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Energy in a Flywheel

Motor Vehicle Engineering Science – ACHA4036

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1 Introduction

The goal of the experiment carried out, was to test the theory behind energy stored within a flywheel. As it stores the kinetic energy produced from asserting increasing potential energy by increasing the mass applied gradually. Research has been conducted to find that use of a flywheel is more efficiently used over other energy storage methods as delved into in, Bolund, B., Bernhoff, H. and Leijon, M. (2007). They explain that the energy stored in flywheels are more efficiently used both in storing and dispersion of said energy. But also, that they are capable of storing large amounts of energy, quoting up to 500MJ.

2 Experimental Procedure

Using the Guidance notes provided by TecQuipment Ltd, 2012. They clearly lay out the steps to follow in order to set up the experiment. We attached the flywheel to the work panel and the string which was cut and adjusted to length by our lecturer. As shown in figure 1.1.



Figure 1 – Flywheel and block bearing attached to work panel

We then proceeded to attach the plastic hanger onto the string which has an initial weight of 10g. we then measured the total distance of travel by attaching magnetic ruler to the work panel. As instructed in the guidance notes the initial height of the hanger would be set to 280mm thus allowing the hanger to fall the same distance and allows us to maintain the initial height of 280mm for our calculations.

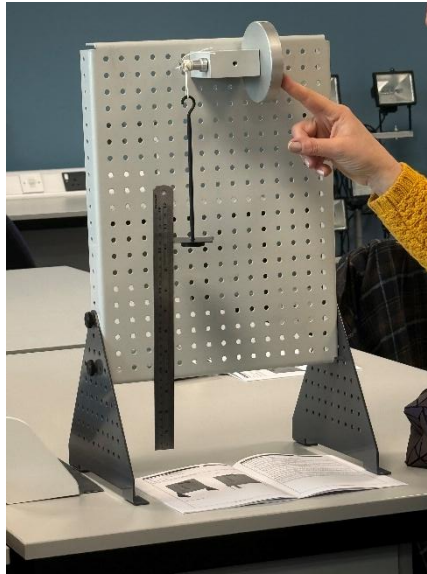


Figure 2 – hanger attached and raised to 280mm from lowest point.

Once the set up was complete and we had tested to ensure that we could reliably get the hanger to the 280mm and it would drop the full distance. We then proceeded to start the experiment and start collecting data. We decided to take 3 separate measurements for both time taken and the rebound height, in order to then take an average to have a more accurate result. The time taken to fall and rise was timed with a stopwatch, and the measure of the height reached as it bounced was measured by eye against the ruler.

We proceeded to add 90g to the hanger in order to get the total weight now acting on the flywheel to 100g or 0.1Kg which is our first point of data. Repeating the drop 3 separate times as we took three separate times taken for the entire cycle of the drop and rebound, as well as the height it reached once it had rebounded. We then repeated these same steps increasing the weight by 0.1Kg until we had a final weight of 0.5Kg on the hanger.

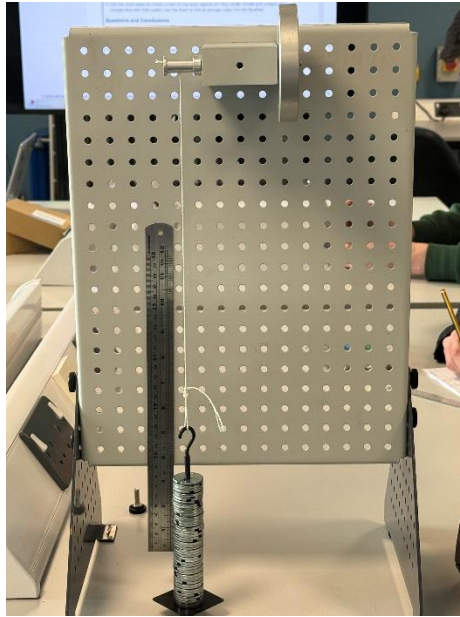


Figure 3 – Hanger with full 0.5Kg of weight attached and at full drop.

Once we had retrieved all the data from the experiment, we consolidated our data as so we had the full set and then used the average formula within excel, to provide us the mean average for both the height in metres and the time taken in seconds. These extra steps to obtain an average was in order to try and create as accurate data as we could within the limited time we had to conduct the experiment. The average allowed us to then use the averages and keep them in the raw state they are to however many decimal places they were to calculate the velocity and acceleration needed for the further calculations whilst eluding any rounding errors that may have occurred.

3 Results

Table 1 – Table of results from energy in flywheel experiment

Mass (m) (kg)	P.E mgh_1 (J)	Time to Fall & Rise t_t (s)	h_2 (m)
0	0	0	0
0.1	0.27468	3.91	0.23
0.1	0.27468	4.71	0.24
0.1	0.27468	4.24	0.24
Average		4.29	0.236667
0.2	0.54936	3.02	0.25
0.2	0.54936	3.12	0.255
0.2	0.54936	2.9	0.25
Average		3.01	0.251667
0.3	0.82404	2.62	0.249
0.3	0.82404	2.6	0.255
0.3	0.82404	2.57	0.25
Average		2.60	0.251333
0.4	1.09872	2.22	0.24
0.4	1.09872	2.24	0.245
0.4	1.09872	1.84	0.245
Average		2.10	0.243333
0.5	1.3734	1.99	0.239
0.5	1.3734	1.98	0.238
0.5	1.3734	1.95	0.237
Average		1.97	0.238

4 Analysis

Given we had the raw measurable data of the consistent height 1 being the 0.28m and then the measured time and rebound height (height 2). We needed to use several formulae to calculate numerous additional metrics such as the potential energy lost, velocity, acceleration, etc.

Table 2 – Provided Data

h_1 (m)	0.28
Gravity (g) (ms^{-2})	9.81
Radius (r) (m)	0.0065
Circumference (c) (m)	0.0408
Inertia (I) (kgm^2)	0.0005

In table 2 are the provided data for the initial drop height being height 1, the value of gravity as standard but also the values of the flywheel itself, including the radius, circumference and the inertia. These values were used in the subsequent formulae to calculate everything from the vertical force acting upon the mass to the torque, angular acceleration and the kinetic energy generated as shown in table 3 and table 4.

Table 3 - First set of Data and Calculations

Mass (m) (Kg)	P.E mgh_1 (J)	Time to Fall & Rise t_t (s)	h_2 (m)	mg (N)	PE Loss Adjusted (J)	Falling Time t_f (s)
0	0	0	0	0	0	0
0.1	00.27	04.29	00.24	00.98	00.02	02.32
0.2	00.55	03.01	00.25	01.96	00.03	01.59
0.3	00.82	02.60	00.25	02.94	00.04	01.37
0.4	01.10	02.10	00.24	03.92	00.08	01.12
0.5	01.37	01.97	00.24	04.91	00.11	01.07

In table 3 the mass was inputted as the raw data, and the time taken to fall and rise in addition to height 2 (h_2) was the averages of the 3 sets of data to attempt a more accurate experiment. Using these values that have not been rounded, to further accuracy, we then inputted the values into the formulas to achieve values for the P.E field and Mass x Gravity field. Once these values had been calculated, we then used these new values in to calculate the P.E loss using the formula:

$$P.E_{loss} = mg(h_1 - h_2)$$

We then substituted the above equation into the following equation:

$$P.E \text{ loss (adjusted)} = P.E_{loss} \times h_1 / (h_1 + h_2)$$

Using this equation, it allows us to calculate the potential energy lost through the motion of the experiment.

Table 4 - Further Calculations

Acceleration(a) (ms⁻²)	Velocity(v) (ms⁻¹)	Velocity(ω) (Rads⁻¹)	Torque (Nm)	Angular acceleration (Rads⁻²)	K.E (J)
0	0	0	0	0	0
00.10	00.24	37.12	00.01	15.96	00.34
00.22	00.35	54.34	00.01	34.21	00.74
00.30	00.41	63.02	00.02	46.01	00.99
00.44	00.50	76.76	00.02	68.25	01.47
00.49	00.53	80.85	00.03	75.72	01.63

Table 4 includes all the calculation for the movement of the hanger, including simple harmonic calculations for the angular velocity and acceleration which have then been used to calculate the torque and kinetic energy of the flywheel. (Peña-Alzola et al., 2011) talks about how the composition of the materials used vastly affects the motion of the components in the experiment. A lighter material used for the flywheel allows a higher acceleration and velocity whereas heavier materials have the inverse effect on the experiment. Other factors need to be considered however as the materials ability to withstand the centrifugal forces as well as the materials tensile strength as due to the angular motion it needs to be able to withstand the forces acted upon it.

Focusing on the torque and angular acceleration, we can compare them and produce a graph (figure 4). The gradient of which should provide us a value for the inertia of the flywheel.

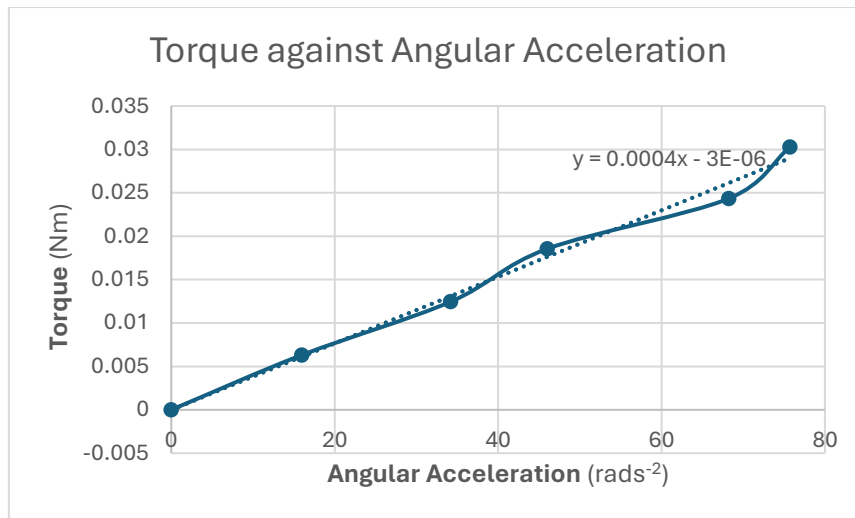


Figure 4 - Graph of Torque vs Angular Acceleration

As the graph indicates, there is a positive correlation between increasing the mass of the applied weight which leads to a larger angular acceleration, whereby the acceleration equation needs to be substituted into the angular acceleration equation

$$a = \frac{2h_1}{t_f^2}$$

$$\alpha = \frac{a}{r}$$

The increase in mass and the increase in angular acceleration then evidently as shown by the graph, causes an increase in torque. And following the trendline on the graph it appears to be linear at that.

5 Conclusion

To conclude, the experiment was executed well and the gradient extrapolated from the graph provides a similar inertia value to the provided inertia from the guidance notes, indicating that the steps we took towards accuracy were beneficial. However the nominal data provided for the parts, shows that the value of inertia for the sum of the parts of the flywheel and the pulley system itself comes to a value of 4.696×10^{-4} to which the value the graph indicates is closer to that of the Inertia value of the flywheel alone, being 3.862×10^{-4} .

6 Evaluation

We took a few procedures to minimise the errors we would get when both acquiring the data from the experiment but also whilst doing the calculations for the further data. We started by agreeing to take a data set of 3 for both the time taken to fall and rise but also the height rebounded for all 5 weight values. This was in order to take a mean average of the data set and carry a more accurate value through our equations. It would also account for the innate factor of human error. As we carried out the experiment with a stopwatch, there will always be a margin of error both in human reaction time as well as the digital stopwatch only able to get to the nearest 0.01s.

Whilst doing the further calculations with the formulae, we ensured to carry values through to the number of decimal places given to minimise and rounding errors through the calculations. The Tables included have been displayed at 2dp to provide a cleaner more legible appearance however the values remain as accurate as possible.

7 Further Work

Under the premise that we would have unlimited time and budget, several differences could be made to the process of carrying out the experiment that would lead to more accurate data being produced thus overall, a better experiment.

Use of a high-speed camera to accurately go frame by frame to find the exact height of the rebound could be used. Furthermore, the use of a 3-strand string would allow for an evermore accurate experiment. (Brunmark et al., n.d., 2021) mentions the theoretical experiment carried out takes some leniencies, one such is the experiment being conducted without any air resistance. Provided the theoretical limitless budget and time, conducting the experiment in a vacuum would be beneficial to minimise the external impact of friction from the air. Also, another method could be use of an automated system to ensure the accuracy of the height being achieved before the drop.

8 References

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