

# **University of Wales Trinity Saint David**

**Wales Institute of Science and Art**



**Prifysgol Cymru**

Y Drindod Dewi Sant

**University of Wales**

Trinity Saint David

**Energy in a Flywheel**

**Motor Vehicle Engineering Science (ACHA4036)**

Owen Hooper

2517449

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## 2. Introduction

A flywheel is a mechanical component used to store energy, specifically in the form of (rotational) kinetic energy. It operates by increasing its angular velocity when energy is supplied. The flywheel then releases this energy when required, which in-turn makes it a key component in many engineering systems.

A flywheel's stored energy heavily depends on both its moment of inertia, and its angular velocity. This can be shown as  $KE = \frac{1}{2} \omega^2$  (Engineering ToolBox, 2024).

Flywheels have a wide range of uses, such as automotive engines, and/or industrial machinery. They're used not only in these environments, but in general to help smooth energy fluctuations and maintain consistent energy output. (Vaia, 2024)

The operation of a flywheel itself is based on the idea of energy conservation, which says that energy cannot be destroyed nor created, but only transferred between different forms.

From this experiment, we've analysed that potential energy from a mass falling from different heights is converted into rotational (kinetic) energy of the flywheel.

Research shows that due to engineering principles, energy transferring between potential and kinetic types are crucial to analysing motion and mechanical systems (Hibbeler, 2017).

However, in real-world applications, there's an energy loss due to resistive factors, such as forces like friction or air resistance, which in turn means that not 100% of the starting energy is recovered.

The objective of this experiment is to analyse and investigate the correlation between potential energy and kinetic energy in a flywheel. The aim is to also calculate the moment of inertia of said flywheel using data acquired during lab experiments. This is calculated by measuring the falling mass' motion and analysing the flywheel system's rotational behaviour.

## 2. Experimental Procedure

This experiment was carried out with assistance of the Potential and Kinetic Energy Kit (ES9), with the objective of investigating energy transfer in a flywheel system.

Off the get-go, the work panel was set up on the work surface, followed by the bearing block being fixed to the work panel, with it being fastened to the work panel, allowing it to remain locked into place.

To ensure the weights had a full, free range of travel, the bearing block/flywheel assembly was mounted as high as possible.

A length of string was then wound around the rear of the bearing block, to which it was hooked on the hanging assembly which will support the weights.

To start, an initial measurement was taken between the height of the weights hanging assembly to the base (240mm).

The hanging assembly was then set free to fall to its bottom position, and a steel rule was set up in place on the work panel, with it being aligned with the hanging assembly.

The flywheel assembly was then wound back until the hanging assembly had returned to the 240mm height. Weights were added to the hanging assembly until the assembly totalled 100g.

To measure the time taken for the hanging assembly to fall from its 240mm position, down to its bottom position, and then back to its maximum height (due to residual kinetic energy), a stopwatch was used. The maximum return height ( $h_2$ ) was also recorded.

The experiment was then repeated a total of 3 times, to ensure reliable average times and height values were recorded. From that point onwards, the process was repeated numerous times with gradually increasing values of weight (starting at 100g, progressing up to 500g).

All the data was then documented in a table. With this data, the potential energy and the potential energy loss was calculated. The velocity and acceleration were then calculated, which further allowed the calculation of moment of inertia.



Seen above, is image 1 displaying the assembly at its highest point ( $h_1 = 240\text{mm}$ ).



Seen above, is image 2, which shows the assembly at its bottom-most point, just before the residual energy in the flywheel brings it back up to  $h_2$ .

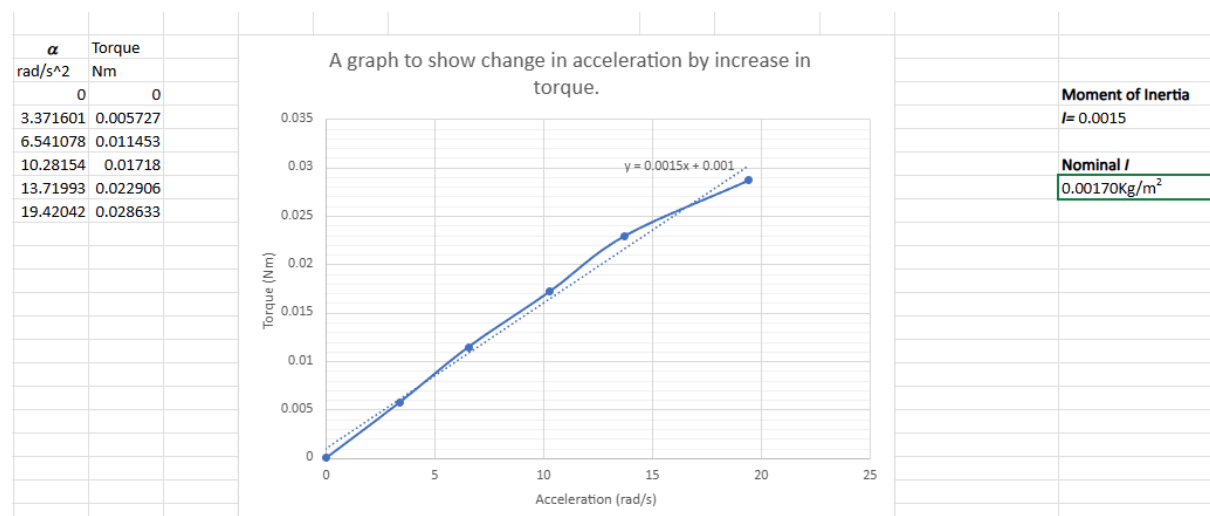
## 4. Results

All of the results acquired were placed in an excel sheet, with each calculation tied to the correct corresponding cells, which in turn allowed efficient calculations throughout the document, as displayed in the image below, for example.

|                  |           |           |           |
|------------------|-----------|-----------|-----------|
| =SUM(B4*\$C\$12) |           |           |           |
|                  | D         | E         | F         |
|                  | <b>Tt</b> | <b>h2</b> | <b>mg</b> |
|                  | s         | m         | N         |
| 0                | 0         | 0         | 0         |
| 4                | 4.68      | 0.24      | 0.981     |
| 3                | 3.36      | 0.25      | 1.962     |
| 2                | 2.68      | 0.25      | 2.943     |
| 5                | 2.32      | 0.25      | 3.924     |
| 2                | 1.95      | 0.23      | 4.905     |

The data recorded was acquired in the form of multiple “trial runs” to allow for any reliability issues to be addressed, and to identify any variations in measurements.

The graph below displays the results of the initial potential energy, the time taken, alongside the return height. It also displays the calculated moment of inertia, alongside the calculated nominal inertia.



## 5. Analysis

The collected data was analysed to which the energy transfer within the flywheel was determined, alongside calculating the moment of inertia. The calculations themselves were carried out to further find the likes of the potential energy, the loss in energy, the acceleration, the velocity, to just name a few.

A graph was also then plotted to determine the moment of inertia from its gradient, as shown in section 4 of this report.

To list some example calculations:

For the calculation for potential energy, the following equation was used:

$$PE = mgh_1$$

For example,

$$PE = 0.1 \times 0.24 \times 9.81 = 0.23544 \text{ J}$$

For the calculation for energy loss, the following equation was used:

$$PE_{\text{loss}} = mg(h_1 - h_2)$$

For example,

$$PE_{\text{loss}} = 0.2 \times 9.81 \times (0.24 - 0.25) = -0.009609796 \text{ J}$$

The table of results can be seen in the image below:

| Mass<br>kg            | Initial PE<br>J | Tt<br>s | h2<br>m | mg<br>N | PE Loss adjusted<br>J | Tf<br>s  | Acceleration<br>m/s <sup>2</sup> | v<br>m/s | $\omega$<br>rad/s | Torque<br>Nm | $\alpha$<br>Rad/s <sup>2</sup> | KE<br>J  |
|-----------------------|-----------------|---------|---------|---------|-----------------------|----------|----------------------------------|----------|-------------------|--------------|--------------------------------|----------|
| 0                     | 0               | 0       | 0       | 0       | 0                     | 0        | 0                                | 0        | 0                 | 0            | 0                              | 0        |
| 0.1                   | 0.23544         | 4.68    | 0.24    | 0.981   | 0                     | 2.34     | 0.021915407                      | 0.051282 | 7.89741743        | 0.0057265    | 3.371601                       | 0.000131 |
| 0.2                   | 0.47088         | 3.36    | 0.25    | 1.962   | -0.009609796          | 1.645714 | 0.042517007                      | 0.069971 | 10.77548501       | 0.011453     | 6.541078                       | 0.00049  |
| 0.3                   | 0.70632         | 2.68    | 0.25    | 2.943   | -0.014414694          | 1.312653 | 0.066830029                      | 0.087725 | 13.50956329       | 0.0171795    | 10.28154                       | 0.001154 |
| 0.4                   | 0.94176         | 2.32    | 0.25    | 3.924   | -0.019219592          | 1.136327 | 0.089179548                      | 0.101337 | 15.60587484       | 0.022906     | 13.71993                       | 0.002054 |
| 0.5                   | 1.1772          | 1.95    | 0.23    | 4.905   | 0.025046809           | 0.995745 | 0.126232742                      | 0.125696 | 19.35707421       | 0.0286325    | 19.42042                       | 0.00395  |
| h1 (m)                | 0.24            |         |         |         |                       |          |                                  |          |                   |              |                                |          |
| g (m/s <sup>2</sup> ) | 9.81            |         |         |         |                       |          |                                  |          |                   |              |                                |          |
| c (m)                 | 0.0408          |         |         |         |                       |          |                                  |          |                   |              |                                |          |
| r (m)                 | 0.0065          |         |         |         |                       |          |                                  |          |                   |              |                                |          |
| I (kgm <sup>2</sup> ) | 0.0005          |         |         |         |                       |          |                                  |          |                   |              |                                |          |

The results clearly display that as the acceleration increases, the torque increases, which demonstrates a linear relationship between the two variables.

This supports the theory behind the equation used to find the moment of inertia.

However, there may be some data variation from any experimental errors or energy losses within the flywheel system.

## 6. Conclusion

To conclude, the experiment was to investigate the relationship between both potential and kinetic energy within a flywheel system, alongside determining the moment of Inertia. The results ended up displaying that potential energy was converted into rotational kinetic energy upon the mass descending, which caused the flywheel to accelerate.

However, it was determined that the mass assembly did not stay at its original height, which indicates that energy was lost during the process. The loss of energy shows to correlate with the factors mentioned previously, such as friction within the bearings, or air resistance. The values calculated alongside the graphical analysis in turn demonstrated a linear relationship between both torque acceleration, which supports the theories applied.

The moment of inertia within the flywheel was taken from the calculations and analysis made with the graph, which provided a reasonable estimate.

Overall, this experiment ended up supporting the principle of energy conservation, whilst also shining light on the inefficiencies in mechanical flywheel systems.

## 7. Evaluation

This experiment could have definitely incorporated some sort of human error, for example, the space between hitting the button on the stopwatch, which could provide inaccuracy of timing, for example, as hand-held stopwatches were used.

Human reaction time can introduce a delay which directly correlates with results shown.

Any friction in the flywheel assembly or between the bearing and the string could also cause loss. As a result, the weighted assembly did not return to its original height, thus the measured kinetic energy alongside the calculated moment of inertia turned out to be lower than expected.

Improvements could include using electronic timing equipment, alongside the use of sensors to eliminate the factor of human error, alongside ensuring the bearings have been well maintained (lubrication) to reduce friction.

Overall, while the experiment does indeed demonstrate the energy transfer within the flywheel system, these limitations found show where there's an impact on real world inefficiencies in the results.

## 8. Further work

If the chance was provided to carry out the experiment again, alongside having an unlimited budget and an increased timeframe, the accuracy of the recordings could be maximised efficiently.

The experiment did not consider factors such as the likes of friction throughout the assembly either, however at the time of our experiment, this did not need to be considered.

## 9. References

The Engineering ToolBox: Flywheels – Kinetic Energy, 2024. [Online]  
Available at: [https://www.engineeringtoolbox.com/flywheel-energy-d\\_945.html](https://www.engineeringtoolbox.com/flywheel-energy-d_945.html)  
[Accessed: 29/03/2026]

Engineering Mechanics Dynamics – 14<sup>th</sup> Edition. *R. C. Hibbeler*. [Online]  
Available at:  
<https://www.aerostudents.com/courses/dynamics/Hibbeler14Solutions.pdf>  
[Accessed: 29/03/2026]

Flywheel Mechanics, vaia.com, 2024. [Online]  
Available at: <https://www.vaia.com/en-us/explanations/engineering/automotive-engineering/flywheel-mechanics/>  
[Accessed: 29/03/2026]