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# The energy in a Flywheel

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## **Abstract**

An experiment was carried out to find out if a flywheel creates energy, and if so, what type of energy and how much of it, The results were used to calculate, the angular velocity of the flywheel when the different weights of loads were applied, and how much kinetic energy was created.

## **Nomenclature**

| Notation | Product                                         | Unit/value                                         |
|----------|-------------------------------------------------|----------------------------------------------------|
| m        | mass                                            | kg                                                 |
| a        | Linear acceleration                             | m/s <sup>2</sup>                                   |
| w        | Angular acceleration                            | rad/s <sup>-1</sup>                                |
| g        | gravity                                         | = 9.81m/s <sup>2</sup>                             |
| r        | radius                                          | M = metres                                         |
| I; If    | Moment of inertia of the flywheel               | 3.862 x 10 <sup>-4</sup> kg.m <sup>2</sup>         |
| c        | Circumference (allowing for the cord thickness) | Pi x d<br>D = diameter<br><br>Pi x 0.013 = 0.04084 |
| r        | Pulley radius                                   | 0.0065m                                            |
| tt       | Total time                                      | s                                                  |
| tf       | Falling time                                    | s                                                  |
| v        | velocity                                        | m/s                                                |

$$1 \text{ rev/s} = 6.28 \text{ rad/s}$$

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## **Introduction**

According to (Softschools.com, 2019) all rotating objects create rotational kinetic energy; which can be stored for mechanical uses. A flywheel is a metal wheel that is commonly used as a part of vehicles and is found at the rear of the engine (Collinsdictionary.com, 2019). It is a rotating part with high inertia that gives the car its power (The Editors of Encyclopaedia Britannica, 2012). It does it by capturing the momentum once is spun and then applies torque. Once it's applied it will spin around its central point and cause acceleration. (Taylor-Smith, 2019).

The main advantages of such flywheels are a good capability for storage and it doesn't involve a lot of maintenance which means that it can be used for a long time in a car and it will not wear off quickly. (Power System Energy Storage Technologies, 2018).

The purpose and aims of this experiment were to prove that flywheel produces and stores kinetic energy.

The objectives of the experiment were:

1. To apply an increasing load to a string attached to a pulley block and a flywheel. Then to measure and analyse the time it took for different loads to fall and rise after letting the flywheel going. Once all the data is obtained the kinetic energy will be calculated, as well as the  $(mg-ma)r$  and  $a/r$  graph will be created to compare the results.
2. To calculate the amount of Kinetic Energy created at different loads and present the trend it creates.
3. To examine the relationship between the force and the radial acceleration.

## **Experimental Procedure**

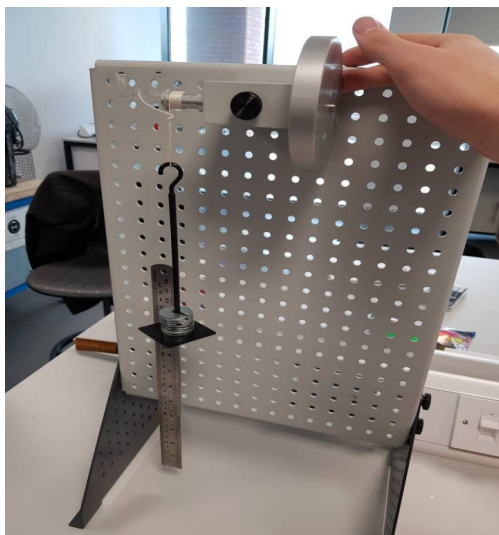


*Figure 1. Apparatus.*

The equipment was set up as displayed in Figure 1. A weight hanger was fitted to the pulley. The string that attaches it together was long enough so that the bottom of the weight hanger travelled through a drop of 280mm (h1). The weight hanger was allowed to fall and the magnetic ruler was attached so that the 0mm edge was straight in line with the bottom of the weight hanger. The weight hanger weighed 10g itself so 90g masses were added onto it to give a total of a 100g.

The flywheel was rotated until the bottom of the weight hanger was straight on edge of 280mm of the ruler. The holes on the work panel were used to ensure all the components were set up straight.

The weight hanger was dropped from the 280mm position and one of the team members used a stopwatch to measure how long it took for it to get to the 0mm position and back up to its maximum height (h2). The experiment was repeated 3 times for each load and an average score was calculated. The following equations were used:

1. Potential energy. It is 'energy that an object has because of its position relative to other objects' (Helemnstine, 2019). It is worked out to find out the initial energy that the object stores can potentially transform into kinetic energy.

$$P.E = m \times g \times h1 \quad [1]$$

2. Mg value. It is the force that the gravitation caused on an object (Kurtus, 2017) and was calculated to find out how strong that force was on the applied load.

3. PE loss (adjusted). Some energy gets lost when the spring bounces. (Chesnutt, 2017)

$$Tf = tt \times (h1/h1+h2) \quad [5]$$

Where tt = total time

$$P.E. \text{ loss (adjusted)} = P.E. \text{ loss} \times h1/(h1+h2) \quad [2]$$

The mass doesn't reach its original height (h1) after coming back up and reaches a lower height (h2).

$$P.E \text{ loss} = mgh1 - mgh2 \quad [3]$$

4. Falling time. It will be recorded by one of the team members with a stopwatch.

5. Acceleration. It is calculated by dividing the h1 (0.28m) by the falling time; squared.

$$a = h1 / tf^2 \quad [4]$$

Where, tf = falling time

To accurately find out the falling time, the total time to fall and rise is multiplied by the ratio ( $h_1 / h_1 + h_2$ ).

6. Velocity. A figure that is determined by how fast an object is moving. (wikiHow Staff, 2019) The linear velocity of the falling load is calculated by multiplying the acceleration and the falling time.

$$v = a \times t_f \quad [6]$$

Since we are working out the kinetic energy of the flywheel its velocity would be angular. It is determined by the product of 2, pi and the linear velocity divided by the circumference of the pulley.

$$w = 2 \times \pi \times v / c \quad [7]$$

7. The  $(mg - ma)r$  value. This is the torque in the cord. It is determined by the product of the force at the radius of the pulley. Because it is in a rotating object it is calculated by multiplying the angular acceleration and the moment of inertia of the flywheel.

$$\text{Angular acceleration} = a/r \quad [8]$$

$$\text{Torque} = I \times \text{angular acceleration}$$

8.  $a/r$  value. The angular acceleration.

9. the  $I$  value is equal to  $3.862 \times 10^{-4} \text{ kg.m}^2$

10. Finally the Kinetic Energy. Kinetic energy is the energy that is accumulated in any moving body and according to (Contributor, 2017) is 'the energy that the object possesses because it is in motion'. It proceeds from rest and gains a velocity 'v' in time 't' through a distance 's'.

$$\text{Kinetic Energy} = \text{Force (F)} \times \text{Distance (s)} \quad [9]$$

For any linear moving object,

$$K.E. = 0.5 \times m \times v^2 \quad [10]$$

For any rotating object,

$$K.E. = 0.5 \times I \times \omega^2 \quad [11]$$

## Results

| Mass<br>m<br>(kg) | P.E. mgh1<br>(J) | Time to<br>fall and<br>rise t2<br>(s) | h2 (m) | mg    | PE loss<br>Adjusted (J) | Falling<br>Time<br>t <sub>f</sub> (s) | Acceleration a (m/s <sup>2</sup> ) | Velocity<br>v<br>(m/s <sup>-1</sup> ) | Velocity w<br>(rad/s <sup>-1</sup> ) | (mg-ma)<br>r | a/r    | KE    |
|-------------------|------------------|---------------------------------------|--------|-------|-------------------------|---------------------------------------|------------------------------------|---------------------------------------|--------------------------------------|--------------|--------|-------|
| 0.1               | 0.27468          | 4.57                                  | 0.24   | 0.981 | 0.0211                  | 2.461                                 | 0.030                              | 0.074                                 | 11.396                               | 0.004        | 4.627  | 0.003 |
| 0.2               | 0.54936          | 3.08                                  | 0.25   | 1.962 | 0.0311                  | 1.627                                 | 0.068                              | 0.110                                 | 16.960                               | 0.009        | 10.413 | 0.006 |
| 0.3               | 0.82404          | 2.87                                  | 0.255  | 2.943 | 0.0385                  | 1.502                                 | 0.079                              | 0.118                                 | 18.227                               | 0.011        | 12.122 | 0.007 |
| 0.4               | 1.09872          | 2.43                                  | 0.251  | 3.924 | 0.0600                  | 1.281                                 | 0.109                              | 0.140                                 | 21.503                               | 0.015        | 16.764 | 0.010 |
| 0.5               | 1.3734           | 2                                     | 0.23   | 4.905 | 0.1346                  | 1.098                                 | 0.154                              | 0.169                                 | 25.957                               | 0.021        | 23.616 | 0.015 |

Figure 2. Table for the experiment results data.

## Relationship between $a/r$ and $(mg-ma)r$

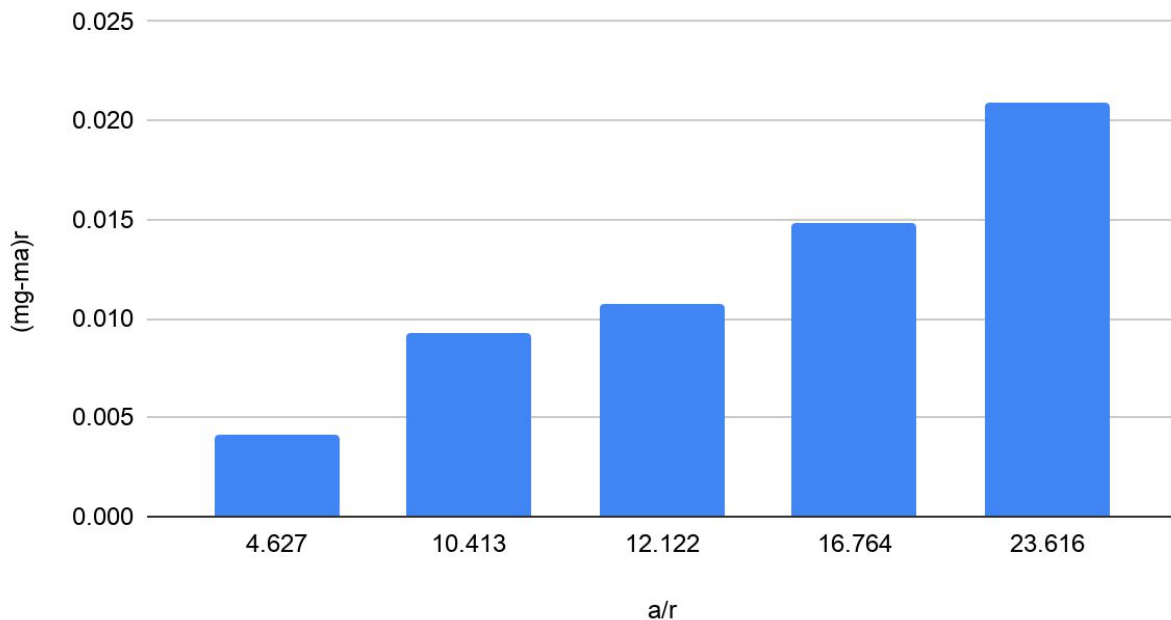


*Figure 3. The graph to show the relationship between  $a/r$  and  $(mg-ma)r$*

### **Discussion**

Figure 3 presents the relationship between the  $a/r$  and the  $(mg-ma)r$ . Its gradient is the average value of the  $I$  of the flywheel. The relationship can be recognised to be linear and is increasing gradually, which means that the higher the angular acceleration of the flywheel, the higher the torque in the cord.

The experiment has proven the initial aim to find out that the flywheel creates energy when it spins. Looking at the results kinetic energy was created when the mass of an object triggering it to move was above 0g. The objective 1 was fulfilled and has shown that the heavier the applied load was, the shorter was the time to fall and rise. This is because the gravity force acts stronger the heavier the mass is, which causes it to fall faster.

Objective 2 has proven that the heavier the mass, the more kinetic energy is created, which is due to stronger forces pulling it down and creating that energy, Objective 3 has proven that the heavier the mass triggering the flywheel was the faster was the radial acceleration. It increased by around 2 radians per second every 0.1kg added.

Some errors that could have possibly affected the accuracy of the results. The main error arose from reading off the measurements from the ruler. It was only to the nearest 1mm. For example, a reading of 240mm gives an error of  $1/240 \times 100 = 0.42\%$  (Helmenstine, 2019) which is insignificant.

Using a stopwatch was another problem. The human reaction isn't 100% accurate and it can be estimated up to a quarter of a second. For a time of 2.46s, this gives an error of,  $0.25/2.46 \times 100 = 10.16\%$ . Altogether, when using such small lab-style figures those errors can be considered negligible.

However, when dealing with a field-scale scientific project specialist equipment would be required to make sure the results are accurate including calculating the time to fall and rise and the height it went up to. Also, the friction forces were not considered which affected the setup of the flywheel, This could have caused a minor inaccuracy in the value of the moment of inertia.

## **Conclusion**

This report has presented a review of what a flywheel is, how it works and how it stores and creates energy. A flywheel is a main component used in cars, spacecraft and other mechanical machinery.

The flywheel creates kinetic energy when it has a mass triggering it to spin. The results in this experiment have shown that there is a linear relationship between the angular acceleration and the K.E.

The results obtained range between 0-0.5kg which is because that the string has broken once 0.6kg load was applied. This has been caused by too much force acting on the string which wasn't strong enough to resist it. The errors that were introduced have been done by a human and experiment were negligible due to a very little error percentage, which makes them accurate.

In conclusion, the moment of inertia of a flywheel is constant. You can change the forces that are applied to it and the velocity of it, yet the moment of inertia will not change. It is, in fact, the resistance of the flywheel when it spins.

## **Further work**

I would improve the experiment by using a slow-motion machine to calculate the height that the string has bounced up to. According to (High speed cameras for motion analysis in sports science, 2016), the cameras are very useful in scientific environments. The video can be slowed down to the desired speed and doesn't lose its quality which means that it will still be sharp and clear. Also to be able to obtain the best possible image, appropriate lighting should be provided e.g. LED lamps.

This would make the results a lot more reliable since there is only so much a human eye can observe. It would also help with measuring the time it took to fall and rise since once the video is

recorded it can be cut to a perfect length, and then an automatic stopwatch could be used to measure the time. The concentration from all the members of the team experimenting should be significant.

Also, I would have used a new string every time I repeated the experiment. Every time the load was let to fall, the string would have stretched which would cause some inaccuracies. Once the 0.6kg load was applied the string broke which means that it was not strong enough.

To increase the accuracy of the results all surrounding forces should be taken into consideration such as friction and air resistance. If available, rotational motion sensors could be used to record the flywheel's properties at its every move.

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