Experiment 4
Moment of Inertia

SAFETY

Make sure that you have read the **General Safety Notes**, in the Introductory section of this manual, before you begin.

Do not, **under any circumstances,** attempt to repair or dismantle any of the equipment. If you suspect equipment to be faulty, turn it off at the power point and talk to your demonstrator.

ADDITIONAL HAZARDS

Rotating and falling objects constitute a potential hazard. Keep your hands away from the spokes of the rotating wheel.

Make sure that the retort stand is securely clamped to the bench.

Outline of Experiment

In this Experiment, you will investigate certain features of rotational motion. In particular, you will measure the moment of inertia (I) for a rotating bicycle wheel through a conservation of energy treatment.

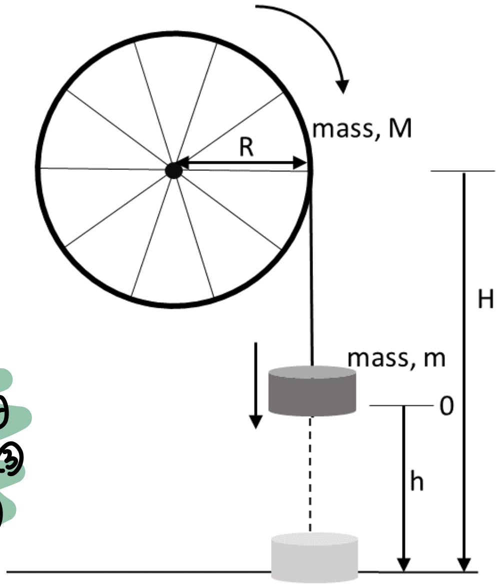
✓***Pre-lab exercises:*** *Read the laboratory exercise, complete the questions below, then submit the pre-lab task online (LMS or http://fyl.ph.unimelb.edu.au/prelabs) for this experiment. [Your marks for the pre-lab will be based on the answers to the online questions, which are taken from the pre-lab work in the manual]*

Learning Goals

- To be efficient in the use of Excel through generating functions and graphs.
- To work together as a team to record data efficiently and accurately.
- To determine the unknown quantity through graphical analysis and making a thoughtful conclusion regarding the results.
- To obtain an experimental value for the moment of inertia for a bike wheel.

Introduction

In this experiment you will make a series of measurements, graph the results and fit a line to these data points in order to calculate the moment of inertia. To do this we will be investigating the energy of the system and the known conservation of this energy.



The system consists of a mass, m, attached to the rim of a wheel by a string as shown in the diagram. As the mass is released, the wheel starts to rotate.

The total mechanical energy of this system at any given time must be the sum of the rotational kinetic energy ($\frac{1}{2}I\omega^2$) of the wheel, the translational kinetic energy ($\frac{1}{2}mv^2$) of the load, the gravitational potential energy (MgH) of the wheel, and the gravitational potential energy (mgh) of the load. Ignoring friction, the total mechanical energy is constant over the entire motion (i.e. it is conserved). 1 2 3 4

✓ Pre-lab question 1

Given that both the wheel and the load are initially at rest, write down an expression for the total mechanical energy E_{Total} of the system just before the load is released. This should be in terms of the initial height h of the load, the initial height H of the wheel's centre of mass, the mass m of the load, and the mass M of the wheel.

✓ Pre-lab question 2

Write down an expression for the total mechanical energy E_{Total} of the system just as the load reaches the ground. This should be in terms of the velocity v of the load, the angular velocity ω of the wheel, and the moment of inertia I of the wheel.

✓ Pre-lab question 3

Because the total mechanical energy is conserved, the value of E_{Total} is the same in both of your equations. Therefore, show that the following relation holds:

$$mgh = \frac{1}{2}(I + mR^2)\omega^2 \qquad \text{Eqn (1)}$$

Recall that the velocity of the load is equal to the velocity of a point on the rim of the wheel at all times: $v = \omega R$, where R is the radius and ω is the angular velocity.

Equation (1) is a useful one. It is in the form of a linear equation (y = mx), where mgh is y and ω^2 is x (as I, m, R are all constant). This means that if we can graph mgh versus ω^2, the graph should be a straight line, and the gradient 'm' of this line should be equal to ½ ($I + mR^2$).

Experimental Set-up

Remember, our aim here is to measure the moment of inertia, I. Take measurements of m and R. Equation (1) above suggests that to calculate I, we must measure the final angular velocity, ω, of the wheel for various values of the drop height, h.

Over a range of heights from 0.6 m to 1.3 m (in 0.1 m steps), measure the time taken for the load to reach the ground. Remember to include uncertainties for all your measurements.

Data

✓ Record your measurements and calculations in Excel. Use the function application to complete any calculations as described in Appendix B, using a table similar to this:

h	t	v	ω	ω^2	**mgh**
(m)	*(sec)*	*(ms^{-1})*	*(rad sec^{-1})*	*(rad^2 sec^{-2})*	*(J)*

✓ Plot a graph of mgh versus ω^2, with mgh on the vertical axis.

✓ Draw a line of best fit to your data points using Excel's **Add Trendline** function. See Appendix B if you need help with this.

✓ Using Equation (1) and the gradient of the trendline, calculate the moment of inertia.

Analysis

Be sure to consider the following points in your logbook:

✓ Is your line of best fit a straight line - why, or why not?

✓ Should the trendline's intercept the mgh axis at 0? What does this value tell you?

Note: Make sure to LABEL & print off your results graph and stick it into your logbook.

✓ Estimate the uncertainties in mgh and ω^2 using the half-range of their maximum and minimum values. Draw lines of maximum and minimum gradient on your graph, and use them to estimate the uncertainty in your value for the moment of inertia.

According to theory, the moment of inertia of a wheel which has its entire mass M located at its rim is $I = MR^2$ (where R is the wheel's radius). However, the moment of inertia of a solid wheel, which has its mass distributed evenly from the centre to the rim, is $I = \frac{1}{2} MR^2$. The mass of the wheel, M, will be given to you by your demonstrator.

✓ Compare your calculated value for the moment of inertia with the two values given by the expressions above. Based on your results, how would you characterise the mass distribution of your wheel?

✓ Are there discrepancies between what the theory predicts, and what you have actually measured and calculated? If so, try to explain them.

Conclusion

✓ Summarise and comment on your final results.