Physics

Higher Level

Internal Assessment

Investigating the Effect of Weight Distribution on a Wheel's Moment of Inertia and Rotational Velocity

Research Question:

To what extent does the weight distribution of a cylindrical mass affect its rotational velocity and moment of inertia?

Word count: Work in progress

1. Research Design

1.1 Introduction

In motorsports minimising a wheel's moment of inertia is essential for maximising angular acceleration and improving racing performance. This experiment investigates the relationship between weight distribution and the moment of inertia of wheels.

Research question: "*To what extent does the weight distribution of a cylindrical mass affect its moment of inertia and rotational velocity*?".

The investigation applies the principle of conservation of energy, using a Maxwell wheel setup to determine the moment of inertia for wheels with varying weight distributions.

1.2 Exploration

1.2.1 Moment of Inertia

Moment of inertia (I) quantifies an object's resistance to rotational acceleration, similar to how mass resists translational acceleration [1]. In order to calculate the moment of inertia of wheels it is useful to model them as perfectly cylindrical masses. These cylinders can be split into infinitesimally small sections with mass dm and an interior radius of r [2].

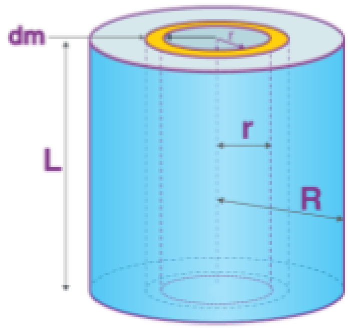


Figure 1. Mathematical representation for moment of inertia of a cylinder. Byju's. (n.d.). Moment of inertia of a solid cylinder. Byju's. Retrieved March 3, 2025, from https://byjus.com/jee/moment-of-inertia-of-a-solid-cylinder/

Using the formula for calculating the moment of inertia of a point mass [5] [Formula 1] the expression dI can be derived in order to represent the moment of inertia of each section of mass dm [Formula 2].

$$I = MR^2$$ *[Formula 1]*

$$dI = r^2 dm$$ *[Formula 2]*

Through integrating formula [Formula 2] the moment of inertia of the whole cylinder can be found in terms of r^2 and dm [Formula 3] [Formula 4].

$$\int_0^R dI = \int_0^R r^2 dm$$ *[Formula 3]*

$$I = \int_0^R r^2 dm$$ *[Formula 4]*

Rearranging the equation for density [Formula 5] gives formula [Formula 6] which can be used to derive the formula for $dm = \rho dV$ in terms of ρ and dV [Formula 7].

$$\rho = \frac{M}{V}$$ *[Formula 5]*

$$M = \rho V$$ *[Formula 6]*

$$dm = \rho dV$$ *[Formula 7]*

Figure 2 visually represents each infinitesimally small sliver of mass dm.

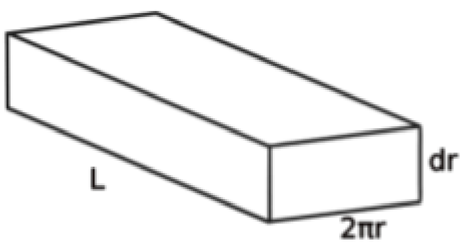


Figure 2. Model for infinitely small sections of cylinder rolled out to form a cuboid

Where:

$L \ = \ the\ height\ of\ the\ sections$

$r \ = \ the\ radius\ of\ each\ section$

$dr \ = a\ representation\ of\ the\ width\ of\ the\ infinitesimally\ small\ sections$

$2\pi r \ = the\ circumference\ of\ the\ infinitesimally\ small\ sections$

dV can be calculated from Figure 2 by finding the volume of the mass section [Formula 8]. Substituting [Formula 8] into [Formula 7] gives [Formula 9].

$$dV = 2\pi rLdr \qquad \text{[Formula 8]}$$

$$dm = 2\rho\pi rLdr \qquad \text{[Formula 9]}$$

Substituting [Formula 9] into [Formula 4] produces a resultant expression for I [Formula 10].

$$I = \int_0^R 2r^3 \rho\pi L dr$$

$$I = 2\rho\pi L \int_0^R r^3 dr$$

$$I = 2\rho\pi L \left[\frac{r^4}{4}\right]_{r=0}^{r=R}$$

$$I = \frac{1}{2}\rho\pi LR^4 \qquad \text{[Formula 10]}$$

The density of a cylindrical mass [Formula 11] can be substituted into [Formula 10] to produce a resultant expression for the mass of a flywheel in terms of its mass and radius [Formula 12].

$$\rho = \frac{M}{V} = \frac{M}{\pi R^2 L}$$ [Formula 11]

$$I = \frac{1}{2}\left(\frac{M}{\pi R^2 L}\right)\pi L R^4$$

$$I = \frac{1}{2} M R^2$$ [Formula 12]

1.2.2 Maxwell wheel

In this experiment a Maxwell wheel is used to calculate the moment of Inertia of wheels, similar to other studies [3]. The apparatus consists of a wheel held by two pieces of string which falls when released. By repeatedly twisting the string around the wheel's axle, the string coils around the axle, bringing it up towards the supporting structure and increasing its gravitational potential energy. By using the principle of conservation of energy the wheel's final translational velocity and gravitational potential energy can be used to calculate its moment of inertia.

Figure 3. Online image of a Maxwell wheel. Scientific Equipment. (n.d.). Rolling pendulum Maxwell wheel apparatus. Scientific Equipment. https://www.scientifcequipment.com/physics-instruments/rolling-pendulum-maxwell-wheel-apparatus

1.2.3 Conservation of energy

The principle of conservation of energy states that energy can be neither created nor destroyed therefore the total energy of a system always remains constant.

This principle can be used to calculate a flywheel's moment of inertia using the Maxwell wheel setup. When the Maxwell wheel is released its gravitational potential energy is transferred into translational and rotational kinetic energy, assuming negligible air resistance [2] [Formula 13].

$$mg\Delta h = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$$ *[Formula 13]*

[4]

Where:

$m = \text{the mass of the flywheel}$

$g = \text{the gravitational constant of acceleration on earth } (9.81\ m/s^2)$

$\Delta h = \text{the change in vertical displacement}$

$v = \text{the translational velocity of the flywheel}$

$I = \text{the moment of inertia}$

$\omega = \text{the angular frequency of the flywheel}$

By substituting the relationship between rotational and translational velocity [Formula 14] into [Formula 13] the gravitational potential energy can be represented in terms of the wheel's final translational velocity [Formula 15].

$$\omega = \frac{v}{r}$$ *[Formula 14]*

Where:

$r = \text{the radius of the flywheel}$

$$mg\Delta h = \frac{1}{2}mv^2 + \frac{v^2}{2r^2}I$$ *[Formula 15]*

Which can be rearranged to make moment of inertia the subject [Formula 16]:

$$I = \frac{2mgr^2\Delta h}{mv^2r^2 + v^2}$$ *[Formula 16]*

1.3 Hypothesis

I expect weight distributions close to the centre of the wheel and small radii to be optimal for reducing the moment of inertia. The reasoning for this is the figure skater's manipulation of the conservation of momentum. Figure skaters open up their bodies when beginning to spin and then close them in order to spin faster. This is because with constant rotational momentum a smaller moment of inertia will result in a higher angular frequency which occurs as a result of them centralising their mass [1].

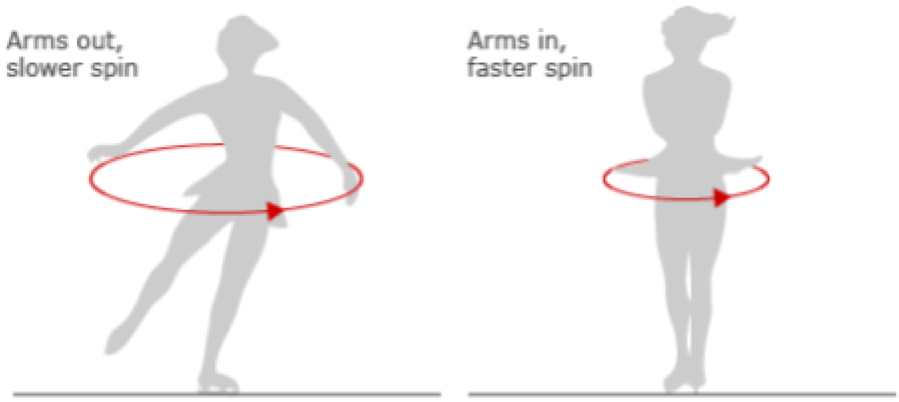


Figure 4. Representation of how figure skaters use the angular momentum to spin faster. BBC News. (2010, March 3). Chile earthquake may have shifted Earth's axis. http://news.bbc.co.uk/2/hi/americas/8547955.stm

1.4 Variables

Independent variable

Variable	Explanation	Range	Interval	Measuring device
Weight distribution of wheel	It is calculated by taking the radius of mass distribution in	[0.35, 0.85] (Extremities pose structural and	+0.1	The ratio can be calculated directly from the 3D design software (Fusion 360) as shown

	Figure 5 and dividing it by the outer radius of the wheel.	strength limitations)		in Figure 6 in order to ensure high accuracy, only slightly affected by printer errors.

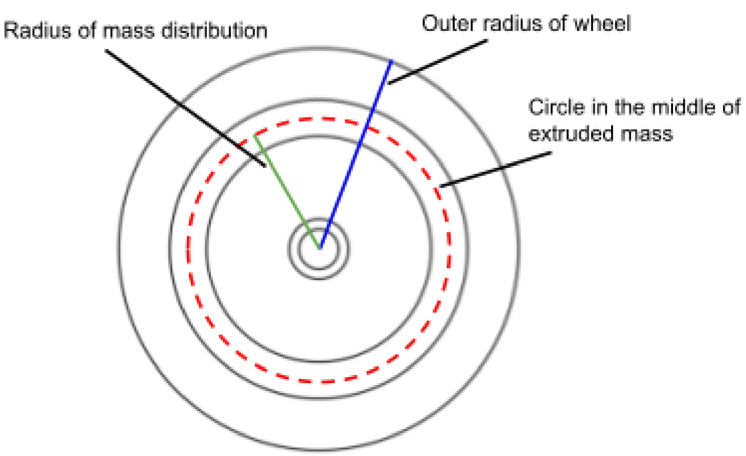


Figure 5. Structural diagram of flywheel design displaying mass distribution factor (Author's own)

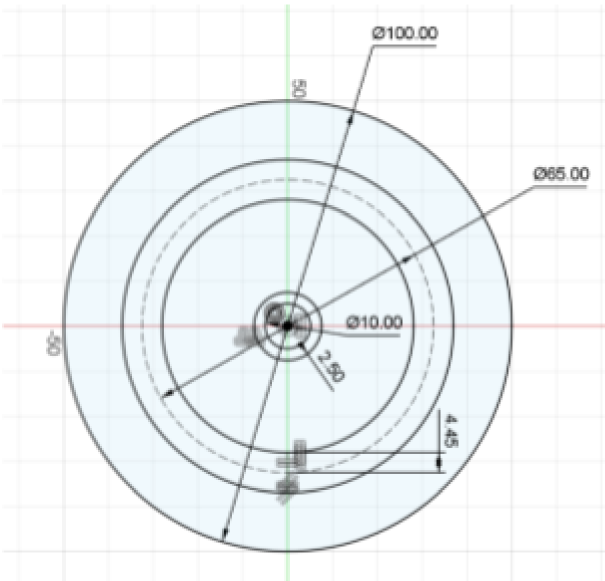


Figure 6. Top view of Fusion 360 technical drawing of the flywheel with a mass distribution factor of 0.65 (Author's own).

Dependent variable

Variable	Explanation	Measuring device
Final translational velocity of the flywheel	Velocity of the wheel right before bouncing off a fully extended string. Calculated using equations of motion [6] by substituting distance and time.	Distance = the length of the fully extended string, measured using a tape measure. Time will be calculated through recording the experiment and conducting frame by frame analysis of the footage with video editing software in order to minimise human error.

Control variables

Variable	Explanation	Control Measure
Distance travelled by the flywheel (0.4m)	Total distance the flywheel moves before bouncing.	Used the same string across iterations.
Gravitational constant of each flywheel ($9.81\ m/s^2$)	Acceleration due to gravity acting on the flywheel. Assumed to be ~9.81.	Conducted all iterations of experiment at the same altitude.
Mass of each flywheel (62g)	The total mass of the flywheel.	All wheels used the same axle, same material and had the same volume (50,000 m^3 as calculated in Fusion 360) and 3D printing irregularities were sanded off to ensure equal masses.
Exterior radius of flywheel (5cm)	Outermost radius of flywheel, affecting the moment of inertia.	Fixed through constraints in 3D design software (5cm)

1.5 Equipment list

- Two tables (at least 80cm tall)
- Two G clamps
- Two beaker clamps
- Gaffer tape
- Nylon string (1m)
- Sellotape
- Tape measurer
- Video recording device
- Video editing software (Microsoft clipchamp)

- 3D design software (e.g. Fusion 360)
- 3D printer
- PLA (400g)
- 3D printed axle (Figure X)
- 3D printed flywheels (Figure X-X)

1.6 Uncertainties

- Measuring tape. Resolution: 1mm. Uncertainty: ±0.5mm
- Video recording device (edited in Microsoft clipchamp), 30 frames per second. Resolution: 0.033s. Uncertainty: ±0.0167s
- Flywheel mass. Measured on a digital scale. Uncertainty: ±0.1g
- Distance travelled. Measured using measuring tape. Uncertainty: ±0.5mm

1.7 Diagram

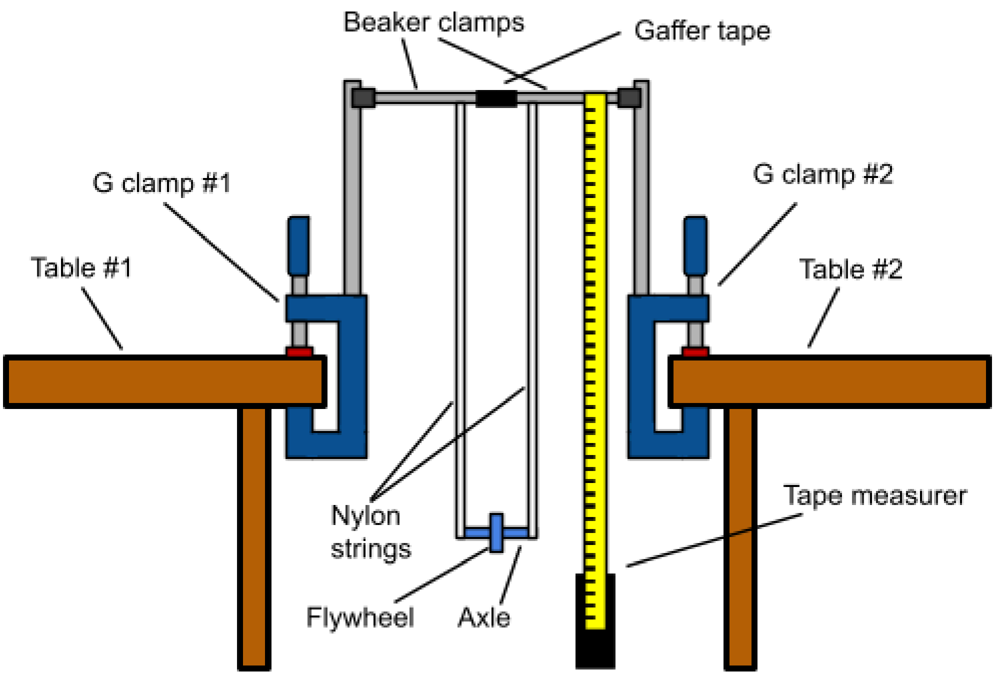


Figure 7. Graphical representation of Maxwell wheel setup used in investigation (Author's own)

1.8 Methodology

1. Setup two equally tall tables (at least 80 cm) with an approximately 20 cm gap between them.
2. Attach two G-clamps to the insides of the tables, facing each other.
3. Connect two beaker clamps to the ends of the G clamp handles.
4. Adjust the distance between the tables until the clamps meet to form a straight support beam.
5. Secure the two clamp handles together using gaffer tape.
6. Setup a video recorder to record the experiment with a 1 metre distance.
7. Sellotape the ends of two nylon strings so they are on the bottom of the support beam and 8 cm apart.
8. Setup an extended measuring tape so it measures parallel to the string
9. Place the AXLE through WHEEL1.
10. Sellotape the free end of each string onto the top of the axle, 8 cm apart.
11. Measure the height of the centre of the flywheel when the supporting string is fully extended, using the aforementioned measuring tape.
12. Coil the strings around the axle so that the flywheel rises 40 cm above its rest height and both sides of the axle remain at equal altitude.
13. Start the video recorder.
14. Drop the flywheel.
15. End recording and use video editing software (Microsoft Clipchamp) to calculate time taken for strings to fully extend from release. Full extension is the moment before the flywheel bounces.
16. Repeat steps 12-15 three times to obtain a mean.
17. Remove the sellotape attaching the string to the flywheel’s axle.
18. Repeat steps 9-17 for each flywheel.

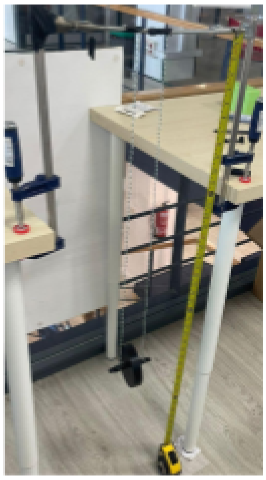


Figure 8. Photo image of Maxwell wheel setup used in the investigation

1.9 Risk assessment

Hazard	Risk	Control
Supporting structure may fall and cause damage.	High	Ensure that all clamps are securely fastened and that adequate tape is used to stabilise the supporting structure. Test stability before each recording by slightly shaking the structure.
Handling wheels could cause cuts due to the irregular surface produced from 3d printing.	Medium	Wear down the faces of the wheels by sanding or use gloves to prevent cuts.
Flywheel could fall and cause injury upon landing on a foot or hand.	Medium	Avoid placing arms and legs below the flywheel and use flywheels of low mass to ensure minimal impulse.
Tables with uneven legs could potentially tilt and affect the accuracy of findings.	Medium	Use a spirit level to ensure the tables aren’t tilted.
Video recorders could potentially pose a tripping hazard.	Low	Place recording devices far enough away to allow for walking around the experiment without risk of tripping.

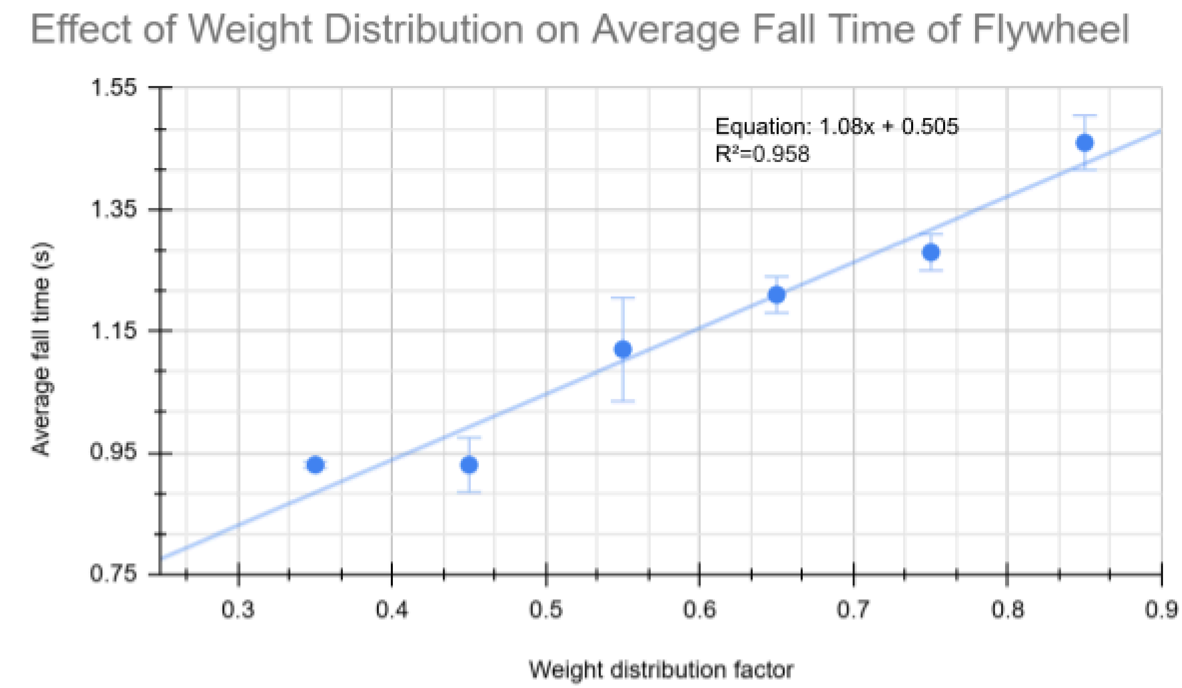
2. Analysis

2.1 Results

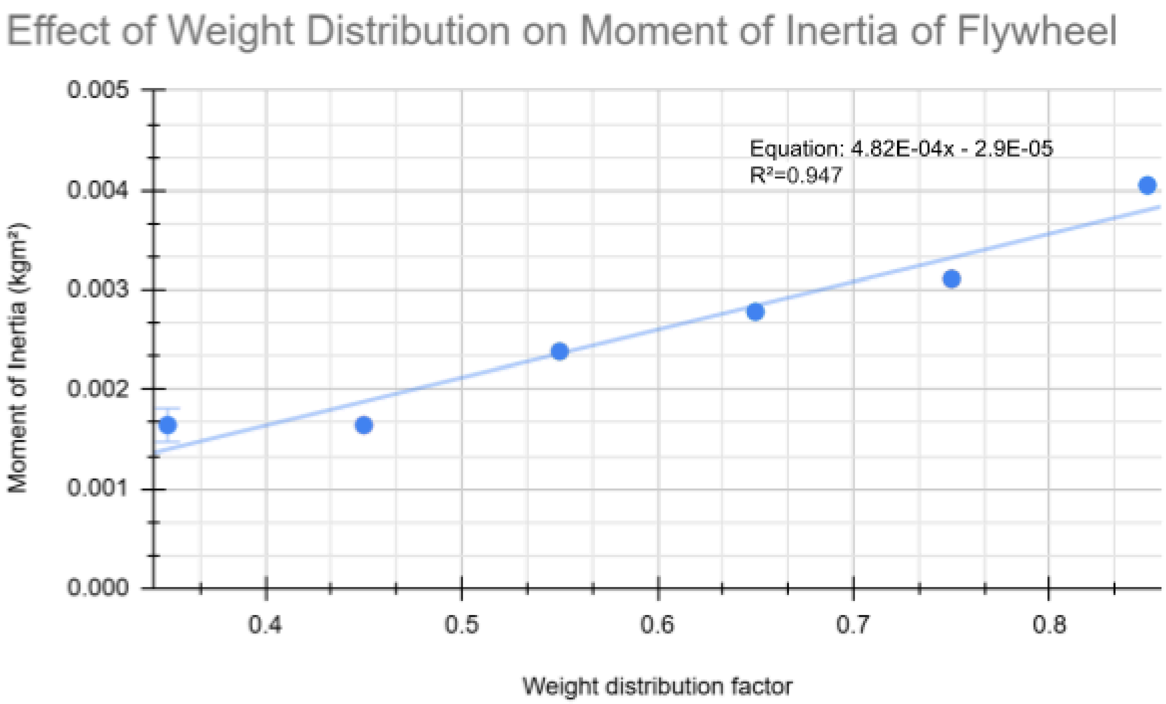
Weight distribution factor	Time (s) Repeat 1 ±0.0167s	Time (s) Repeat 2 ±0.0167s	Time (s) Repeat 3 ±0.0167s	Average time (s)
0.35	0.93	0.93	0.92	0.93 (±0.005)
0.45	0.93	0.89	0.98	0.93 (±0.045)
0.55	1.12	1.04	1.21	1.12 (±0.085)
0.65	1.21	1.18	1.24	1.21 (±0.03)
0.75	1.25	1.27	1.31	1.28 (±0.03)
0.85	1.51	1.42	1.45	1.46 (±0.045)

Weight distribution factor	Moment of Inertia (kgm^2)
0.35	$1.64\times10^{-3}\pm1.70\times10^{-4}$
0.45	$1.64\times10^{-3}\pm3.11\times10^{-4}$
0.55	$2.38\times10^{-3}\pm5.82\times10^{-4}$
0.65	$2.78\times10^{-3}\pm3.95\times10^{-4}$
0.75	$3.11\times10^{-3}\pm4.34\times10^{-4}$
0.85	$4.05\times10^{-3}\pm6.25\times10^{-4}$

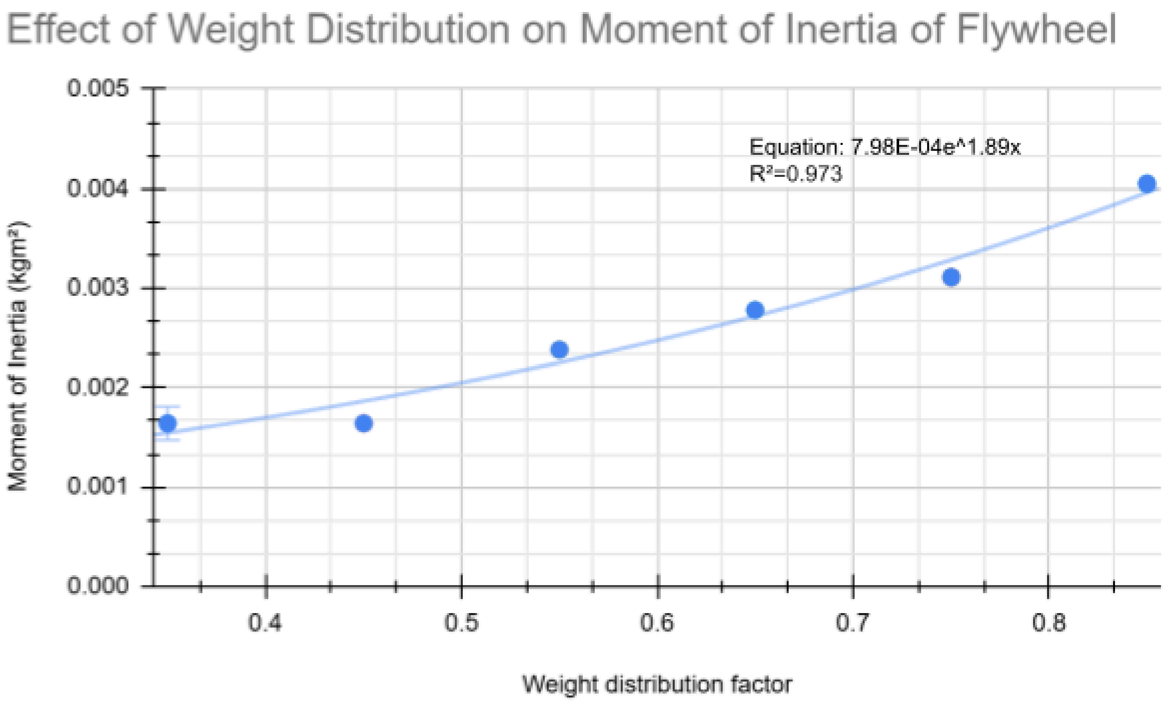
2.2 Graphs



Graph 1. Effect of Weight Distribution on Average Fall Time of Flywheel (Author's own)



Graph 2. Effect of Weight Distribution on Moment of Inertia of Flywheel (Author's own)



Graph 3. Effect of Weight Distribution on Moment of Inertia of Flywheel (Author's own)

2.3 Data processing

2.3.1 Moment of inertia calculations

The moment of inertia of each wheel was calculated from substituting each wheel's translational velocity into [Formula 16]. This was done by rearranging the equations of motion [Formula 17] to make translational velocity the subject [Formula 18].

$$s = \frac{v+u}{2}t \qquad \text{[Formula 17]}$$

$$v = \frac{2s}{t} - u \qquad \text{[Formula 18]}$$

Where:

$s = the\ total\ distance\ travelled$

$u = the\ initial\ velocity$

$v = the\ final\ velocity$

$t = the\ time\ taken$

Since the wheel initially begins at rest the value of u is 0 and therefore can be excluded giving [Formula 19].

$$v = \frac{2s}{t} \qquad \textit{[Formula 19]}$$

And substituting [Formula 19] into [Formula 16] produces [Formula 20].

$$I = \frac{2mgr^2\Delta h}{m(\frac{2s}{t})^2 r^2 + (\frac{2s}{t})^2} \qquad \textit{[Formula 20]}$$

The following is the process for calculating the moment of inertia for weight distribution factor = 0.35:

$m = 0.062kg$

$g = 9.81m/s^2$

$r = 0.05m$

$\Delta h = 0.4m$

$s = 0.4m$

$t = 0.93s$

$$I = \frac{2(0.062kg)(9.81m/s^2)(0.05m)^2(0.4m)}{(0.062kg)[\frac{2(0.4m)}{(0.93s)}]^2(0.05m)^2 + [\frac{2(0.4m)}{(0.93s)}]^2}$$

$$I = 0.00164kgm^2$$

2.3.2 Uncertainty calculations

The uncertainty of the average fall time was calculated by finding the difference between the smallest and the largest value of repeats and dividing by two, as is common practice.

The uncertainty calculation for the moment of inertia was done using the following principles:

$\Delta y = \Delta a + \Delta b$ when $y = a + b$

$\frac{\Delta y}{y} = \frac{\Delta a}{a} + \frac{\Delta b}{b} + \frac{\Delta c}{c}$ when $y = \frac{ab}{c}$

$\frac{\Delta y}{y} = \left| n \frac{\Delta a}{a} \right|$ when $y = a^n$

Where:

$\Delta x = \ the\ uncertainty\ of\ x$

Applying these principles to [Formula 20] produces the following derivations:

$$I = \frac{2mgr^2h}{m(\frac{2s}{t})^2 r^2 + (\frac{2s}{t})^2}$$

$$I = \frac{2mgr^2h}{(\frac{4s^2}{t^2})(mr^2 + 1)}$$

$$I = \frac{t^2mgr^2h}{2s^2(mr^2 + 1)}$$

$$\frac{\Delta I}{I} = \frac{\Delta t^2}{t} + \frac{\Delta m}{m} + \frac{\Delta g}{g} + \frac{\Delta r^2}{r} + \frac{\Delta h}{h} + \frac{\Delta 2s^2}{2s^2} + \frac{\Delta(mr^2 + 1)}{(mr^2 + 1)}$$

$$\frac{\Delta I}{I} = 2\frac{\Delta t}{t} + \frac{\Delta m}{m} + \frac{\Delta g}{g} + 2\frac{\Delta r}{r} + \frac{\Delta h}{h} + 2\frac{\Delta s}{s} + \frac{\Delta(mr^2 + 1)}{(mr^2 + 1)}$$

In order to calculate the relative uncertainty of $mr^2 + 1$ it can be substituted for y:

$$y = mr^2 + 1$$

$$\frac{\Delta y}{y} = \frac{\Delta(mr^2 + 1)}{(mr^2 + 1)}$$

Since 1 is a constant we can remove it in the uncertainty calculation:

$$\frac{\Delta y}{y} = \frac{\Delta(mr^2)}{(mr^2 + 1)}$$

In order to calculate the uncertainty of mr^2 it can be substituted for z:

$$z = mr^2$$

$$\Delta z = \Delta mr^2$$

$$\frac{\Delta z}{z} = \frac{\Delta m}{m} + \frac{\Delta r^2}{r^2}$$

$$\frac{\Delta z}{z} = \frac{\Delta m}{m} + 2\frac{\Delta r}{r}$$

$$\frac{\Delta z}{mr^2} = \frac{\Delta m}{m} + 2\frac{\Delta r}{r}$$

$$\Delta z = \Delta mr^2 = mr^2(\frac{\Delta m}{m} + 2\frac{\Delta r}{r})$$

Substituting it into the relative uncertainty for y gives:

$$\frac{\Delta y}{y} = \frac{\Delta(mr^2+1)}{(mr^2 + 1)} = \frac{mr^2(\frac{\Delta m}{m}+2\frac{\Delta r}{r})}{(mr^2 + 1)}$$

Which can be used to calculate the relative uncertainty for I:

$$\frac{\Delta I}{I} = 2\frac{\Delta t}{t} + \frac{\Delta m}{m} + \frac{\Delta g}{g} + 2\frac{\Delta r}{r} + \frac{\Delta h}{h} + 2\frac{\Delta s}{s} + \frac{mr^2(\frac{\Delta m}{m}+2\frac{\Delta r}{r})}{(mr^2 + 1)}$$

Giving a final formula for the uncertainty of I:

$$\Delta I = I(2\frac{\Delta t}{t} + \frac{\Delta m}{m} + \frac{\Delta g}{g} + 2\frac{\Delta r}{r} + \frac{\Delta h}{h} + 2\frac{\Delta s}{s} + \frac{mr^2(\frac{\Delta m}{m}+2\frac{\Delta r}{r})}{(mr^2 + 1)})$$

Substituting the control variables:

$\Delta m = \pm 0.0001kg$

$m = 0.062kg$

$\Delta g = \pm 0.01m/s^2$

$g = 9.81 m/s^2$

$\Delta r = \pm 0.0005 m$

$r = 0.05 m$

$\Delta h = \pm 0.0005 m$

$h = 0.4 m$

$\Delta s = \pm 0.0005 m$

$s = 0.4 m$

Gives the final equation for uncertainty of the moment of inertia in the investigation [Formula 21].

$$\Delta I = I[\, 2\frac{\Delta t}{t} + \frac{(0.0001kg)}{(0.062kg)} + \frac{(0.01m/s^2)}{(9.81m/s^2)} + 2\frac{(0.0005m)}{(0.05m)} + \frac{(0.0005m)}{(0.4m)}$$

$$+ 2\frac{(0.0005m)}{(0.4m)} + \frac{(0.062kg)(0.05m)^2(\frac{(0.0001kg)}{(0.062kg)} + 2\frac{(0.0005m)}{(0.05m)})}{((0.062kg)(0.05m)^2 + 1)}]$$

$$\Delta I = I(2\frac{\Delta t}{t} + 0.001613 + 0.001019 + 0.02 +$$

$$0.00125 + 0.0025 + 2.078 \times 10^{-7})$$

$$\Delta I = I(2\frac{\Delta t}{t} + 0.0263822)$$ *[Formula 21]*

The following is the process for calculating the uncertainty of the moment of inertia for weight distribution factor = 0.35:

$t = 0.93 s$

$\Delta t = 0.005$

$I = 1.64 \times 10^{-3} kgm^2$

$$\Delta I = (1.64 \times 10^{-3} kgm^2)(\frac{2 \times (0.005)}{(0.93s)} + 0.0263822)$$

$$= 1.70 \times 10^{-4} kgm^2$$

2.4 Summary of results

Summary of results
A statement of WHAT is the general relationship between your independent variable and
dependent variable.
Clarification for Analysis
Data refers to quantitative data or a combination of both quantitative and qualitative data.
Communication
Clear communication means that the method of processing can be understood easily.
Precise communication refers to following conventions correctly, such as those relating to the
annotation of graphs and tables or the use of units, decimal places and significant figures.
Consideration of uncertainties is subject specific and further guidance is given in the Physics teacher
support material.
Major omissions, inaccuracies or inconsistencies impede the possibility of drawing a valid conclusion
that addresses the research question.
Significant omissions, inaccuracies or inconsistencies allow the possibility of drawing a conclusion
that addresses the research question but with some limit to its validity or detail.

By looking at these results we can tell that as predicted by the hypothesis weight distributions more geared to the outside of the wheel have a higher moment of inertia whereas weight distributions closer to the centre of the wheel will result in a lower moment of inertia.

It is also notable from the results that the radius of the wheels plays a big impact on the moment of inertia of the wheels with smaller radii having much lower moments of inertia.

3. Conclusion

CO - CONCLUSION

An explanation of what you have discovered in terms of your investigation, and how it can be explained in terms of physics.

Interpretation of the data: The conclusion is justified, relevant to the RQ, fully justified and consistent with the analysis presented., *including comparisons with accepted values where appropriate.*

Scientific context of the conclusion, based on prior published info, textbooks, citations, etc, is justified by making relevant comparison.

In order to understand the results of the experiment it is important to understand how to calculate the moment of inertia of a particular object which is by using the following principle where the moment of inertia of an object is equal to the moments of inertia of its point masses:

$$I = \sum_{i=1}^{n} m_i r_i^2$$ *[32]*

Meaning if we treat a wheel as a collection of point masses the way we would be able to maximise the moment of inertia is to concentrate these points with the highest radius possible which explains why the wheel with its mass distributed around the outside had a much higher moment of inertia than the wheel where the mass was distributed centrally.

There are however some weaknesses present within the experiment such as: the application of the equations of motion due to them only applying in cases where there is uniform acceleration and is not completely reliable in real world cases due to drag and other external forces affecting the final results.

The investigation also has the limitation that it contains a relatively small sample size of wheel dimensions and weight distributions as it does not explore complexities such as uneven or layered structures which could have significant impact on the moment of inertia.

What I have found with the results of the experiment is that weight distributions closer to the rim have a greater moment of inertia compared to wheels with weight distributions around the centre and this disparity is heightened in wheels with smaller radii as shown by the longer time period taken for the rim weighted wheels to reach full extension on the maxwell apparatus showing it has a higher moment of inertia as it is defined by: the opposition that the body exhibits to having its speed of rotation about an axis altered by the application of a torque[1] meaning a smaller magnitude of acceleration.

This investigation has allowed me to gain experience with the scientific method and allowed me to demonstrate and understand a concept that I had only been presented with in a theoretical standpoint being the fundamental theorem for moment of inertia *[32].*

This internal assessment has various applications as stated in the introduction it can be used to optimise the creation of wheels however there are also other applications such as in aerospace engineering with the international space station where most of the weight is distributed around the outside of the structure, this is done in order to maximise the moment of inertia. The reason you would want to maximise the moment of inertia of an object in orbit is because angular momentum is directly proportional to moment of inertia meaning a higher moment of inertia will

[1] The Editors of Encyclopaedia Britannica. (2024, August 2). Moment of inertia | Definition, Equation, Unit, & Facts. Encyclopedia Britannica. https://www.britannica.com/science/moment-of-inertia

result in more angular momentum. The reason why the international space station wants to maximise its angular momentum is to protect itself in the case of collisions with objects such as space debris, if its angular momentum is high enough then it will be mostly unaffected by such a collision but if its mass was centrally distributed or evenly distributed the effects could be much more severe.

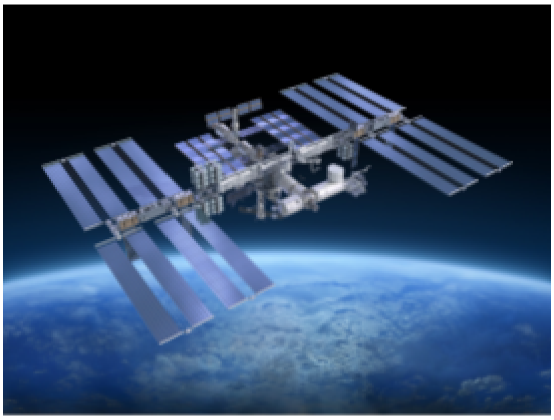


Figure 13. Image of the international space station

4. Evaluation

EV - EVALUATION

What went well? What didn't go well?

Weaknesses or limitations: The report explains specific weaknesses or limitations and explains their impact on the methodology, *including how they influence the data and the validity of the conclusions drawn.*

What would you change to improve the experiment? To make it more precise and accurate?

➔ Do calculations on the effects of the changes on uncertainties:
I.e.: If you changed the ruler from one with a cm scale to one with a mm scale, you need to re-do the fractional and percentage uncertainty calculations to show the new uncertainties, and that they would be reduced.

How could this investigation be extended?

Realistic Improvements are relevant to the weaknesses or limitations and described and explained. *Discussed realistic and relevant improvements and extensions including i.e., include how this would add to or enhance the work already done.*

7. Bibliography

[1] D. Halliday, R. Resnick, and J. Walker, Fundamentals of Physics, 10th ed.

Hoboken, NJ: Wiley, 2014.

[2] R. A. Serway and J. W. Jewett, Physics for Scientists and Engineers, 10th ed. Boston, MA: Cengage Learning, 2018.

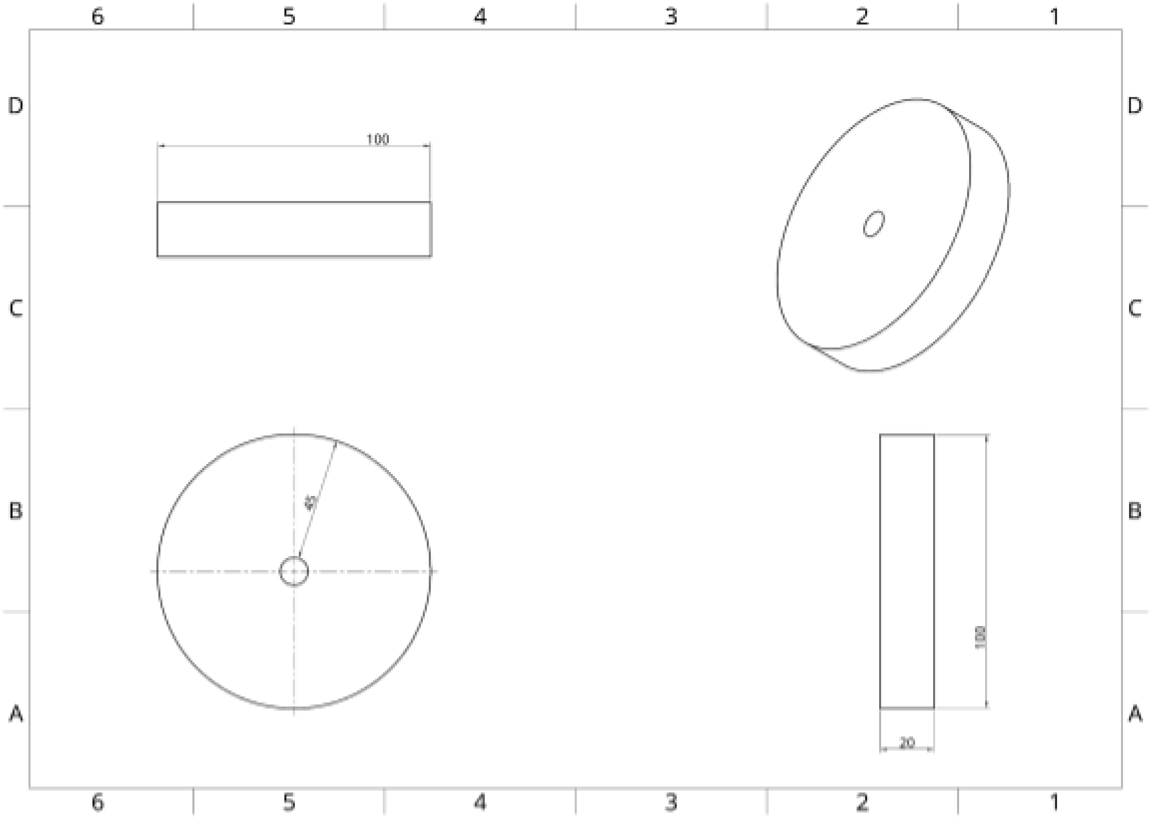
[3] MIT OpenCourseWare, “Lecture Notes: Rotational Dynamics,” Massachusetts Institute of Technology, 2021. [Online]. Available: https://ocw.mit.edu

[4] HyperPhysics, “Rotational Motion,” Georgia State University, 2022. [Online]. Available: http://hyperphysics.phy-astr.gsu.edu/

[5] Kognity, “Moment of inertia (HL),” [Online]. Available: https://app.kognity.com/study/app/dp2-phys-hl2/sid-423-cid-254994/book/moment-of-inertia-hl-id-43154/. [Accessed: 18-Dec-2024].

[6] Kognity, “The equations of motion,” [Online]. Available: https://app.kognity.com/study/app/dp2-phys-hl2/sid-423-cid-254994/book/the-equations-of-motion-id-44299/. [Accessed: 18-Dec-2024].

7. Appendix



Engineering drawing for Object A