



ASTRONOMY, SPACE SCIENCE AND ASTROPHYSICS

Deduction of a Law

STAGE 1 - PH370 PHYSICS LABS

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1 Abstract

Within this experiment, using [1] as a guide, will prove if a materials physical property has any change on its period of oscillation, it will be found that in small changes of its specific physical property, no change is seen in terms of its period of oscillation. Only in larger value differences will the period of oscillation see significant change.

2 Introduction

This is quite a short scripted experiment, the purpose is to find the relationship between the period of a mechanical oscillator via physical properties e.g. mass, volume, area, thickness, density and side length. This will be done first empirically and then theoretically, when completed the moment of inertia of a rectangular parallelepiped about axis through centre perpendicular to its face, this will be then used to calculate the acceleration due to gravity.

3 Aims & Equipment

3.1 Apparatus

- Electronic scales
- Bosshead
- 30cm steel rule
- Graph paper
- Suspension bar
- Stop clock
- Retort stand
- Metre rule
- Various sized metal/
plastic squares
- x4 Metal square
(20cm x 20cm)

3.2 Data Collected

- Mass of squares
- Area of squares
- Density of squares
- Thickness of squares
- Volume of squares
- Length of sides of
squares
- The period of oscillation
- Acceleration due to
gravity

3.3 Risk Assessment

In this experiment, there are two potential hazards that could occur. The first involves swinging metal plates, the second is equipment falling off the desk. Both of these hazards have the potential to cause bruising/ injury to feet and the lower body.

The above hazards can be controlled by moving the equipment away from the edges of the desk and keeping them in the middle of the desk, the retort stand will be secured to the desk via a G-clamp.

4 Experimental Procedure

The experiment started by selected squares with one similar physical property e.g. area, thickness, density and side length. This fixed variable was the same for five selected squares, five square for each one fixed physical property, this allows for a fair analysis when comparing how the fixed physical property affects the period of oscillation. When selecting a fixed physical property, each of the five squares are measured for different physical properties e.g. mass, volume, area, thickness, density and side length. The measurement of the varied physical property each square contains has the potential to alter the individual squares period of oscillation.

As the squares are of small measurement and the angle of attack is large, there is a lot of potential human error when timing the period of oscillation, thus to deter the amount of human error that affects the recording of the period of oscillation, the squares will complete 20 oscillations fully timed, then will divide the overall time by 20 to get one period of oscillation for each square. Then the period of oscillations for each square will be plotted against their own chosen physical property.

5 Results & Discussion

5.1 Task 3.1 - Moment of Inertia

Moment of Inertia for a rectangle through its centre of mass;

$$I_{cm} = M \times (a^2 + b^2) \quad (1)$$

Where;

$I_{cm} \Rightarrow$ Moment of Inertia at centre of mass

$a + b \Rightarrow$ Height & length of rectangle

$M \Rightarrow$ Mass

Parallel Axis Theorem ;

$$I = I_{cm} + (M \times h^2) \quad (2)$$

Where;

$I_{cm} \Rightarrow$ Moment of Inertia at centre of mass

$h \Rightarrow$ Distance between centre of mass and pivot

$M \Rightarrow$ Mass

Therefore;

$$I = (M \times (a^2 + b^2)) + (M \times h^2) \quad (3)$$

Where;

$h \Rightarrow$ Distance between centre of mass and pivot

$a + b \Rightarrow$ Height & length of rectangle

$M \Rightarrow$ Mass

5.2 Task 3.2 - Period of Oscillation

Table 1: Area vs Period

Area (mm ²)	Period (s)
22,201	0.705
12,100	0.622
3,136	0.433
2,401	0.422
4,900	0.472

Table 3: Thickness Vs Period

Thickness (mm)	Period (s)
3.02	0.844
5.01	0.819
7.96	0.835
10.06	0.832
11.96	0.827

Table 2: Density Vs Period

Density (g/mm ³)	Period (s)
1.156×10^{-3}	0.716
9.978×10^{-4}	0.708
1.216×10^{-3}	0.702

Table 4: Side Length Vs Period

Side Length (mm)	Period (s)
149	0.705
110	0.622
56	0.433
49	0.422
70	0.472

5.3 Task 3.3 - Physical Properties Vs Period Graphs

Table 5: Period Vs Area Results

Side Length (mm)	Thickness (mm)	Area (mm ²)	Volume (mm ³)	Mass (g)	Period (s)
149	4.89	22,201	108,592.23	134.12	0.705
110	4.86	12,100	58,806	41.20	0.622
56	4.88	3,136	15,303.68	23.84	0.433
49	4.76	2,401	11,428.76	16.68	0.422
70	4.78	4,900	22,422	31.78	0.472

Table 6: Period Vs Density Results

Side Length (mm)	Thickness (mm)	Volume (mm ³)	Density (g/mm ³)	Mass (g)	Period (s)
149	4.98	110,560.98	1.156×10^{-3}	127.85	0.716
149	4.98	110,560.98	9.978×10^{-4}	110.32	0.708
149	4.98	110,560.98	1.216×10^{-3}	134.46	0.702

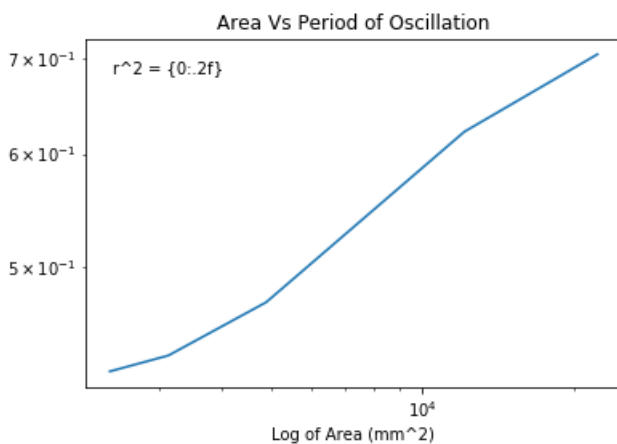


Figure 1: Area Vs Period Graph.

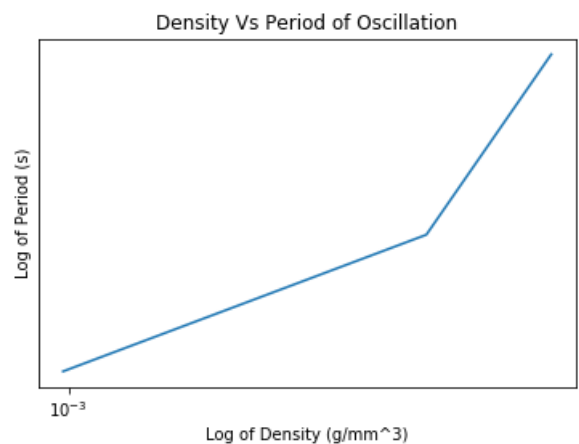


Figure 2: Density Vs Period Graph.

Table 7: Area vs Period

Log of Area (mm ²)	Log of Period (s)
10.0078926	-0.3495575
9.40096073	-0.4748152
8.05070338	-0.8370176
7.7836406	-0.86275
8.49699048	-0.7507763

Table 8: Density Vs Period

Log of Density (g/mm ³)	Log of Period (s)
-6.7627895	-0.3347737
-6.9099577	-0.3460176
-6.7121885	-0.3545344

Table 9: Period Vs Thickness Results

Side Length (mm)	Thickness (mm)	Area (mm ²)	Volume (mm ³)	Mass (g)	Period (s)
200	3.02	40200	121,404	122.67	0.844
200	5.01	40200	608,234.04	196.43	0.819
200	7.96	40200	4,841,542.958	315.67	0.835
200	10.06	40200	48,705,922.16	395.85	0.832
200	11.96	40200	582,522,829.10	469.78	0.827

Table 10: Period Vs Side Length Results

Side Length (mm)	Thickness (mm)	Area (mm ²)	Volume (mm ³)	Mass (g)	Period (s)
149	4.89	22,201	108,592.23	134.12	0.705
110	4.86	12,100	58,806	41.20	0.622
56	4.88	3,136	15,303.68	23.84	0.433
49	4.76	2,401	11,428.76	16.68	0.422
70	4.78	4,900	22,422	31.78	0.472

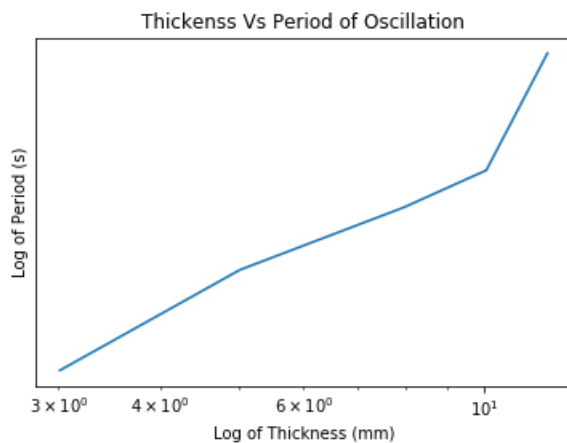


Figure 3: Thickness Vs Period Graph.

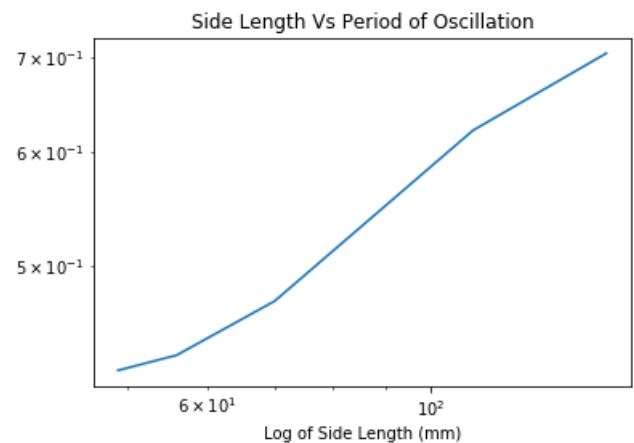


Figure 4: Side Length Vs Period Graph.

Table 11: Thickness Vs Period

Log of Thickness (mm)	Log of Period (s)
1.10194008	-0.1696028
1.61143592	-0.2002819
2.074429	-0.1809225
2.30856717	-0.184524
2.48156775	-0.1905554

Table 12: Side Length Vs Period

Side Length (mm)	Period (s)
5.00394631	-0.3502669
4.70048037	-0.4748152
4.02535169	-0.838173
3.8918203	-0.86275
4.24849524	-0.7507763

5.4 Theoretical Considerations

Period of a Pendulum;

$$T = 2\pi \times \sqrt{\frac{I}{Mgd}} \quad (4)$$

Where;

$d \Rightarrow$ Distance between centre of mass and pivot

$g \Rightarrow$ Gravitational Constant

$I \Rightarrow$ Moment of Inertia

$M \Rightarrow$ Mass

Moment of Inertia for the Period for a Pendulum.

$$T = 2\pi \times \sqrt{\frac{I}{Mgd}} \rightarrow 2\pi \times \sqrt{\frac{(a^2 + b^2) + h^2}{gd}} \quad (5)$$

5.5 Task 4.1 - Theory Vs Empirical

Comparing both the theoretical formula in section 5.4 against the empirical formulas received from the graphs, it can be seen that they are show no relationship.

5.6 Task 4.2 - Acceleration due to Gravity

$$T = 2\pi \times \sqrt{\frac{(a^2 + b^2) + h^2}{gd}} \quad (6)$$

$$\left(\frac{T}{2\pi}\right)^2 = \frac{(a^2 + b^2) + h^2}{gd} \quad (7)$$

$$\frac{(a^2 + b^2) + h^2}{\left(\frac{T}{2\pi}\right)^2} = gd \quad (8)$$

$$g = \frac{(a^2 + b^2) + h^2}{d \left(\frac{T}{2\pi}\right)^2} \quad (9)$$

6 Analysis

Plotting the natural log of each physical property and its individual period of oscillation shows that there is not a clear relationship between these physical properties and the period of oscillation. By analyzing the graphs and tables, it shows little change when each physical property was larger or smaller, the period of oscillation remained the same with a small tolerance. The only physical property that changed the period of oscillation was Area, where even the second highest area produced a lower period whether this abnormality was due to human error or is practically proven is unclear but reviewing the results, human error seems to play a huge part within this experiment.

7 Conclusion

In terms of the whole experiment, it was carried out in a fair standard. Within the mathematical side of the experiment, all measurements had fixed errors and no human error was at play but the physical measurement of the oscillation of each square was purely down to human error, where it was not truly fair and thus being inaccurate, there were delays in counting the oscillations by eye and starting/ stopping the stopwatch. All in all this experiment proved that physical properties do not have much effect in their periods of oscillation, only if the difference in each plate's physical property was at a larger value may it be found that physical property changes the period of oscillation.

References

- [1] G. Roch. Llr.3 deduction of a law. University of Kent Moodle 2017, June 2017. LLR.3 Lab script.