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‘The conservation of Energy within a Flywheel’

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Introduction

This report provides a detailed technical analysis of a kinetic energy experiment conducted to investigate the effects of varying masses which are being subjected to gravitational acceleration. The main objective regarding the experiment is to observe the way in which these, when effected by gravity (falling due to gravity), cause a flywheel with controlled properties to rotate. With the collection and analysis of this data, the experiment aims to confirm the expected values related to the flywheel's motion and energy transfer ([Beck,2022](#)).

This experiment demonstrates the conversion of gravitational potential energy into rotational kinetic energy as the falling masses make the flywheel spin, thus storing energy in the process. As the mass arrives at its lowest point, the stored energy within the flywheel is harnessed to lift the mass up to its starting height.

This back-and-forth energy transfer is a thorough example on the 'Law of conservation of mass' (. Which states that energy cannot be created or destroyed, only changed from one form to another. By altering the mass and measuring the direct effects on the flywheel, the law of the conservation of mass is proven in a practical way visually and through comprehensible graphical data.

Experimental Procedure

Equipment:
Weight Hanger
Magnetic Ruler
Weights:
10 x 10g = 100g (0.1 kg)
20 x 10g = 200g (0.2 kg)
30 x 10g = 300g (0.3 kg)
40 x 10g = 400g (0.4 kg)
50 x 10g = 500g (0.5 kg)



Figure 1 Required Equipment

During the simple spring test conducted for one of the experiments the guide should be securely attached to the bottom of the weight hanger to ensure detailed and accurate measurements to record.

Following this, place the magnetic ruler directly behind the guide with appropriate alignment taken into consideration. This allows the ruler to act as a fixed reference point for the experiments. The ruler should be used to track the downward elongation of the spring system as weights are applied in the range of 100g-500g (0.1 kg-0.5 kg) at intervals of 100 g (0.1 kg).

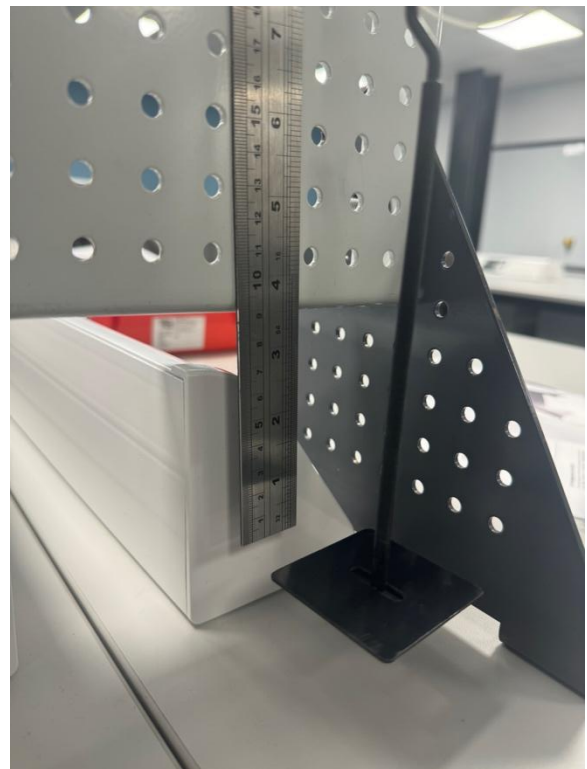


Figure 2 Ruler Guide/ Weight Hanger

At the beginning of the experiment, it is essential to determine the total number of weights that will be used for data collection. To ensure consistency, the process starts by carefully counting the number of weights for the first increment. In this initial stage, a total of 10 weights is selected. Given that each individual weight has a mass of 10g, the combined mass for the first increment = $(10 \times 10\text{g} = 0.1\text{ kg})$. this value has been selected as the starting point as it provides an optimal balance between measurable results whilst maintaining accuracy throughout the experiment.



Figure 3 Counting Weights (carefully)

The experiment follows a structured approach where data is collected in five increments. The first increment, consisting of 0.1 kg, shows $\frac{1}{5}$ of the total weight progression planned for the experiment. As subsequent additional increments are introduced, the weight will gradually increase to provide a broader range of data to analyse.



Figure 4 Weight = $(10 \times 10\text{g} = 0.1\text{ kg})$

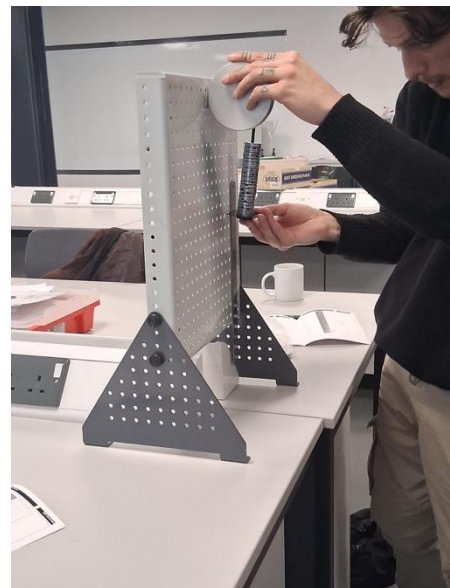


Figure 5 Weight = $(50 \times 10\text{g} = 0.5\text{ kg})$

Results

Mass (kg)	Time (seconds)
0.1	4.45
	4.21
	3.9
Average	
(seconds):	
	4.19

Mass (kg)	Time (seconds)
0.4	1.83
	1.95
	2.05
Average	
(seconds):	
	1.94

Mass (kg)	Time (seconds)
0.2	2.71
	2.69
	2.85
Average	
(seconds):	
	2.75

Mass (kg)	Time (seconds)
0.5	1.61
	1.95
	1.78
Average	
(seconds):	
	1.78

Mass (kg)	Time (seconds)
0.3	2.35
	2.51
	2.78
Average	
(seconds):	
	2.55

Mass of Flywheel
m_f
(kg)
0.390

The results from the experiment are recorded in a structured format for analysis. On the left-hand side, the table displays the mass (kg) of the weight used in each increment. This represents different loads being applied to the weight hanger. On the right-hand side, the table shows the time (seconds) required for the weight to return to its original starting point (point at which weight hanger is released). At the bottom of each table, an average time (seconds) is calculated to give a more accurate measure of the time to fall and rise for the weights. This average time is calculated by taking the total sum of the three recorded times for each mass respectively and then dividing the result by 3 (the number of times the weight hanger is released from its starting position).

$$\text{I.e. Average 'Time to Fall and Rise' (tt)} \quad \left(\frac{4.45 + 4.21 + 3.90}{3} \right) = 4.19$$

Analysis

	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
12															
13															
14															
15															

Figure 7 Accurized Data from Experiment using appropriate formulae

Formulae:

To Calculate 'Initial **PE** (mgh_1)': $m \cdot g \cdot h_1$
 $0.1 \cdot 9.81 \cdot 0.28 = 0.27468 \text{ J}$

To Calculate 'Initial **PE** (mgh_1)' in Excel: **=SUM((E9*\$H\$4))*\$E\$4**

To Calculate '**PE loss**': $m \cdot g \cdot h_1 - m \cdot g \cdot h_2$
 $0.1 \cdot 9.81 \cdot (0.28 - 0.235) = 0.044145 \text{ J}$

To Calculate '**PE loss**' in Excel: **=E9*\$H\$4*(\$E\$4-H9)**

To Calculate '**PE_{loss}** (adjusted)':

$$\text{PE}_{\text{loss}} = 0.044 \cdot \left(\frac{h_1}{h_1 + h_2} \right) = 0.0239223301 \text{ J}$$

To Calculate '**PE_{loss}** (adjusted in **Excel**): =J9*(\$E\$4/(\$E\$4+H9))

To Calculate **mg** :

$$m \cdot g = 0.1 \cdot 9.81 = 0.981 \text{ N}$$

To Calculate **mg** in Excel: =SUM((E9*\$H\$4))

To Calculate **Falling Time(tf)** :

$$t_t = 4.190 \cdot \left(\frac{h_1}{h_1 + h_2} \right) = 2.278058252 \text{ s}$$

To Calculate **Falling Time(tf)** in Excel: =G9*(\$E\$4/(\$E\$4+H9))

$$\text{To Calculate Acceleration (a): } \frac{h_1}{\left(\frac{2 \cdot 0.28}{t_f^2} \right)} = 0.107725454 \text{ (m.s}^{-2}\text{)}$$

To Calculate **Acceleration (a)**: =2*\$E\$4/(L9^2)

$$\text{To Calculate Velocity (v): } \frac{a \cdot t_f}{0.108 \cdot 2.280} = 0.24624 \text{ (m.s}^{-1}\text{)}$$

To Calculate **Velocity (v)** in Excel: =(M9*L9)

$$\text{To Calculate Velocity (}\omega\text{): } \frac{\pi \cdot v}{\left(\frac{2\pi \cdot 0.246}{0.0408} \right) \cdot c} = 37.88391141 \text{ (rad.s}^{-1}\text{)}$$

To Calculate **Velocity (ω)** in Excel: =(2*\$J\$4*N9)/\$G\$4

$$\text{To Calculate Velocity } (\tau): \quad \frac{m \cdot g - m \cdot a}{r} = \frac{(0.1 \cdot 9.81 - 0.1 \cdot 0.108)}{0.0065} = 0.0063063 \text{ } \tau$$

To Calculate **Velocity (τ)** in Excel: `=F$4*E9*(H$4-M9)`

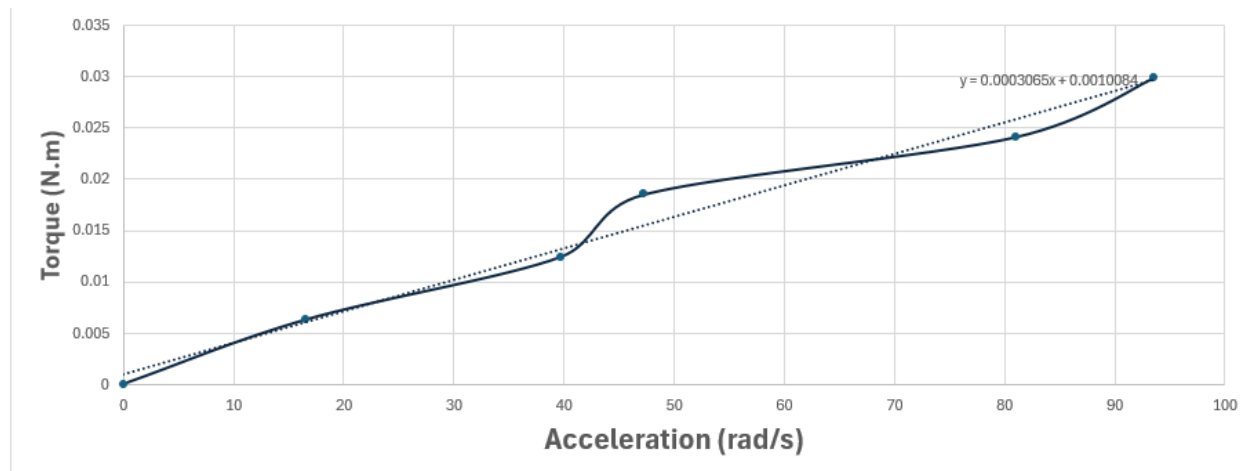
$$\text{To Calculate } a/r \text{ (a):} \quad \frac{a}{r} = \frac{0.108}{0.0065} = 16.61538462$$

To Calculate **a/r (a)** in Excel : `=M9/F$4`

$$\text{To Calculate Moment of Inertia } (I_f): \quad \frac{M_f \cdot r}{2} = \frac{0.5 \cdot 0.390 \cdot (0.0065^2)}{2} = 8.23875 \times 10^{-6} \text{ (kg.m}^2\text{)}$$

To Calculate **Moment of Inertia (I_f)** in Excel : `=0.5*B4*(F4^2)`

To Calculate **Total Moment of Inertia (I_t)**:



= **0.00030650** (kg.m²)

To Calculate **Kinetic Energy (KE)** : $0.5 \cdot \overset{I_f}{0.0003065} \cdot \overset{\omega}{(37.832^2)} = 0.2193406293$

To Calculate **Kinetic Energy (KE)** in Excel : = 0.5*\$N\$4*(O9^2)

Conclusion

It is clear from the data above that the higher the increment of mass is equal to a higher level of potential energy. The only values that decrease with the larger increments of mass are as follows; the **'Time to Fall and Rise'** and **'Falling Time'**. This may appear counterintuitive at first glance, as it could be expected that the increment with the higher mass would surely increase (longer time to fall and rise).

However, in this context it is important to remember that the decrease in time is simply due to effects of gravity acting upon the heavier objects. Therefore, it results in a higher rate of acceleration. This is in accordance with **Newton's second law of motion: $F = ma$**

As the mass increases during the experiment (0.1 kg – 0.5 kg), the greater the forces acting upon the mass increase alongside it e.g. in this context an increase in gravitational force leads to a higher rate of acceleration. Thus, reducing the time taken to fall and rise as this would account for a higher level of **downforce** being present.

The relationship between mass and time follows the law of motion, where increased force on a **heavier object = a higher rate of acceleration ∴ less time is required** for the mass to complete its cycle (go up and down).

When looking at the discrepancies within the equation: **PE + PE loss = KE** it is important to note that although frictional losses due to contacting surrounding surfaces become slightly less significant at higher loads, air resistance still plays a factor, especially considering when higher loads have a higher surface area ([Freedman, Young, 2012](#))

PE loss is supposed to take into consideration energy losses during the mass' downward motion. These types of non-conservative forms of energy in this context are **friction** and **air-resistance**.

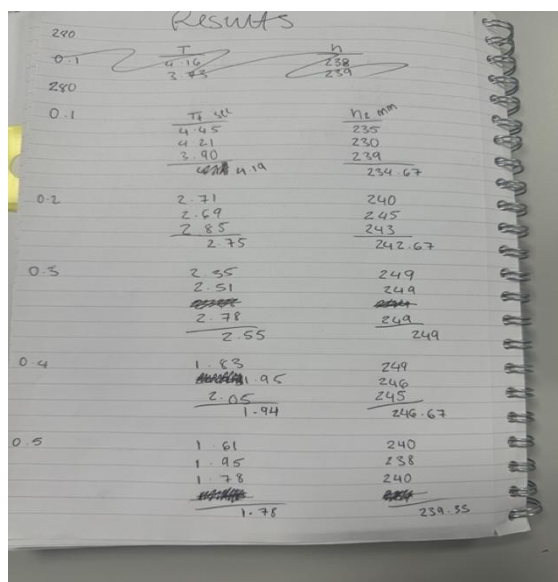


Figure 9 observing the hanger against the guide

Evaluation

Throughout the experiment, it is vital to ensure accurate data recording. It is recommended that a peer should be assigned the responsibility of documenting each measurement in the results table. This collaborative approach helps minimize human errors, ensuring that the recorded values are precise and reflect accurately under different weight increments.

It is crucial to the integrity of the experiment that the observer remains eye-levelled with the hanger and guide. This is done to reduce the risk of user related errors, as such errors could potentially invalidate the results of the experiment or lead to certain data not being accurately interpreted, subsequently, this will have a negative knock-on effect for the rest for the data accumulated ([Olugboji O , 2004](#)).



Handwritten results table in a spiral notebook. The table is titled 'Results' and has two columns: 'T' (Time) and 'h' (Height). The data is organized by weight increments (0.1, 0.2, 0.3, 0.4, 0.5 kg). Each increment shows multiple readings and a calculated average.

Weight (kg)	T (s)	h (mm)
0.1	4.16 4.21 3.90 Average: 4.19	235 230 239 Average: 234.67
0.2	2.71 2.69 2.85 Average: 2.75	240 245 243 Average: 242.67
0.3	2.55 2.51 2.78 Average: 2.55	249 249 249 Average: 249
0.4	1.83 1.95 2.05 Average: 1.94	249 246 245 Average: 246.67
0.5	1.61 1.95 1.78 Average: 1.78	240 238 240 Average: 239.33

Figure 8 recorded results via peer



Figure 9 observing the hanger against the guide

Further Work

Although most variables in the experiment have been controlled, things like room temperature, humidity and string elasticity have a role to play in the experiment, that of which has yet to be quantified and taken into consideration ([Pryce.R,2022](#)). This acknowledgement would play a role in future experiments, leading to even more accurate results.

References & Bibliography

Resources	In Text Referencing	End-Text Referencing (Reference list)
Article: Single Author	With the collection and analysis of this data, the experiment aims to confirm the expected values related to the flywheel's motion and energy transfer (Beck,2022).	Beck, K. (2020). Law Of Conservation Of Mass: Definition, Formula, History (W/ Examples). [online] Sciencing. Available at: https://www.sciencing.com/law-of-conservation-of-mass-definition-formula-history-w-examples-13720453/ .
Lecture Resource: Two Authors	air resistance still plays a factor, especially considering when higher loads have a higher surface area (Freedman,Young, 2012)	Young, H. and Freedman, R. eds., (2012). Chapter 7 - Potential Energy and Energy Conservation. [online] Pdf. Available at: https://eies.njit.edu/~tyson/P111_chapter7.pdf .
Technical Report: One Author	, subsequently, this will have a negative knock-on effect for the rest for the data accumulated (Olugboji O , 2004	Development of a Flywheel System for the Determination of Moment of Inertia. (2004). [online] 7(4), p.193. Available at: https://www.thaiscience.info/journals/Article/AUJT/10290514.pdf .
Article: One Author	elasticity have a role to play in the experiment, that of which has yet to be quantified and taken into consideration (Pryce,R,2022).	Pryce, R. (2022). 5.5 Nonconservative Forces. [online] Openedmb.ca. Available at: https://pressbooks.openedmb.ca/introtobiomechanics/chapter/5-5-nonconservative-forces/ [Accessed 23 Mar. 2025].

