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Engineering Science
Coursework 1
Potential and kinetic energy

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1.0 - Introduction

The experiment that I am going to do for my coursework will replicated how the energy in a flywheel works. It will be replicated with the potential and kinetic energy kit that my lecturer will provide me with. The kit has to be set up and it involves fixing the bearing block and the flywheel to the panel and then attaching a string with a loop at the end of it to the flywheel. Weights will then be added to the string to create a quicker downward motion. The data that will be collected in this experiment will be the time for the ball to reach the highest point possible once it has bounced, along with the maximum height that the ball reached after the bounce.

The Aim

The aim of this experiment is to prove the theory of energy in a flywheel. I will do this by creating a database with loads of information that will be useful to conclude on the theory of energy in a flywheel. Increasing the mass by 0.1 kg for each test and testing each mass more than once will help solidify the information and data gained from doing the tests. This data will then allow me and my group to assess what we have found out and conclude on the theory of energy in a flywheel.

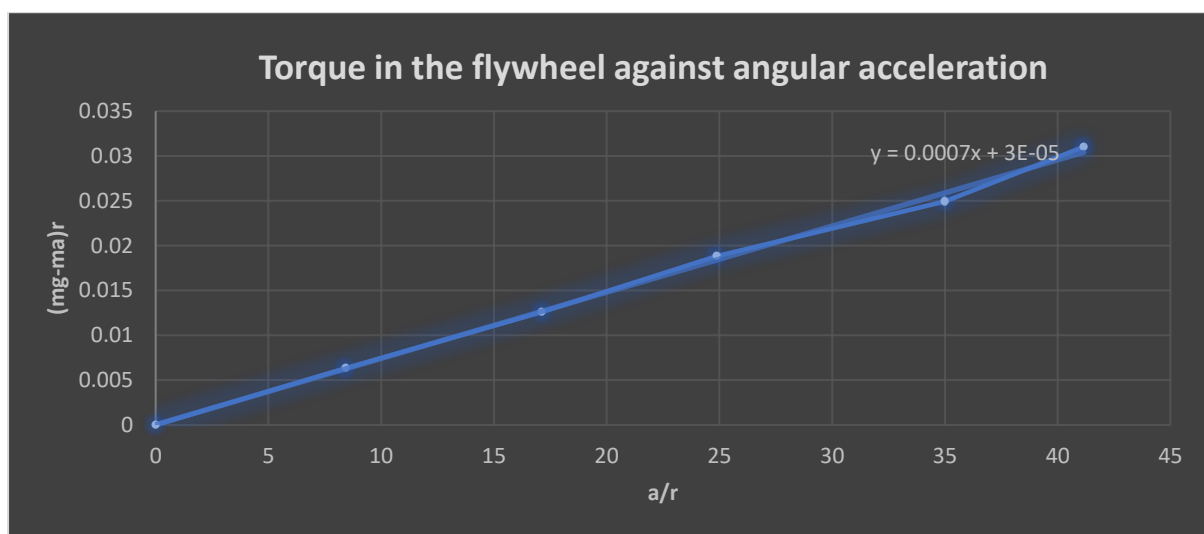
2.0 - Experimental procedure

The experimental procedure starts with a weight of 100g hanging from the string that was attached to the flywheel. After that I have to measure that the length of the string. I have to make it accurate so that the bottom of the weight hanger can only travel through a vertical drop of around 280mm. Once everything is in place, the weights will drop. I will time how long it would take for the weights to go as low as possible and then rise to the highest point it can, this height will also be measured as it is one of the factors on how to work out the energy in a flywheel. Each weight will be tested at least 3 times so that we can get an accurate average number for time and also the height. After I have done at least 3 tests on the starting weight, I will then increase the weight to 200g and do the same as the first test. I will repeat this until I reach 500g, run that test and then stop. After the experiment I then have to do multiple calculations to get more data from the experiment. With this data I can then plot a graph to see if my data that I collected from the experiment was accurate. If the line in the graph is straight with some slight scattering, it was accurate. If the graph was scattered a lot, then the data gathered was not accurate.

3.0 - Results

Mass m (kg)	PE mgh ₁ (J)	mgh ² (J)	Time to fall and rise t (seconds)	h ₁ (m)	h ₂ (m)	mg	PE (J)	Loss	PE loss adjusted (J)	Falling time t _f (seconds)
0	0	0	0	0	0	0	0		0	0
0.1	0.27468	0.23544	4.2	0.28	0.24	0.981	0.03924		0.021129231	2.2615385
0.2	0.54936	0.4905	3	0.28	0.25	1.962	0.05886		0.031095849	1.5849057
0.3	0.82404	0.741636	2.5	0.28	0.252	2.943	0.082404		0.043370526	1.3157895
0.4	1.09872	0.981	2.1	0.28	0.25	3.924	0.11772		0.062191698	1.109434
0.5	1.3734	1.1772	1.9	0.28	0.24	4.905	0.1962		0.105646154	1.0230769

Mass M (kg)	Acceleration a (m.s ⁻²)	Velocity v (m.s ⁻¹)	Velocity ω (rad.s ⁻¹)	(mg-ma)r	a/r	KE
0	0	0	0	0	0	0
0.1	0.054745708	0.1238095	19.0479476	0.00634092	8.422417	0.12698851
0.2	0.111468254	0.1766667	27.179956	0.01260809	17.14896	0.2585625
0.3	0.161728	0.2128	32.7390263	0.01881413	24.88123	0.37514534
0.4	0.227486233	0.252381	38.8285086	0.02491454	34.99788	0.52767858
0.5	0.267510882	0.2736842	42.1059895	0.03101309	41.15552	0.62052002



4.0 - Analysis

Above is the complete database of all the results the group calculated from the original results of “Time to fall and rise” and “h2”. These two results gave the group the possibility to work out an entire new lot of factors such as the acceleration for each run, the falling time and two types of velocities along with many more. The original results went like the figure below:

Mass m (kg)	Time to fall and rise t (seconds)	h2 (m)
0	0	0
0.1	4.2	0.24
0.2	3	0.25
0.3	2.5	0.252
0.4	2.1	0.25
0.5	1.9	0.24

As you can see from the table, it shows the time it took for each weight to fall and then rise up to the starting point. As you would expect, the heavier the weight, the less time it took. However, the ending height after the bounce varies and doesn’t have the same sort of consistent drop in numbers that the “time to fall and rise” column. This was because as the weight increased, the bounce changed and wobbled afterwards, losing momentum. The heavier the drop, the bigger the wobble and bigger the momentum loss. This explains why they are all of similar height and there isn’t a steady descent in height.

These results then allowed the group to create other factors so that I could increase the information on the data. One piece of results this allowed the group to create was potential energy, potential energy loss and potential energy loss adjusted. Potential energy (PE) was calculated by having the weight of that test times by gravity and then times by the starting height. The sum to work it out in excel was $(=SUM(A3)*9.81*0.28)$ to work out the 0.1 Potential energy. I then swapped out the weights for the rest of them and collected the data.

Mass m (kg)	PE mgh1 (J)	PE Loss (J)	PE loss adjusted (J)
0	0	0	0
0.1	0.27468	0.0392	0.0211
0.2	0.54936	0.05886	0.0311
0.3	0.82404	0.0824	0.0434
0.4	1.09872	0.1177	0.0622
0.5	1.3734	0.1962	0.1056

To work out potential energy loss (PE Loss), I had to have the Potential energy (PE) – $MGH2$ $(=SUM(B3)-C3)$ to get the Potential Energy Loss (PE Loss). For the Potential energy loss adjusted, it was PE Loss times by the starting height of the weights, divided by the value of the height again added to the height that was recorded after the bounce in the experiment. All this results in the equation being $(=SUM(H3*(E3/(E3+F3))))$ for the equation to work in excel.

Mass m (kg)	Falling time tf (seconds)	Acceleration a (m.s-2)	Velocity v (m.s-1)
0	0	0	0
0.1	2.2615	0.0547	0.1238
0.2	1.5849	0.1115	0.1767
0.3	1.3158	0.1617	0.2128
0.4	1.1094	0.2274	0.2524
0.5	1.0231	0.2675	0.2736

Falling time, acceleration and velocity were all other results could collect after the initial 2 results that were recorded. Falling time is simply the time taken for the weights to go from the highest point of the string, to the lowest point. To work this out, the group started with the total time taken for the weight to go down and back up as high as it could. This was the times by the starting height and was then divided by the starting height again but had the height after the bounce added onto it. The equation for excel was $=SUM(D3*(E3/(E3+F3)))$ and it worked for all of the weights. The figures drawn from this show that the more weight added, the

quicker the drop which is as expected. However, the time jump from each weight gets shorter and shorter, for example, 0.1kg has a time of 2.2 seconds and 0.2kg has a time of 1.5, over half a second difference. 0.4kg has a time of 1.1 seconds and 0.5kg has a time of 1 second, barely a tenth of a second difference. So, the time goes from being over half a second to being barely over a tenth which is a massive jump. This is because the heavier ball is reaching terminal velocity and the acceleration slows down as it keeps falling.

Acceleration is worked out by having the starting height divided by the falling time squared. A very simple equation to get good data. My method of the ball reaching terminal velocity is backed up by the figures in this result as the acceleration decreases and then starts to increase as more weight gets added on. The velocity is just as easy to work out. Now that the group had the falling time and the acceleration, multiplying the two values will give the linear velocity. The angular velocity is worked out by a completely separate equation. Pi is multiplied by 2 which is then multiplied by the linear velocity. All of that is then divided by the radius of the flywheel which is 0.04084 to give you the angular velocity. As you can see in the figure to the right, the velocity increases consistently as the weight is added, however the increase in velocity slows down as more weight is added.

Mass m (kg)	Velocity ω (rad.s-1)
0	0
0.1	19.0479
0.2	27.18
0.3	32.739
0.4	38.8285
0.5	42.106

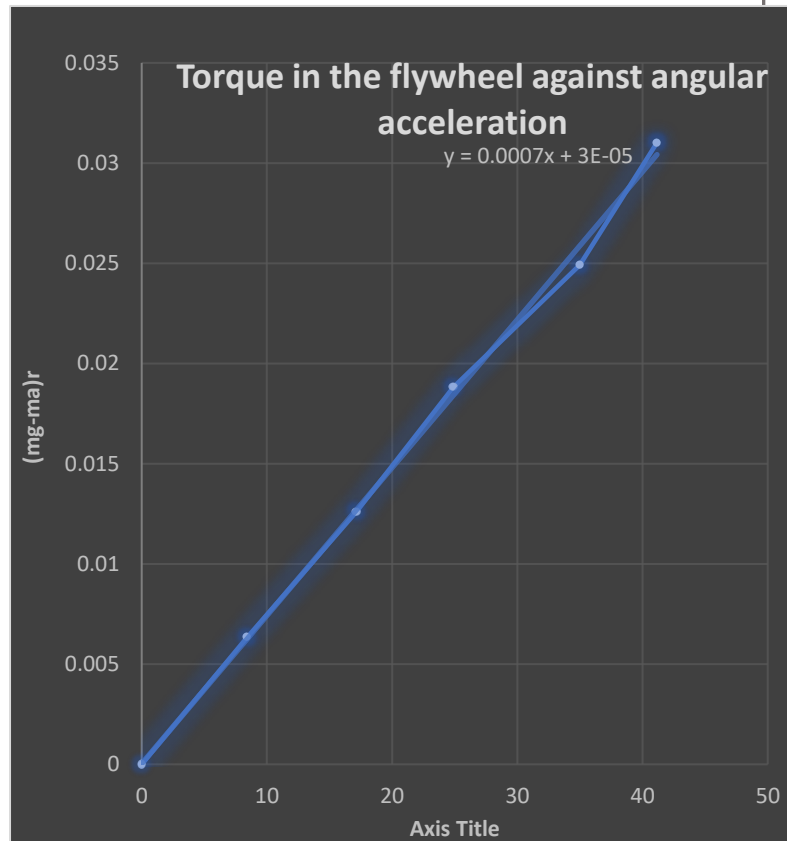
The final three results of the table were mass times gravity, minus mass times acceleration, multiplied by the radius of the flywheel which is 0.0065. The excel equation for this sum would be $=SUM((G3)-(K3*A3))*0.0065$. as you can see from the figure on the left, the value of the force in the cord of the flywheel steadily increase as the mass is added on, indicating that the greater the mass, the greater the force on the cord.

Mass m (kg)	(mg-ma)r	a/r	KE
0	0	0	0
0.1	0.006341	8.422417	0.126989
0.2	0.012608	17.14896	0.25856
0.3	0.018814	24.88123	0.375145
0.4	0.024915	34.99788	0.527678
0.5	0.031013	41.15552	0.62052

The angular acceleration is worked out by having the acceleration divided by the radius of the flywheel. This is because “the angular acceleration in the flywheel is

equal to the acceleration of the moving mass divided by the pulley radius” [1]. The excel equation would simply be $=SUM(K3)/0.0065$. from the figures above, you can see that as the mass is increased, the acceleration is also increased with a steady jump of acceleration from each weight.

Moving parts of a machine can store an amount of kinetic energy within them, in this case, it is the flywheel that stores the kinetic energy. The faster something moves, the greater the kinetic energy. For this experiment, the amount of kinetic energy stored increased as more mass was put on. Because the amount of mass that was added each test was so small, the amount of kinetic energy is minimal, yet energy is still stored within the apparatus. “its kinetic energy is equal to half the product of its moment of inertia and its angular velocity squared”, this equation in terms of excel form would be $=SUM(0.5*0.0007*M3^2)$. The inertia is worked out by having the angular acceleration (a/r) in the flywheel in a graph compared to the force of the cord $[(mg-ma)r]$ in a chart equation of $y = mx+c$. This will then give a good average for inertia (I) of the flywheel. As you can see from the figure on the right, the line of best fit follows the plots closely showing that the test was accurate and that it was a fair test. In this case, the moment of inertia is $y=0.0007x + 3E-05\text{KG/M}^2$.



5.0 – Conclusion

In conclusion, it is clear that the heavier the ball means the faster the time that the ball drop. However, just because the mass of the ball increases and the speed of the ball increases, doesn't mean that the height of the ball after the bounce would increase like the speed. In fact, it does the opposite and decreases as the mass increases, something that I thought wouldn't happen when going into this experiment. A lot of factors turned out to not be what I predicted beforehand. When going into the experiment, I didn't think of how the bounce could upset the flow of the speed, which turned out to have a massive effect on the total time of each run and the height of the ball after the bounce.

5.1 – Aim reflection

At the start of the experiment, the aim was to prove the energy on a flywheel. The plan was to do the experiment and then come up with a database that would show the potential energy and kinetic energy made by the flywheel at different mass values along with other results that I picked up and calculated. I believe that I did manage to prove the energy in a flywheel as the data that was collected shows and proves energy in the flywheel and how it differs when mass is added or taken away.

6.0 – Evaluation

I believe that the experiment went well because we managed to prove the energy in a flywheel with loads of data to prove it. We managed to prove 2 types of energy within a flywheel, along with the loss of energy. We worked out potential energy and kinetic energy with promising results.

Having set out to prove the energy in a flywheel and ending up with reliable data to back the prove the energy in flywheels at different weights.

6.1 – What went well

The entire experiment was a success, I believe I have done everything there was to do in terms of the procedure, tables, information and data. I believe I have explained how I got certain data and why I got it. I believe I stuck to the aim of the experiment and proved the energy in a flywheel in different values of mass.

7.0 - Further work

7.1 – Comparison

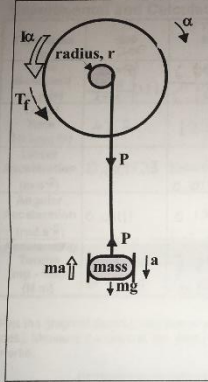
(Physics by B. Karpowicz, 2019)

I managed to find a reliable comparison that had data from a similar experiment. The moment of inertia values are very similar.

Use the dimensional information given for the flywheel to calculate a theoretical value of Moment of Inertia, I , for the flywheel.

Compare these values and comment on your results.

Useful Information



RELATIONSHIPS

Flywheel: $P \cdot r = I \alpha$
(friction torque balanced)

Mass: $P = (mg - ma)$

Combined Equation:
$$I = \frac{(mg - ma)r}{\alpha}$$

Circumference 3.5 cm
0.63 m

Radius of flywheel.

$$I = \frac{1}{2} M R^2$$

mass of flywheel

$R = 0.101$
 $m = 8 \text{ kg}$

Theo $I = 0.04 \text{ kg m}^2$