



Digital version

ENGS121 Mechanics Lab Section B

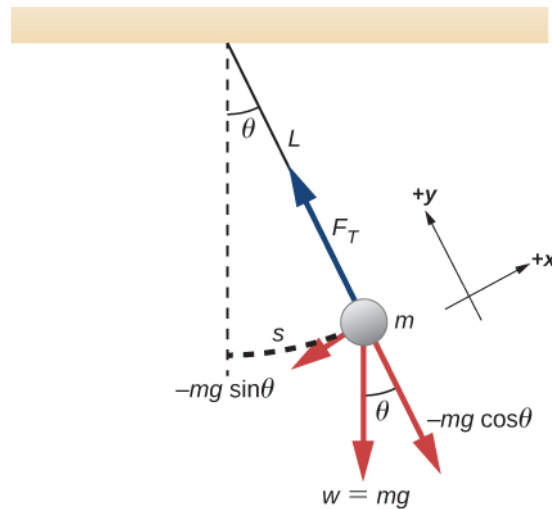
Measuring the period of oscillations of a pendulum and reaction time of a person

Mher Saribekyan A09210183

April 21, 2024

1 Introduction

This experiment investigates the period of a pendulum. The period of a pendulum can be derived by solving a differential equation, that was constructed from the diagram of a pendulum:

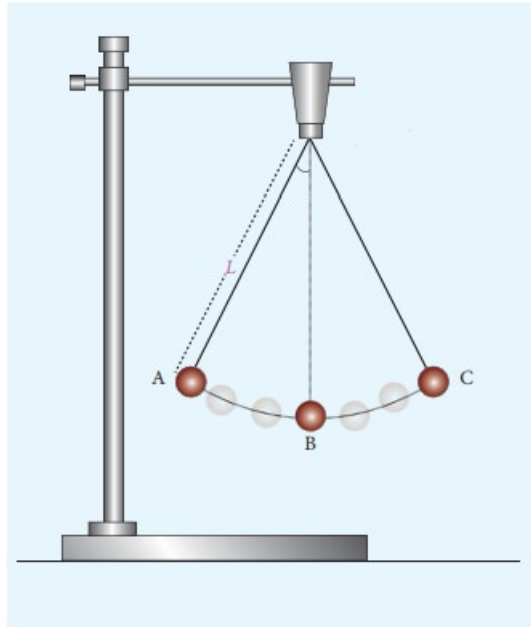


$$\frac{d^2\theta}{dt^2} + \frac{g}{L} \sin \theta = 0$$

For this experiment, the approximation of $\sin \theta \approx \theta$ was used to investigate the formula for the period of a pendulum $T = 2\pi\sqrt{\frac{L}{g}}$.

2 Measurements and data

A pendulum was constructed with a measured length of string from the clamp to the center of mass of the metal ball. A group of 10 oscillation with a consistent low amplitude were repeated for 60 rounds, and the time for each round was recorded.



A supplementary experiment was carried out to test the reaction time of a student. Fingers of a student were held at the 0cm marking of a 30cm ruler, and the objective was to catch the ruler as fast as possible, after the other student let it go. It was repeated 10 times.

Variable	Value	Resolution
Length of string	Controlled	1mm
Amplitude	Controlled	2cm
Period	Measured	0.1s

Table 1: List of variables

Instrument or material	Description
Ruler	A long ruler of at least 30cm, with a resolution of 1mm.
Stand	Stand
Stopwatch	A smartphone was used, with 0.01 s resolution
String	As long as the ruler
Metal Ball	Heavy, to provide stability

Table 2: List of instruments and materials

Source of error	Type of error	Countermeasures
Reaction time	Random and Systematic	Repeating oscillations 10 times, lessens the role of reaction time. Moreover, the string was taken as long as possible, to make the period longer and the effect of reaction time less
Amplitude	Systematic	As mentioned above, the period formula is an approximation, which only holds for small angles. Hence, a low amplitude was used

Table 3: Estimated errors

String length: 40.0cm.

n	1	2	3	4	5	6	7	8	9	10
t (s)	13.07	13.09	13.07	13.12	13.07	13.26	13.16	13.14	13.16	13.26
n	11	12	13	14	15	16	17	18	19	20
t (s)	12.86	13.11	12.99	13.24	13.06	13.14	13.16	13.06	13.07	13.16
n	21	22	23	24	25	26	27	28	29	30
t (s)	13.17	13.21	13.32	13.34	13.21	13.06	13.27	13.24	13.14	13.37
n	31	32	33	34	35	36	37	38	39	40
t (s)	13.11	13.07	13.03	13.26	13.21	13.17	13.33	13.21	13.26	13.27
n	41	42	43	44	45	46	47	48	49	50
t (s)	13.22	13.27	13.24	13.07	13.22	13.12	13.14	13.36	13.09	13.27
n	51	52	53	54	55	56	57	58	59	60
t (s)	13.34	13.27	13.39	13.24	13.12	13.06	13.46	13.01	13.23	13.24

Table 4: Raw Oscillation Data

n	1	2	3	4	5	6	7	8	9	10
x(cm)	17	20	13	17	18	27	17	22	19	16

Table 5: Reaction Time Data

3 Calculations and plots

The oscillation times were divided by 10, to get the time of a single oscillation.

n	1	2	3	4	5	6	7	8	9	10
t (s)	1.307	1.309	1.307	1.312	1.307	1.326	1.316	1.314	1.316	1.326
n	11	12	13	14	15	16	17	18	19	20
t (s)	1.286	1.311	1.299	1.324	1.306	1.314	1.316	1.306	1.307	1.316
n	21	22	23	24	25	26	27	28	29	30
t (s)	1.317	1.321	1.332	1.334	1.321	1.306	1.327	1.324	1.314	1.337
n	31	32	33	34	35	36	37	38	39	40
t (s)	1.311	1.307	1.303	1.326	1.321	1.317	1.333	1.321	1.326	1.327
n	41	42	43	44	45	46	47	48	49	50
t (s)	1.322	1.327	1.324	1.307	1.322	1.312	1.314	1.336	1.309	1.327
n	51	52	53	54	55	56	57	58	59	60
t (s)	1.334	1.327	1.339	1.324	1.312	1.306	1.346	1.301	1.323	1.324

Table 6: Oscillation Data

Frequency distribution and probability density distribution histograms were drawn, taking a bin size of 0.01s. It was assumed a measurement error of 0.1s, which results in 0.01s error in the calculated data. Hence, choosing a smaller bin size does not make calculations any more accurate.

Interval (s)	Midpoint (s)	Frequency	Probability	Probability Density
1.280-1.290	1.285	1	0.0167	1.67
1.290-1.300	1.295	1	0.0167	1.67
1.300-1.310	1.305	14	0.2333	23.33
1.310-1.320	1.315	15	0.2500	25.00
1.320-1.330	1.325	21	0.3500	35.00
1.330-1.340	1.335	7	0.1167	11.67
1.340-1.350	1.345	1	0.0167	1.67

Table 7: Oscillation Data

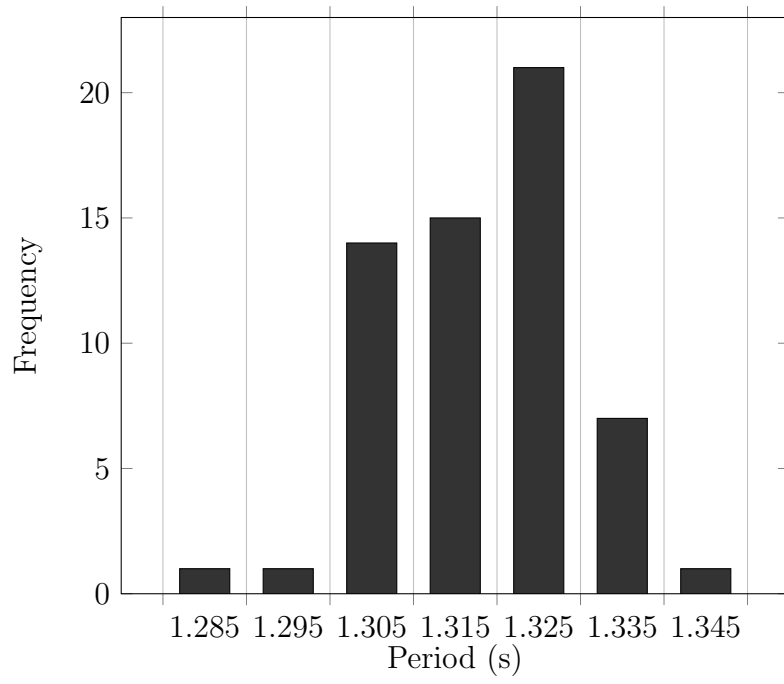


Figure 1: Frequency distribution

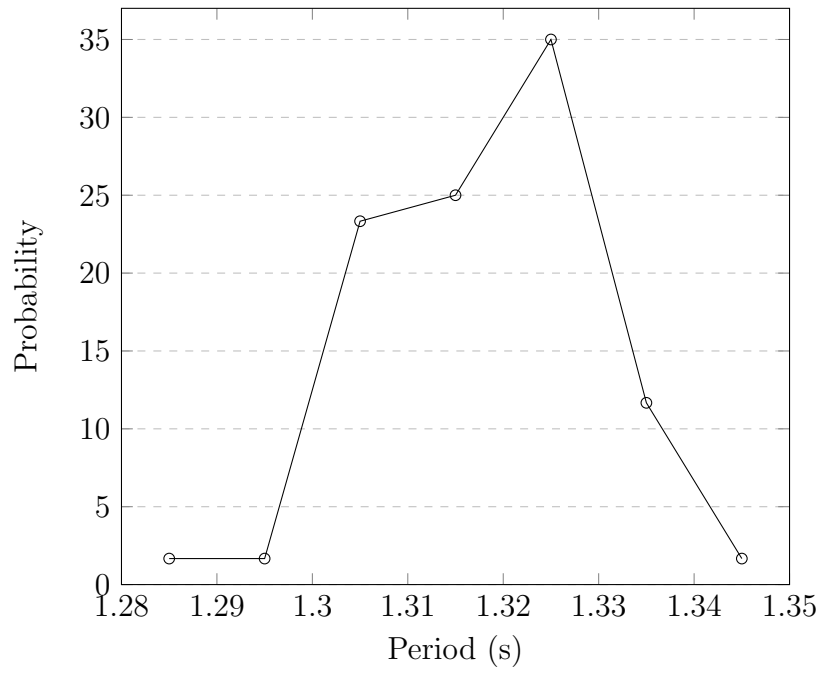


Figure 2: Probability Density Function

4 Evaluation

Most values have a value above 1, which is because this a probability density function and the area underneath the function does not represent a probability. From the Probability distribution function, we have $T_{peak} = 1.325s$, $T_{mean} = 1.318s$ and $\sigma = 0.011s$. T_{peak} is greater than T_{mean} , because we are working with random data and all situation can happen, regarding T_{peak} and T_{mean} . From the standard deviation, we get the following confidence intervals:

65%	95%	99%
$T_{mean} \pm \sigma$	$T_{mean} \pm 2\sigma$	$T_{mean} \pm 3\sigma$
$1.318 \pm 0.01s$	$1.318 \pm 0.02s$	$1.318 \pm 0.03s$

Table 8: Confidence intervals

Using the approximation in the Introduction, the value of the gravitation constant is $g = \frac{4\pi^2 L}{T^2} = \frac{4\pi^2 \cdot 0.4}{1.325^2} \approx 9.00m/s^2$, which gives an error of 8% from the agreed value of $9.8m/s^2$. From the supplementary experiment, the reaction time is estimated to be $0.19s$. The reaction time is much higher than the standard deviation of our data, suggesting that we have a systematic error in our experiment. Even though the measurements were precise, the systematic error of reaction time reduced the accuracy of the results.

5 Conclusion

An experiment was carried out to investigate the period of a pendulum and find the effect of reaction time on the measurements. The value of the gravitation constant was calculated and compared with the agreed value with an 8% accuracy.

References

- Kurghinyan, B. (2024, Mar). *Analysis of random continuous data*.
- OpenStax. (2016, Aug). *15.4 pendulums*. Retrieved from <https://pressbooks.online.ucf.edu/phy2048tjb/chapter/15-4-pendulums/>