac{2h}{t^2} = \frac{2 \times 0,75}{(0,43)^2} = \frac{1,5}{0,1849} = 8,112ms^{-2}$	⁵	$g_5 = \frac{2h}{t^2} = \frac{2 \times 0,75}{(0,60)^2} = \frac{1,5}{0,36} = 4,1666ms^{-2}$
⁶	$g_6 = \frac{2h}{t^2} = \frac{2 \times 0,75}{(0,44)^2} = \frac{1,5}{0,1976} = 7,5910ms^{-2}$	⁶	$g_6 = \frac{2h}{t^2} = \frac{2 \times 0,75}{(0,56)^2} = \frac{1,5}{0,3136} = 4,7831ms^{-2}$
⁷	$g_7 = \frac{2h}{t^2} = \frac{2 \times 0,75}{(0,42)^2} = \frac{1,5}{0,1764} = 8,5034ms^{-2}$	⁷	$g_7 = \frac{2h}{t^2} = \frac{2 \times 0,75}{(0,61)^2} = \frac{1,5}{0,3721} = 4,0311ms^{-2}$
⁸	$g_8 = \frac{2h}{t^2} = \frac{2 \times 0,75}{(0,45)^2} = \frac{1,5}{0,2025} = 7,4074ms^{-2}$	⁸	$g_8 = \frac{2h}{t^2} = \frac{2 \times 0,75}{(0,70)^2} = \frac{1,5}{0,49} = 3,0612ms^{-2}$
⁹	$g_9 = \frac{2h}{t^2} = \frac{2 \times 0,75}{(0,46)^2} = \frac{1,5}{0,2116} = 7,0888ms^{-2}$	⁹	$g_9 = \frac{2h}{t^2} = \frac{2 \times 0,75}{(0,68)^2} = \frac{1,5}{0,4624} = 3,2439ms^{-2}$
¹⁰	$g_{10} = \frac{2h}{t^2} = \frac{2 \times 0,75}{(0,43)^2} = \frac{1,5}{0,1849} = 8,11244ms^{-2}$	¹⁰	$g_{10} = \frac{2h}{t^2} = \frac{2 \times 0,75}{(0,65)^2} = \frac{1,5}{0,4225} = 3,5502ms^{-2}$
$g = \frac{\sum g}{n} = \frac{62,90504}{10} g = 6,29050 ms^{-2}$		$\bar{g} = \frac{\sum g}{n} = \frac{41,3815}{10} g = 4,13815 ms^{-2}$	

Table 6. Calculation of Gravity Value at height 90 cm (0.9 meters)

Small Iron Ball		Big Iron Ball	
1	$g_1 = \frac{2h}{t^2} = \frac{2 \times 0,9}{(0,58)^2} = \frac{1,8}{0,3364} = 5,3507ms^{-2}$	$g_1 = \frac{2h}{t^2} = \frac{2 \times 0,9}{(0,52)^2} = \frac{1,8}{0,2704} = 6,656ms^{-2}$	
2	$g_2 = \frac{2h}{t^2} = \frac{2 \times 0,9}{(0,53)^2} = \frac{1,8}{0,2809} = 2,8479ms^{-2}$	$g_2 = \frac{2h}{t^2} = \frac{2 \times 0,9}{(0,55)^2} = \frac{1,8}{0,3025} = 5,950ms^{-2}$	
3	$g_3 = \frac{2h}{t^2} = \frac{2 \times 0,9}{(0,56)^2} = \frac{1,8}{0,3136} = 5,7397ms^{-2}$	$g_3 = \frac{2h}{t^2} = \frac{2 \times 0,75}{(0,70)^2} = \frac{1,5}{0,49} = 3,0612ms^{-2}$	
4	$g_4 = \frac{2h}{t^2} = \frac{2 \times 0,9}{(0,48)^2} = \frac{1,8}{0,25} = 7,20ms^{-2}$	$g_4 = \frac{2h}{t^2} = \frac{2 \times 0,9}{(0,50)^2} = \frac{1,8}{0,25} = 7,20ms^{-2}$	
5	$g_5 = \frac{2h}{t^2} = \frac{2 \times 0,9}{(0,47)^2} = \frac{1,8}{0,2209} = 8,1484ms^{-2}$	$g_5 = \frac{2h}{t^2} = \frac{2 \times 0,9}{(0,51)^2} = \frac{1,8}{0,2601} = 6,920ms^{-2}$	
6	$g_6 = \frac{2h}{t^2} = \frac{2 \times 0,9}{(0,49)^2} = \frac{1,8}{0,1401} = 7,4968ms^{-2}$	$g_6 = \frac{2h}{t^2} = \frac{2 \times 0,9}{(0,51)^2} = \frac{1,8}{0,2601} = 6,920ms^{-2}$	
7	$g_7 = \frac{2h}{t^2} = \frac{2 \times 0,9}{(0,37)^2} = \frac{1,8}{0,2738} = 6,5741ms^{-2}$	$g_7 = \frac{2h}{t^2} = \frac{2 \times 0,9}{(0,69)^2} = \frac{1,8}{0,4761} = 3,7807ms^{-2}$	
8	$g_8 = \frac{2h}{t^2} = \frac{2 \times 0,9}{(0,53)^2} = \frac{1,8}{0,2809} = 6,4079ms^{-2}$	$g_8 = \frac{2h}{t^2} = \frac{2 \times 0,9}{(0,64)^2} = \frac{1,8}{0,4096} = 4,3945ms^{-2}$	
9	$g_9 = \frac{2h}{t^2} = \frac{2 \times 0,9}{(0,57)^2} = \frac{1,8}{0,3249} = 5,5401ms^{-2}$	$g_9 = \frac{2h}{t^2} = \frac{2 \times 0,9}{(0,72)^2} = \frac{1,8}{0,5184} = 3,4722ms^{-2}$	
10	$g_{10} = \frac{2h}{t^2} = \frac{2 \times 0,9}{(0,67)^2} = \frac{1,8}{0,4489} = 4,0098ms^{-2}$	$g_{10} = \frac{2h}{t^2} = \frac{2 \times 0,9}{(0,65)^2} = \frac{1,8}{0,4225} = 4,2603ms^{-2}$	
$\bar{g} = \frac{\Delta g}{n} = \frac{54,2257}{10} = 5,42257$		$\bar{g} = \frac{\Delta g}{n} = \frac{45,5447}{10} = 4,55447ms^{-2}$	
ms^{-2}			

Table 7. Calculation of the Speed of an Object at a Height 75 cm

No	Big Iron Ball	Small Iron Ball
1	$v = \sqrt{2gh}$ $= \sqrt{2 \cdot 6,0 \cdot 75}$ $= \sqrt{9} = 3 \text{ ms}^{-1}$	$= \sqrt{2 \cdot 2,83 \cdot 0,75} = \sqrt{2gh}$ $= \sqrt{4,245}$ $v = 2,06 \text{ ms}^{-1}$
2	$v = \sqrt{2gh}$ $= \sqrt{2 \cdot 6,5 \cdot 0,75}$ $= \sqrt{9,75} = 3,12 \text{ ms}^{-1}$	$v = \sqrt{2gh}$ $= \sqrt{2 \cdot 3,0 \cdot 75}$ $v = \sqrt{4,5} = 2,121 \text{ ms}^{-1}$
3	$v = \sqrt{2gh}$ $= \sqrt{2 \cdot 3,06 \cdot 0,75}$ $= \sqrt{4,59} = 2,142 \text{ ms}^{-1}$	$v = \sqrt{2gh}$ $= \sqrt{2 \cdot 9,36 \cdot 0,75}$ $= \sqrt{14,04} = 3,75 \text{ ms}^{-1}$
4	$v = \sqrt{2gh} = \sqrt{2 \cdot 3,0 \cdot 75}$ $= \sqrt{4,5} = 2,12 \text{ ms}^{-1}$	$v = \sqrt{2gh} = \sqrt{2 \cdot 5,0 \cdot 75}$ $= \sqrt{7,5} = 2,74 \text{ ms}^{-1}$
5	$v = \sqrt{2gh} = \sqrt{2 \cdot 4,17} = \sqrt{8,34} = 2,89 \text{ ms}^{-1}$	$v = \sqrt{2gh} = \sqrt{2 \cdot 81 \cdot 0,75}$ $= 3,48 \text{ ms}^{-1}$
6	$v = \sqrt{2gh} = \sqrt{2 \cdot 4,7831 \cdot 0,75}$ $= \sqrt{7,17465} = 2,6785 \text{ ms}^{-1}$	$v = \sqrt{2gh} = \sqrt{2 \cdot 81 \cdot 0,75}$ $= 3,48 \text{ ms}^{-1}$
7	$v = \sqrt{2gh} = \sqrt{2 \cdot 4,0311 \cdot 0,75}$ $= \sqrt{6,04665} = 2,4589 \text{ ms}^{-1}$	$v = \sqrt{2gh} = \sqrt{2 \cdot 81 \cdot 0,75}$ $= 3,48 \text{ ms}^{-1}$
8	$v = \sqrt{2gh} = \sqrt{2 \cdot 3,0612 \cdot 0,75}$ $= \sqrt{6,1224} = 2,4743 \text{ ms}^{-1}$	$v = \sqrt{2gh} = \sqrt{2 \cdot 7,4074 \cdot 0,75}$ $= 3,333 \text{ ms}^{-1}$

No	Big Iron Ball	Small Iron Ball
9	$v = \sqrt{2gh} = \sqrt{2.3.2439.0.75}$ $\sqrt{4,86585} = 2,2058 \text{ ms}^{-1}$	$v = \sqrt{2gh} = \sqrt{2.7.0888.0.75}$ $= 3,2608 \text{ ms}^{-1}$
10	$v = \sqrt{2gh} = \sqrt{2.3.5502.0.75}$ $\sqrt{5,3253} = 2,30766 \text{ ms}^{-1}$	$v = \sqrt{2gh} = \sqrt{2.8.1124.0.75}$ $= 3,48883 \text{ ms}^{-1}$

Table 8. Calculation of the Speed of an Object at a Height 90 cm

No	Big Iron Ball	Small Iron Ball
1	$v = \sqrt{2gh} = \sqrt{2.6.67.0.9}$ $= \sqrt{12,006} = 3,65 \text{ ms}^{-1}$	$v = \sqrt{2gh} = \sqrt{2.5.25.0.9}$ $= \sqrt{9,45} = 3,07 \text{ ms}^{-1}$
2	$v = \sqrt{2gh} = \sqrt{2.6.0.9}$ $= \sqrt{10,8} = 3,29 \text{ ms}^{-1}$	$v = \sqrt{2gh} = \sqrt{2.6.43.0.9}$ $\sqrt{11,574} = 3,40 \text{ ms}^{-1}$
3	$v = \sqrt{2gh} = \sqrt{15,43}$ $= 3,93 \text{ ms}^{-1}$	$v = \sqrt{2gh} = \sqrt{2.5.73.0.9}$ $\sqrt{10,31} = 3,21 \text{ ms}^{-1}$
4	$v = \sqrt{2gh} = \sqrt{2.7.2.0.9}$ $= \sqrt{12,96}$ $= 3,6 \text{ ms}^{-1}$	$v = \sqrt{2gh} = \sqrt{2.7.82.0.9}$ $= \sqrt{14,076} = 3,75 \text{ ms}^{-1}$
5	$v = \sqrt{2gh} = \sqrt{2.6.92.0.9}$ $= \sqrt{12,456} = 3,53 \text{ ms}^{-1}$	$v = \sqrt{2gh} = \sqrt{2.8.15.0.9}$ $= \sqrt{2.8.15.0.9}$ $= 3,83 \text{ ms}^{-1}$
6	$v = \sqrt{2gh} = \sqrt{2.3.78072.0.9}$ $= \sqrt{6,8056} = 2,0868 \text{ ms}^{-1}$	$v = \sqrt{2gh} = \sqrt{2.7.82.0.9}$ $= \sqrt{14,076} = 3,75 \text{ ms}^{-1}$
7	$v = \sqrt{2gh} = \sqrt{2.6.92.0.9}$ $= \sqrt{12,456} = 3,53 \text{ ms}^{-1}$	$v = \sqrt{2gh} = \sqrt{2.7.82.0.9}$ $= \sqrt{14,076} = 3,78 \text{ ms}^{-1}$
8	$v = \sqrt{2gh} = \sqrt{2.6.92.0.9}$ $= \sqrt{12,456} = 3,53 \text{ ms}^{-1}$	$v = \sqrt{2gh} = \sqrt{2.7.82.0.9}$ $= \sqrt{14,076} = 3,70 \text{ ms}^{-1}$
9	$v = \sqrt{2gh} = \sqrt{2.6.92.0.9}$ $= \sqrt{12,456} = 3,53 \text{ ms}^{-1}$	$v = \sqrt{2gh} = \sqrt{2.7.82.0.9}$ $= \sqrt{14,076} = 3,77 \text{ ms}^{-1}$
10	$v = \sqrt{2gh} = \sqrt{2.6.92.0.9}$ $= \sqrt{12,456} = 3,53 \text{ ms}^{-1}$	$v = \sqrt{2gh} = \sqrt{2.7.82.0.9}$ $= \sqrt{14,076} = 3,752 \text{ ms}^{-1}$

$$\bar{v} = \frac{\Delta V}{n} = \frac{23,7}{10} = 2,37 \text{ ms}^{-1}$$

$$\bar{v} = \frac{\Delta V}{n} = \frac{35,98}{10} = 3,598 \text{ ms}^{-1}$$

From the results of the data analysis above in table 7, the speed values at different heights are almost the same and also the time values are different. So, for a height of 75 cm, the large iron ball and the small iron ball have an average speed value of $(2.37 \pm 3.452) \text{ ms}^{-1}$ and for table 8, the large iron ball and the small iron ball at a height of 90 cm have an average speed value of $(3.6 \pm 3.452) \text{ ms}^{-1}$

The average gravity value for the small iron ball is 5.4225 ms^{-2} and for the large iron ball, the average gravity value is 4.55447 ms^{-2} and from the two tables above, the heights are different, namely 75 cm and 90 cm. The experiment was carried out 10 times using two objects, namely a large iron ball and a small iron ball. When collecting data, the time was always different at a height of 75 cm and 90 cm. When the experiment was carried out at a height of 75 cm using a ball small iron and large iron balls are found to have different time values and different gravity values at different heights, while the speed of moving objects in the analysis of Tables 7 and 8, the values obtained for each vary or differ, the average speed for large iron balls and small iron balls is $(2.37 \pm 3.452 \text{ ms}^{-1})$

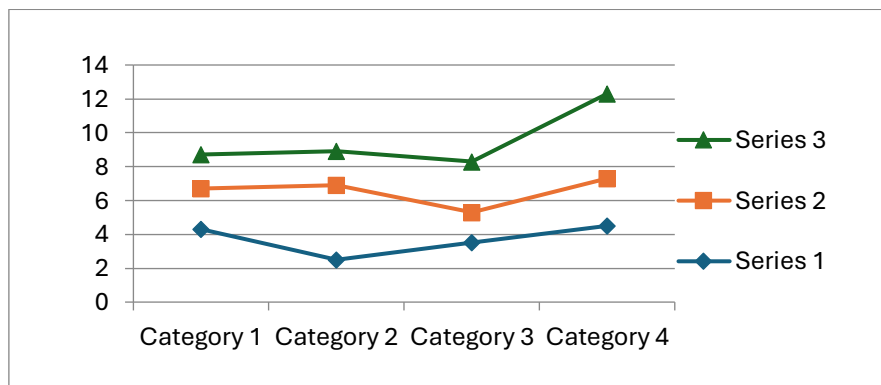


Figure 1. Relationship between Height (h) and Time (t)

From the figure 1, it tends to be non-linear due to the different heights, namely 75 cm and 90 cm, and the graph of the relationship between height and time also tends to be non-linear due to the different heights, namely 75 cm and 90 cm and different times.

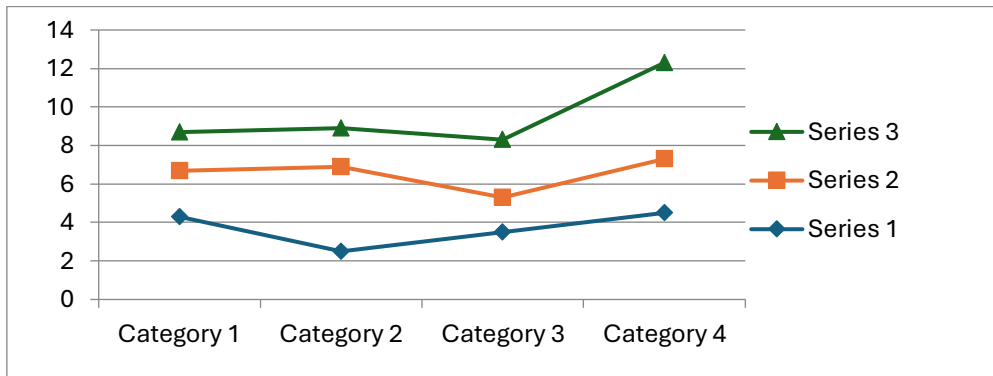


Figure 2. Relationship between Height (h) and Earth's Gravitational Acceleration (g)

Figure 2 shows that the relationship between height and the Earth's gravitational acceleration is always non-linear because heights vary and also affect the Earth's gravitational acceleration.

Table 9. Calculation of Gravity Value at height 95 cm

	Small Iron Ball	Big Iron Ball
¹	$g_1 = \frac{2h}{t^2} = \frac{2 \times 0,95}{(0,70)^2} = \frac{1,9}{0,49} = 3,877 m s^{-2}$	$g_1 = \frac{2h}{t^2} = \frac{2 \times 0,95}{(0,51)^2} = \frac{1,9}{0,2601} = 7,3048 m s^{-2}$
²	$g_2 = \frac{2h}{t^2} = \frac{2 \times 0,95}{(0,72)^2} = \frac{1,9}{0,5184} = 3,665 m s^{-2}$	$g_2 = \frac{2h}{t^2} = \frac{2 \times 0,95}{(0,53)^2} = \frac{1,9}{0,2809} = 6,7639 m s^{-2}$
³	$g_3 = \frac{2h}{t^2} = \frac{2 \times 0,95}{(0,69)^2} = \frac{1,9}{0,4761} = 3,990 m s^{-2}$	$g_3 = \frac{2h}{t^2} = \frac{2 \times 0,95}{(0,47)^2} = \frac{1,9}{0,2209} = 8,6011 m s^{-2}$
⁴	$g_4 = \frac{2h}{t^2} = \frac{2 \times 0,95}{(0,59)^2} = \frac{1,9}{0,3481} = 5,4282 m s^{-2}$	$g_4 = \frac{2h}{t^2} = \frac{2 \times 0,95}{(0,69)^2} = \frac{1,9}{0,4761} = 3,990 m s^{-2}$
⁵	$g_5 = \frac{2h}{t^2} = \frac{2 \times 0,95}{(0,56)^2} = \frac{1,9}{0,3136} = 6,058 m s^{-2}$	$g_5 = \frac{2h}{t^2} = \frac{2 \times 0,95}{(0,68)^2} = \frac{1,9}{0,4624} = 4,1089 m s^{-2}$
⁶	$g_6 = \frac{2h}{t^2} = \frac{2 \times 0,95}{(0,52)^2} = \frac{1,9}{0,2704} = 7,0266 m s^{-2}$	$g_6 = \frac{2h}{t^2} = \frac{2 \times 0,95}{(0,50)^2} = \frac{1,9}{0,25} = 7,60 m s^{-2}$
⁷	$g_7 = \frac{2h}{t^2} = \frac{2 \times 0,95}{(0,60)^2} = \frac{1,9}{0,36} = 5,2777 m s^{-2}$	$g_7 = \frac{2h}{t^2} = \frac{2 \times 0,95}{(0,41)^2} = \frac{1,9}{0,2304} = 8,2465 m s^{-2}$
⁸	$g_8 = \frac{2h}{t^2} = \frac{2 \times 0,95}{(0,63)^2} = \frac{1,8}{0,3969} = 4,787 m s^{-2}$	$g_8 = \frac{2h}{t^2} = \frac{2 \times 0,95}{(0,55)^2} = \frac{1,9}{0,3025} = 6,2809 m s^{-2}$
⁹	$g_9 = \frac{2h}{t^2} = \frac{2 \times 0,95}{(0,55)^2} = \frac{1,9}{0,3025} = 6,2809 m s^{-2}$	$g_9 = \frac{2h}{t^2} = \frac{2 \times 0,95}{(0,49)^2} = \frac{1,9}{0,2401} = 7,9133 m s^{-2}$
¹⁰	$g_{10} = \frac{2h}{t^2} = \frac{2 \times 0,95}{(0,58)^2} = \frac{1,8}{0,3366} = 5,6480 m s^{-2}$	$g_{10} = \frac{2h}{t^2} = \frac{2 \times 0,95}{(0,63)^2} = \frac{1,9}{0,3969} = 4,7871 m s^{-2}$
	$\bar{g} = \frac{\Delta g}{n} = \frac{54,2257}{10} g = 5,2037 m s^{-2}$	$\bar{g} = \frac{\Delta g}{n} = \frac{65,5972}{10} = 6,5597 m s^{-2}$

Table 10. Calculation of Earth's Gravity Value (g) Against Height (h)=98 cm

	Small Iron Ball	Big Iron Ball
1	$g_1 = \frac{2h}{t^2} = \frac{2 \times 0,98}{(0,00)^2} = \frac{1,96}{0,64} = 3,065 ms^{-2}$	$g_1 = \frac{2h}{t^2} = \frac{2 \times 0,98}{(0,49)^2} = \frac{1,96}{0,2401} = 8,1362 ms^{-2}$
2	$g_2 = \frac{2h}{t^2} = \frac{2 \times 0,98}{(0,79)^2} = \frac{1,9}{0,6241} = 3,1405 ms^{-2}$	$g_2 = \frac{2h}{t^2} = \frac{2 \times 0,98}{(0,50)^2} = \frac{1,96}{0,25} = 7,84 ms^{-2}$
3	$g_3 = \frac{2h}{t^2} = \frac{2 \times 0,98}{(0,81)^2} = \frac{1,96}{0,6561} = 3,0178 ms^{-2}$	$g_3 = \frac{2h}{t^2} = \frac{2 \times 0,98}{(0,52)^2} = \frac{1,9}{0,2704} = 7,2485 ms^{-2}$
4	$g_4 = \frac{2h}{t^2} = \frac{2 \times 0,98}{(0,82)^2} = \frac{1,96}{0,6724} = 2,949 ms^{-2}$	$g_4 = \frac{2h}{t^2} = \frac{2 \times 0,98}{(0,47)^2} = \frac{1,96}{0,2209} = 8,8727 ms^{-2}$
5	$g_5 = \frac{2h}{t^2} = \frac{2 \times 0,98}{(0,78)^2} = \frac{1,96}{0,6084} = 3,254 ms^{-2}$	$g_5 = \frac{2h}{t^2} = \frac{2 \times 0,98}{(0,68)^2} = \frac{1,96}{0,4624} = 4,2387 ms^{-2}$
6	$g_6 = \frac{2h}{t^2} = \frac{2 \times 0,98}{(0,74)^2} = \frac{1,96}{0,5476} = 3,6157 ms^{-2}$	$g_6 = \frac{2h}{t^2} = \frac{2 \times 0,98}{(0,48)^2} = \frac{1,96}{0,2304} = 8,5069 ms^{-2}$
7	$g_7 = \frac{2h}{t^2} = \frac{2 \times 0,98}{(0,71)^2} = \frac{1,96}{0,5041} = 3,9277 ms^{-2}$	$g_7 = \frac{2h}{t^2} = \frac{2 \times 0,98}{(0,62)^2} = \frac{1,96}{0,3844} = 5,0988 ms^{-2}$
8	$g_8 = \frac{2h}{t^2} = \frac{2 \times 0,98}{(0,69)^2} = \frac{1,96}{0,4761} = 4,1587 ms^{-2}$	$g_8 = \frac{2h}{t^2} = \frac{2 \times 0,98}{(0,65)^2} = \frac{1,96}{0,4225} = 4,6390 ms^{-2}$
9	$g_9 = \frac{2h}{t^2} = \frac{2 \times 0,98}{(0,75)^2} = \frac{1,96}{0,5625} = 3,4844 ms^{-2}$	$g_9 = \frac{2h}{t^2} = \frac{2 \times 0,98}{(0,56)^2} = \frac{1,96}{0,3136} = 6,25 ms^{-2}$
10	$g_{10} = \frac{2h}{t^2} = \frac{2 \times 0,98}{(0,77)^2} = \frac{1,96}{0,5929} = 3,3057 ms^{-2}$	$g_{10} = \frac{2h}{t^2} = \frac{2 \times 0,98}{(0,60)^2} = \frac{1,96}{0,36} = 5,444 ms^{-2}$
	$\bar{g} = \frac{\Delta g}{n} = \frac{33,9285}{10} g = 3,3928 ms^{-2}$	$\bar{g} = \frac{\Delta g}{n} = \frac{66,2784}{10} g = 6,627 ms^{-2}$

Table 11. Calculation of Object Speed (v) Against Height (h) = 95 cm

No.	Big Iron Ball	Small Iron Ball
1	$v = \sqrt{2gh} = \sqrt{2 \cdot 3,877 \cdot 1,9} = \sqrt{20,8350} = 4,564 ms^{-1}$	$v = \sqrt{2gh} = \sqrt{2 \cdot 8,251365 \cdot 1,9} = \sqrt{31,895} = 5,6475 ms^{-1}$
2	$v = \sqrt{2gh} = \sqrt{2 \cdot 3,666 \cdot 1,9} = \sqrt{13,908} = 3,729 ms^{-1}$	$v = \sqrt{2gh} = \sqrt{2 \cdot 7,84 \cdot 1,9} = \sqrt{30,7328} = 5,5437 ms^{-1}$
3	$v = \sqrt{2gh} = \sqrt{2 \cdot 3,990 \cdot 1,9} = \sqrt{15,162} = 3,893 ms^{-1}$	$v = \sqrt{2gh} = \sqrt{2 \cdot 7,248 \cdot 1,9} = \sqrt{28,414} = 5,330 ms^{-1}$
4	$v = \sqrt{2gh} = \sqrt{2 \cdot 5,428 \cdot 1,9} = \sqrt{20,627} = 4,5417 ms^{-1}$	$v = \sqrt{2gh} = \sqrt{2 \cdot 8,872 \cdot 1,9} = \sqrt{34,778} = 5,8973 ms^{-1}$
5	$v = \sqrt{2gh} = \sqrt{2 \cdot 6,028 \cdot 1,9} = \sqrt{23,0204} = 4,797 ms^{-1}$	$v = \sqrt{2gh} = \sqrt{2 \cdot 6,0326 \cdot 1,9} = \sqrt{23,6477} = 4,8628 ms^{-1}$
6	$v = \sqrt{2gh} = \sqrt{2 \cdot 7,0266 \cdot 1,9} = \sqrt{26,7010} = 5,1673 ms^{-1}$	$v = \sqrt{2gh} = \sqrt{2 \cdot 8,5069 \cdot 1,9} = \sqrt{33,3470} = 5,774 ms^{-1}$
7	$v = \sqrt{2gh} = \sqrt{2 \cdot 5,277 \cdot 1,9} = \sqrt{20,0526} = 4,478 ms^{-1}$	$v = \sqrt{2gh} = \sqrt{2 \cdot 5,098 \cdot 1,9} = \sqrt{19,984} = 4,470 ms^{-1}$
8	$v = \sqrt{2gh} = \sqrt{2 \cdot 4,787 \cdot 1,9} = \sqrt{18,626} = 4,358 ms^{-1}$	$v = \sqrt{2gh} = \sqrt{2 \cdot 4,634 \cdot 1,9} = \sqrt{18,165} = 4,262 ms^{-1}$

No.	Big Iron Ball	Small Iron Ball
9	$v = \sqrt{2gh} = \sqrt{2.6,2809.1.9}$ $= \sqrt{23,867} = 4,885 \text{ ms}^{-1}$	$v = \sqrt{2gh} = \sqrt{2.625.1.9}$ $= \sqrt{24,5} = 4,949 \text{ ms}^{-1}$
10	$v = \sqrt{2gh} = \sqrt{2.5,6480.1.9}$ $= \sqrt{21,4624} = 4,6327 \text{ ms}^{-1}$	$v = \sqrt{2gh} = \sqrt{2.5,44.1.9}$ $= \sqrt{21,3248} = 4,6178 \text{ ms}^{-1}$

Table 12. Calculation of Object Speed (v) Against Height (h) = 98 cm

Num	Big Iron Ball	Small Iron Ball
1	$v = \sqrt{2gh} = \sqrt{2.8,136.1.9}$ $= \sqrt{31,895}$ $= 5,847 \text{ ms}^{-1}$	$v = \sqrt{2gh} = \sqrt{2.8,251365.1.9}$ $= \sqrt{31,895} = 5,6475 \text{ ms}^{-1}$
2	$v = \sqrt{2gh} = \sqrt{2.7,84.1.9}$ $= \sqrt{30,7328} = 5,5437 \text{ ms}^{-1}$	$v = \sqrt{2gh} = \sqrt{2.7,84.1.9}$ $= \sqrt{30,7328} = 5,5437 \text{ ms}^{-1}$
3	$v = \sqrt{2gh} = \sqrt{2.7,248.1.9} =$ $\sqrt{28,414}$ $= 5,330 \text{ ms}^{-1}$	$v = \sqrt{2gh}$ $= \sqrt{2.7,248.1.9}$ $= \sqrt{28,414} = 5,330 \text{ ms}^{-1}$
4	$v = \sqrt{2gh} = \sqrt{2.8,872.1.9}$ $= \sqrt{34,778} = 5,8973 \text{ ms}^{-1}$	$v = \sqrt{2gh} = \sqrt{2.8,872.1.9}$ $= \sqrt{34,778} = 5,8973 \text{ ms}^{-1}$
5	$v = \sqrt{2gh} = \sqrt{2.6,032.1.9}$ $= \sqrt{23,6477} = 4,8628 \text{ ms}^{-1}$	$v = \sqrt{2gh} = \sqrt{2.6,0326.1.9}$ $= \sqrt{23,6477}$ $= 4,8628 \text{ ms}^{-1}$
6	$v = \sqrt{2gh} = \sqrt{2.8,5069.1.9}$ $= \sqrt{33,3470} = 5,774 \text{ ms}^{-1}$	$v = \sqrt{2gh} = \sqrt{2.8,5069.1.9}$ $= \sqrt{33,3470}$ $= 5,774 \text{ ms}^{-1}$
7	$v = \sqrt{2gh} = \sqrt{2.5,098.1.9}$ $= \sqrt{19,984} = 4,470 \text{ ms}^{-1}$	$v = \sqrt{2gh} = \sqrt{2.5,098.1.9}$ $= \sqrt{19,984} = 4,470 \text{ ms}^{-1}$
8	$v = \sqrt{2gh} = \sqrt{2.4,6340.1.9}$ $= \sqrt{18,165} = 4,262 \text{ ms}^{-1}$	$v = \sqrt{2gh} = \sqrt{2.4,634.1.9}$ $= \sqrt{18,165} = 4,262 \text{ ms}^{-1}$
9	$v = \sqrt{2gh} = \sqrt{2.6,25.1.9}$ $= \sqrt{24,5} = 4,949 \text{ ms}^{-1}$	$v = \sqrt{2gh} = \sqrt{2.625.1.9}$ $= \sqrt{24,5} = 4,949 \text{ ms}^{-1}$
10	$v = \sqrt{2gh} = \sqrt{2.5,44.1.9}$ $= \sqrt{21,3248} = 4,6178 \text{ ms}^{-1}$	$v = \sqrt{2gh} = \sqrt{2.5,44.1.9}$ $= \sqrt{21,3248} = 4,6178 \text{ ms}^{-1}$

$$v = \frac{\Delta V}{n} = \frac{51,552}{10} = 5,1552 \text{ ms}^{-1}$$

$$v = \frac{\Delta V}{n} = \frac{46,491}{10} = 4,6491 \text{ ms}^{-1}$$

From the analysis in Tables 9 and 10 above, we can obtain different or varying gravitational acceleration values, and the average value of the Earth's gravitational acceleration for both the small iron ball and the large iron ball is (5.2037 ± 6.5597) .

Meanwhile, the speed of the object's motion at a height of 95 cm and 98 cm always varies or differs, with the average speed being $(4.3468 \text{ ms}^{-1} \pm 4.6883 \text{ ms}^{-1})$.

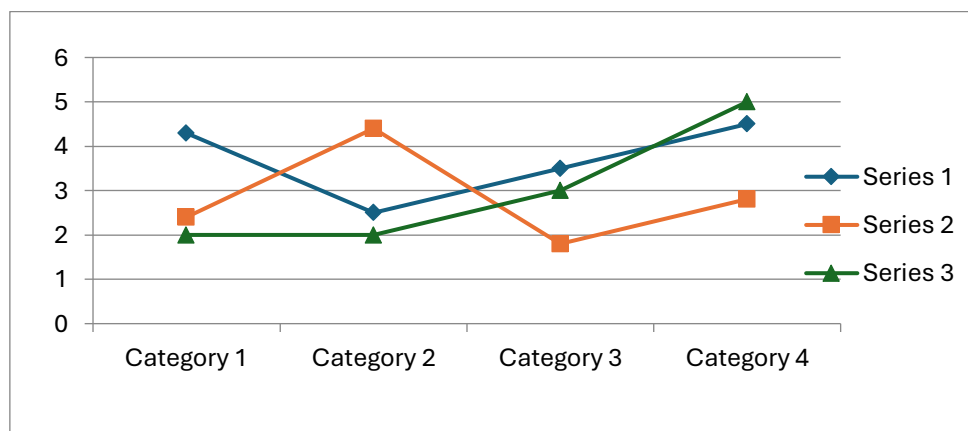


Figure 3. Relationship Between Height (h = 95 cm) and Time (t)

From the Figure 3, the relationship between height (h) and time (t) tends to be non-linear because it is influenced by height and therefore also affects time. So if the height changes, time will also change.

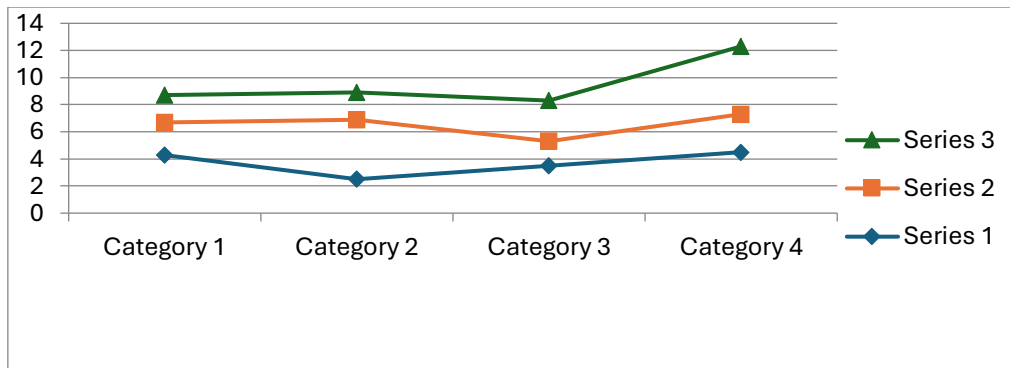


Figure 4. Relationship Between Height (98 cm) and Time (t)

From the Figure 3 and 4, it always tends to be non-linear because the influence of height varies or is different.

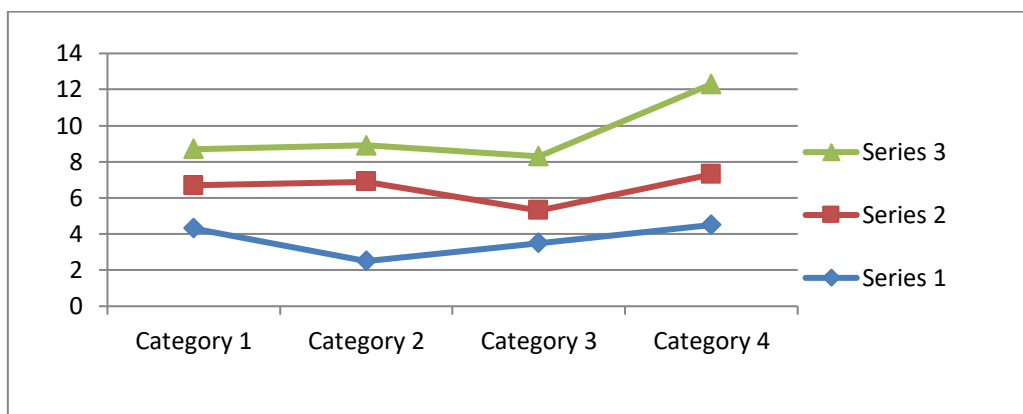


Figure 5. Relationship between Height (h = 95 cm) and the Acceleration of Gravity (g)

From Figure 5 relationship between height (h) and the acceleration of gravity (g), it tends to be non-linear because the influence of height and gravity values also vary.

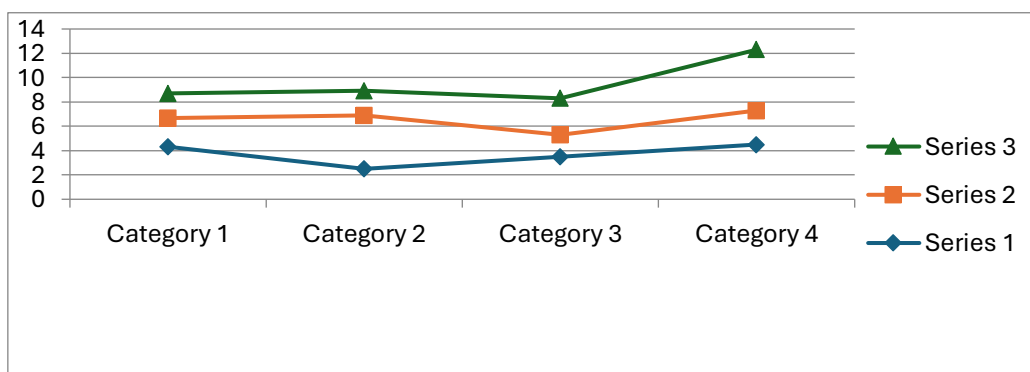


Figure 6. Relationship Between Height (h = 95 cm) and the Acceleration of Gravity (g)

Figure 6 shows that it is always non-linear because the influence of height varies and also affects the speed of the object's movement.

4. Conclusion

From the analysis above, the following conclusions can be drawn: (1) The magnitude of the Earth's gravitational acceleration at heights of 75 cm and 90 cm is nearly the same, and the velocity of a falling object depends on the altitude. If the altitude is constantly changing, the values of the Earth's gravitational acceleration and the velocity of a falling object will vary greatly, depending on the height and time of the object's fall. The average value of the Earth's gravitational acceleration at a height of 75 cm for a small iron ball is 4.84 ms⁻², and for a large iron ball it is 4.54 ms⁻². At a height of 90 cm, the average value of the gravitational acceleration is 4.84 ms⁻² (for the small iron ball) and 4.54 ms⁻² for the large iron ball. At heights of 95 cm and 98 cm, the values of the gravitational acceleration always vary, because as the height of a moving object changes, the value of the

Earth's gravitational acceleration and the object's velocity also change. of all the existing graphs, none of them are linear due to the influence of changing or varying heights. So, the further away from the Earth's surface, the smaller the value of the Earth's gravitational acceleration (g) will be, and vice versa, the closer to the Earth's surface, the greater the value of the Earth's gravitational acceleration (g).

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Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/ or publication of this article.

Data Availability

The datasets generated during and/ or analyzed during the current study are available from the corresponding author on reasonable request.

Declaration on AI Use

The authors declare that no artificial intelligence (AI) or AI-assisted tools were used in the preparation of this manuscript.

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