جامعة بيرزيت

BIRZEIT UNIVERSITY

Physics Lab 211

Experiment No. 2

Freely Falling Objects

Name: Laith Marzouka **ID:** 1160827

Partners: Ahmed Awawda **ID:** 1163113

Lamia' Abu Awwad **ID:** 1150993

Advisor: Dr. Areej Abdel Rahman

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Abstract:

-Aims: To determine the acceleration due to gravity at Birzet .

-Methods: By measuring the time needed for an object to free fall from different heights, and using newton's laws of motion to calculate the acceleration .

-Main Result:

$$g = (9.7 \pm 0.3)\ m/s^2$$

Theoretical Background:

Free falling is accompanied with nearly constant acceleration when air friction is neglected. By using Newton's second law:

$mg = m\frac{d^2h}{dt^2} \rightarrow g = \frac{d^2h}{dt^2}$, The solution to that differential equation:

$h(t) = h_0(t) + v_0 t + \frac{1}{2}gt^2$

In free falling, the object is dropped from rest, which means that v_0 equals zero. h is also measured so that h_0 equals zero as well.

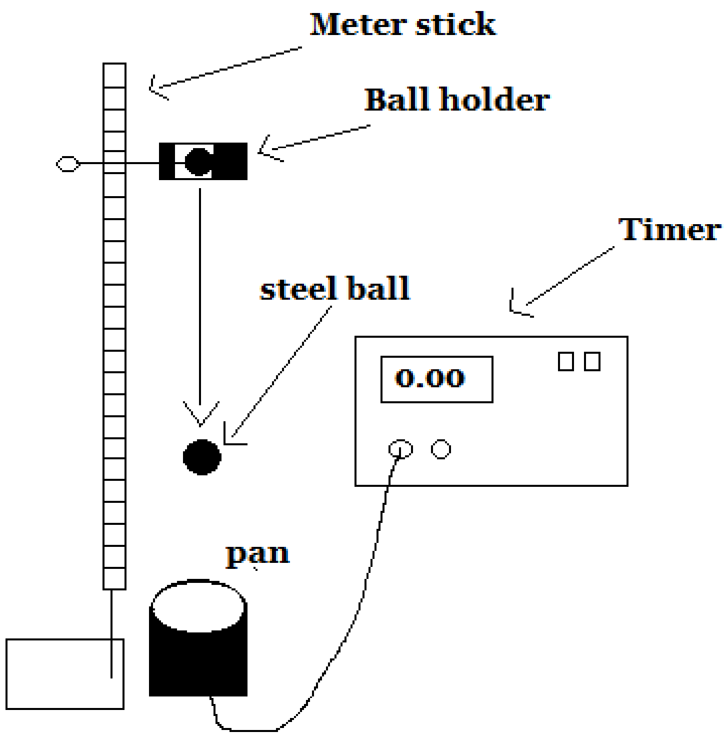
So, now the latter equation is simplified to a quadratic relationship:

$h = \frac{1}{2}gt^2$

By plotting $(h\ vs.\ t^2)$ we get $\frac{1}{2}g$ as slope, also by plotting $(\log h\ vs.\log t)$, the y-intercept has the value of $\log\frac{1}{2}g$, so we calculate the value of g from both graphs and then we take the average value.

Procedure:

The ball is dropped from a measured distance h, when the ball hit the pan below it, the stop switch for the timer is closed stopping the time measurement. This process is repeated another 5 times at different known heights.



Data Sheet:

$Height\ (m)$	$t_1\ (sec)$	$t_2\ (sec)$	$t_3\ (sec)$	$t_{avg}\ (sec)$	t^{α}	$log\ h$	$log\ t_{avg}$
0.4	0.285	0.287	0.292	0.288	0.083	−0.398	−0.541
0.5	0.318	0.319	0.319	0.319	0.101	−0.301	−0.497
0.6	0.351	0.350	0.355	0.352	0.124	−0.222	−0.453
0.7	0.379	0.381	0.383	0.381	0.145	−0.155	−0.419
0.8	0.407	0.404	0.407	0.406	0.165	−0.097	−0.391
0.9	0.432	0.43	0.427	0.430	0.184	−0.046	−0.367

Calculations:

From the first graph ($\log h \; vs. \log t$):

$\log h = \log \frac{1}{2} g + 2 \log t$

The theoretical slope 'α' for the graph is 2, our value is equal to $2.0012 \approx 2$

The y-intercept has a value of $\log \frac{1}{2} g$, We obtained $y\_int \approx 0.687$

$0.687 = \log \frac{1}{2} g \rightarrow 10^{0.687} = \frac{1}{2} g \rightarrow g = 2 \times 10^{0.687} = 9.7 \; m/s^2$

The error in this value:

$y\_int = \log \frac{1}{2} g \rightarrow g = 2 \times 10^{y\_int} \rightarrow \frac{\Delta g}{g} = \ln 10 \; \times \Delta y\_int$

$\rightarrow \Delta g = g \times (\ln 10 \; \times \Delta y\_int) = 9.7 \times (\ln 10 \times 0.012) = 0.3 \; m/s^2$

$\rightarrow \boldsymbol{g_1} = (\mathbf{9.7 \pm 0.3}) \; \boldsymbol{m/s^2}$

From the second graph ($h \; vs. \; t^{\alpha}$):

$h = \frac{1}{2} g t^{\alpha}$, the slope is equal to the value $\frac{1}{2} g$, our obtained value was $4.86 \; m/s^{\alpha}$, where α is equal to 2.

$slope = 4.86 = \frac{1}{2} g \rightarrow g = 2 \times 4.86 = 9.7 \; m/s^2$

The error in this value: $\frac{\Delta g}{g} = \frac{\Delta slope}{slope} \rightarrow \Delta g = \frac{\Delta slope}{slope} \times g = \frac{0.0564}{4.865} \times 9.7 = 0.11 \; m/s^2$

$\rightarrow \boldsymbol{g_1} = (\mathbf{9.7 \pm 0.11}) \; \boldsymbol{m/s^2}$

The average value of the acceleration due to gravity:

$g_{avg} = \frac{g_1 + g_2}{2} = \frac{9.7 + 9.7}{2} = 9.7 \; m/s^2$

Since the 2 values are equal, we cannot take the standard error of the mean (σ_m). Thus, the value which has the largest error is taken as the error of the mean:

$\rightarrow \boldsymbol{g_{avg}} = (\mathbf{9.7 \pm 0.3}) \boldsymbol{m/s^2}$

Results & Conclusions:

$$\boldsymbol{g = (9.7 \pm 0.3)\ m/s^2}$$

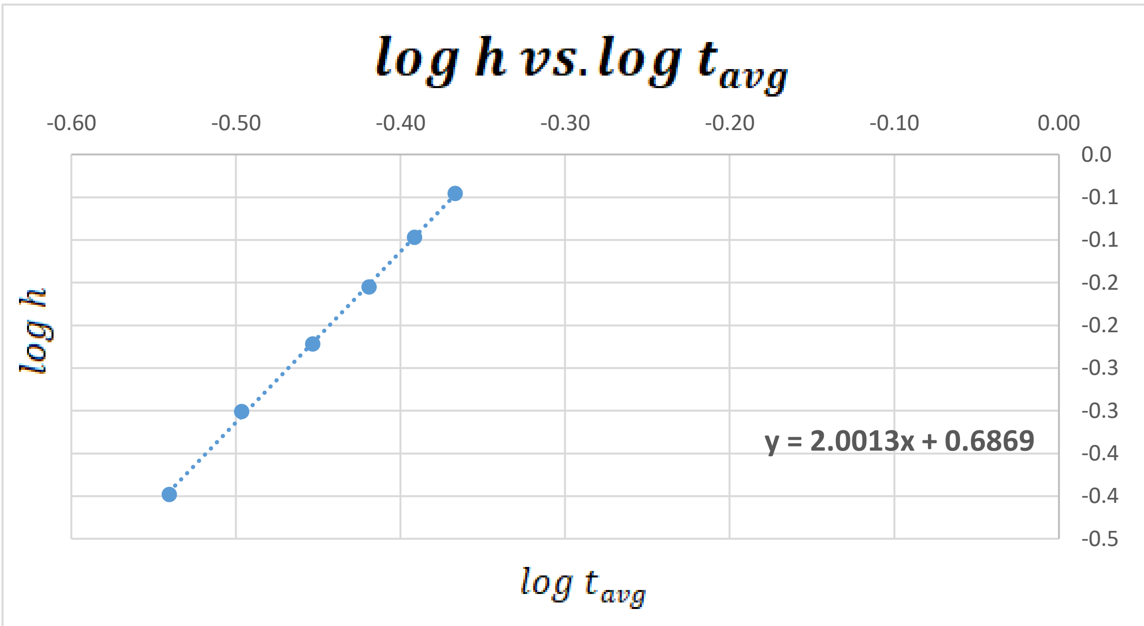
The theoretical value of the acceleration due to gravity at sea level is 9.8 m/s^2.

$Discrepancy = |g_{theo} - g_{exp}| = |9.8 - 9.7| = 0.1\ m/s^2$

It is clear that the value is accepted within the errors estimated. In fact, our value is very reasonable since Birzeit is higher than the sea level – about 788 m above sea level -, so the value is expected to be lower.

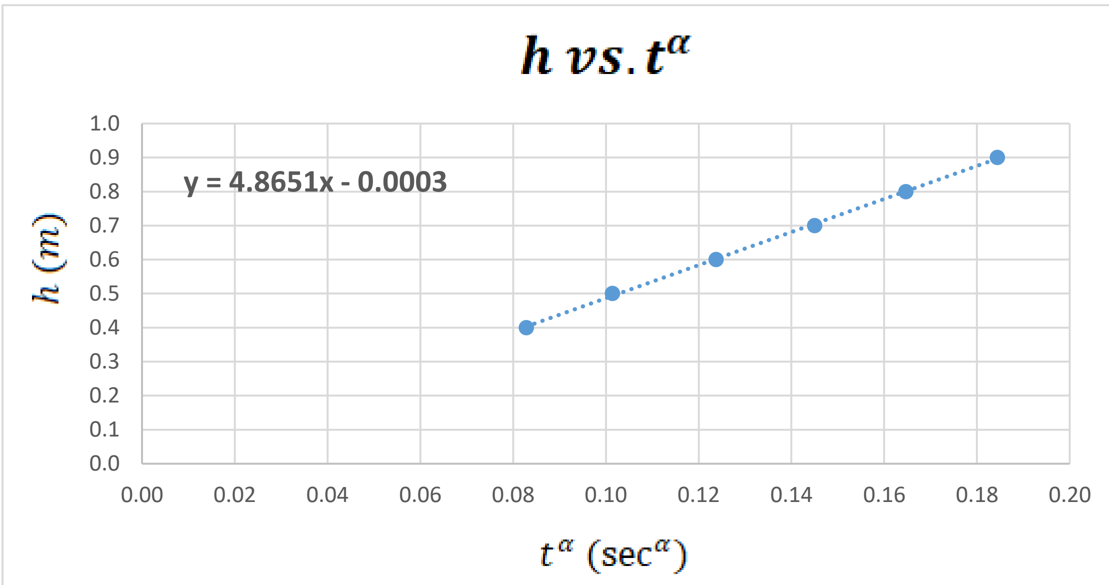
Not many sources of errors are found in this experiment. Air friction was very low in the room of the experiment and can be safely neglected in the calculations. 3 readings at every height were took, which decreases the opportunity of errors happening. Maybe the only reasonable errors were at establishing the ball holder at the meter stick at the specific height, and the error in the apparatus specially the timer.

Graph I



	slope	y-intercept
	2.001294	0.686893
error	0.026134	0.011727

Graph II



	slope	y-intercept
	4.865115	-0.00035
error	0.056392	0.007794