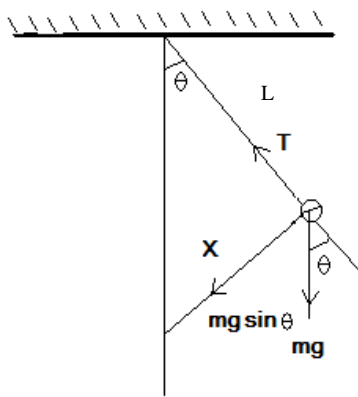


ABSTRACT:

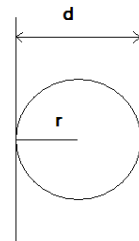
1. The aim of the experiment is: to measure the acceleration of gravity (g) at BZU.
2. The method used is: simple pendulum method.
3. The main result is : $g = 960 \pm 30 \text{ cm/s}^2$

THEORY:



First of all we have to make a few assumptions which are needed for making the experiment to be successful. Those assumptions are: the string is weightless, the ball is completely spherical, and the angle between the string and the normal is too small so that $q = \sin(q) = \tan(q)$ where q is the angle between the string and the normal measured with radian measure which is without a unit.

Where L is the length of the string taking in our accounts the radius of the ball where we take the radius and add it to the length of the string to have the right measurement we want to have to be accurate in the other measurements after it , surely , we took the radius of the ball because we considered the ball as spherical body 100%.



$$L = S + d / 2$$

We take :

$$mg \cos(q) = T$$

By Newton's second law:

$$F=ma$$

By substitution :

$$- mg \sin(q) = m \frac{d^2x}{dt^2}$$

While $\frac{d^2x}{dt^2} = - g \sin(q) @ - g \tan(q) = - g \frac{X}{L}$

$$\frac{d^2x}{dt^2} = - \frac{g}{L} X$$

So that the equation is a straight line equation :

$$X = A \sin(\omega t)$$

$$\frac{dx}{dt} = \omega A \cos(\omega t)$$

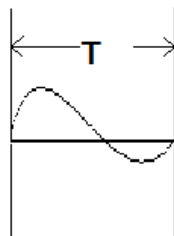
$$\frac{d^2x}{dt^2} = - \omega^2 A \sin(\omega t)$$

$$= - \omega^2 X$$

$$- \omega^2 X = - \frac{g}{L} X$$

$$\omega = \sqrt{g / L}$$

$$T = \frac{2\pi}{\omega} = 2\pi \sqrt{L / g}$$



To find the best estimation for the angle could be found for it to as small as we want by measuring the values of the sin & tan for a number of angles as shown in the table below(table2).

To find the wanted quantity which is (g) we make a graph of T^2 vs. L we find the slope $\frac{4\pi^2}{g}$ and so we find (g).

The error could be found by the following :

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

$$\text{Then } Dg = \frac{4p^2}{m^2} Dm \text{ \& } \frac{Dg}{g} = \frac{Dm}{m}$$

For the graph which we are going to draw :

After we draw the points on the graph we start to find the best equation of the straight line for the points, of course we find this equation by finding the best slope , and the best Y-intercept for the equation.

The best estimation for the best line is that line that intersects the larger number of the data points, and also is the line that the points on each side of it have the same sum of distances, between it and the line, and those on the other side.

Simply we make a calculation for the estimated distances for the points from the line and then we make the real and best equation for the line.

Those equations are shown in the calculations below.

First we draw the points and then we draw the line from the equation get from the calculations, so that we consider if our work is good or there is some errors in it.

PROCEDURE:

First of all we took the measurement of the radius of the ball with a caliper by taking the measurement of diameter and dividing it by 2.

$$\text{Radius} = \text{diameter}/2$$

Then we fixed the pendulum on the table after fixing the string and the ball strongly on the stand.

Then we measured the length of the string to the edge of the ball and added it to our measurement of the radius which we took before and wrote it in the table below.

After that we fixed the angle of the string (between it and the normal) to be at most 15 degrees. At that moment we let the ball to oscillate freely ,after starting the timer with it , for ten times and then stopped the timer and measured that period and wrote it down in the table. We repeated the measurement of time for the same situation each time for three times and at the end we took the average of them to have the right time.

We increased the length of the string each time of about 20-30 cm and repeated our measurements ,but , keeping the angle to be almost the same.

DATA:

No.	S	L				t	One	t^2
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	(string length-cm)	(Whole length-cm)	t1	t2	t3	average	period	sec ²
1	47.40	48.420	13.77	13.77	13.86	13.80	1.380	1.904
2	78.30	79.320	17.87	17.72	17.80	17.80	1.780	3.167
3	106.5	107.52	20.87	20.63	20.59	20.70	2.070	4.284
4	142.6	143.62	23.33	23.91	23.86	23.70	2.370	5.618
5	156.7	157.72	25.52	25.69	25.63	25.61	2.561	6.560
6	182.2	183.22	27.20	27.36	27.33	27.30	2.730	7.451

$$\text{Diameter} = 2.04 \text{ cm}$$

$$\text{Radius} = \text{diameter}/2 = 2.04/2 = 1.02 \text{ cm}$$

We add the radius to the string length (S) to get the whole length wanted (L).

q degrees	q radian	$\sin(q)$	$\tan(q)$	$\frac{\tan(q) - \sin(q)}{\tan(q)} \cdot 100\%$
5	0.0873	0.0872	0.0875	0.38%
10	0.175	0.174	0.176	1.52%
15	0.262	0.259	0.268	3.41%
20	0.349	0.342	0.364	6.03%
30	0.524	0.500	0.577	13.4%
45	0.785	0.707	1.00	29.3%
60	1.05	0.866	1.73	50.0%
75	1.31	0.966	3.73	74.1%

From the table above we see that the angle in radian equals its sin and also its cos during the range of 0 – 20 degrees but not above that range so that we used the angle to be small enough which is almost 15 degrees to fit with the differentiated formula which depends on the tan of the angle which equals it.

CALCULATIONS:

$$A = \sum_{i=1}^6 L_i = 719.82 \quad \text{cm} \quad H = \sum_{i=1}^6 T_i^2 = 28.98354211 \quad \text{s}^2$$

$$F = \sum_{i=1}^6 L_i T_i^2 = 4010.595351 \quad \text{cm.s}^2 \quad Z = \sum_{i=1}^6 L_i^2 = 99268.5804 \quad \text{cm}^2$$

$$\overline{T^2} = 4.830590352 \quad \text{s}^2$$

$$\overline{L} = 119.97 \quad \text{cm}$$

For demonstration here are the values for LT^2 from which we calculated the sum of them:

The values of LT^2

92.211048 **251.223370** **460.5640823** **806.699178** **1034.710774** **1365.186898**

$$D = N \left(\sum_{i=1}^6 L_i^2 \right) - \left(\sum_{i=1}^6 L_i \right)^2 = 6(99268.5804) - (518140.832) = 77470.65$$

$$\text{Best slope, } m = \frac{N \times F - A \times H}{D} = \frac{6(4010.595351) - (719.82)(28.98354)}{77470.65} = 0.041314$$

$$\gg 0.04 \text{ s}^2/\text{cm}$$

$$\text{Best y-intercept, } b = \frac{Z \times H - A \times F}{D} =$$

$$= \frac{(99268.5804)(28.98354211) - (719.82)(4010.595351)}{77470.65} = -0.125875608$$

So that we see that the equation of the best line is :

$$y = 0.041314 x - 0.125875608$$

For calculating the error :

$k_i = T_i^2 - mL_i - b$	0.029841	0.016056	-0.032708	-0.19077	0.17023	0.0073659
k_i^2	0.00089051	0.00025747	0.0010698	0.036394	0.028977	0.000054256

$$\sum_{i=1}^6 k_i^2 = 0.0676429$$

$$\sigma_y^2 = \frac{1}{N-2} \sum_{i=1}^6 k_i^2 = 0.016910729$$

$$\sigma_m^2 = \frac{N\sigma_y^2}{D} = 2.455932013$$

$$Dm = 1.56714135$$

$$\sigma_b^2 = \frac{\sigma_y^2}{D} Z = 40632.814$$

$$Db = 201.57583$$

$$g = \frac{4p^2}{m} = 955.5672614 = 960 \text{ cm/s}^2$$

For calculating the error in g :

$$\frac{Dg}{g} = \frac{Dm}{m} \rightarrow Dg = g \frac{Dm}{m}$$

$$Dg = 955.5672614 \cdot \frac{1.56714135}{0.041314} = 26.469 \gg 30 \text{ cm/s}^2$$

Then:

$$g = 960 \pm 30 \text{ cm/s}^2$$

RESULTS AND CONCLUSION:

$$g = 960 \pm 30 \text{ cm/s}^2$$

First we say that the real known (g) nationally is to equal (9.81 m/s^2), but in our case here we see that it differs, but , that is normal because as we know that the place we tried to measure it from is higher than the sea level from which the national value for the known (g) were measured. As a result for the high level we expect that the value for (g) will be smaller, and this results from the general law of gravitation were the center of earth will be farther than the sea level and so the radius of earth at that point which affects the result to be less than known. So that we see that the result is within the expected new value for the location of Birzeit university where we made the experiment.

About the experimental errors, we always expect some systematic errors and also random errors (which always occur) to be found as there is no perfect results could be obtained in any experiment in the real world as always we return our measurements to our senses and also our tools which are also inaccurate or not accurate as we hope to make perfect results.

One expected error is caused from the measurement of time lasted for the oscillating of the pendulum and that error is a result of the delay of our natural response between the two operations of seeing the moment of the stop or the starting of the pendulum and the moment when the brain responds and sends the signal to make the timer tool stops or starts and that affects the measurement of time intervals and that would of course affect also our later calculations. (It is as we know some mental operation which lasts of about 0.1 of a second).

A second expected error is that we supposed the cord to be weightless and that the ball is completely spherical and also our neglect of the air friction with our ball. These all are factors which would affect the measurement but we neglect them all because , of course , of the simple ways we use, the simple tools we have, and because the aim of the experiment is only to learn simple method for measuring things which looks so complicated, but not to find the real exact value for the wanted variable.

There is another point which we must consider always which is that the line we draw on the plot sheet is not always accurate and that returns for some reasons which depends on the scale we use and other factors. But one of the important things which makes a difference, of course after the scale we take according to the paper we have, is the thickness of the pencil we use to draw the line and that always makes a difference from what we want.

