Rotational Dynamics#71920
4001654

Torque Theorem

Objectives: In this lab, you will compare two experimentally determined values for the moment of inertia of a solid cylinder. You will use a PASCO experimental setup for one of the determinations, and measurements and geometry for the other.

Background Understanding: To be successful, you will need to apply your understanding of rotational kinematics, as well as the relationship between angular and translational quantities. You will also need to calculate the moment of inertia using the known formula for a solid cylinder.

Procedure

The experimental setup includes a large cylinder supported in an almost frictionless manner by a cushion of air. This cylinder is attached via a wound string to a hanging mass, which when released causes the string to unwind and the cylinder to accelerate. The PASCO measuring device records the number of silver lines per second that are passing by the detector. This measurement, which is reported every 2 seconds, can be used to find the tangential velocity of the cylinder.

Make at least 5 independent experimental runs for each of the cylinders (one aluminum and one steel). Use your data to calculate five experimental values of the moment of inertia for each cylinder, then use these values to find the mean as well as the standard deviation of the mean for the moment of inertia.

You should create a data table that lists the masses and radii you measure for both large cylinders as well as the small wound cylinder. You need to use the mechanical balance to weight the steel cylinder.

You should also create a measurement table that lists, for each cylinder, the values you find for N_1 and N_2 for each of the 10 runs, and the derived values for moments of inertia (see Analysis, below).

Analysis

A tricky part of the experiment is understanding the data that the PASCO system provides. It gives you a number N, which is:

N = (the number of silver bars that pass) per second

We need to turn this into a tangential speed so we can use it in our equations:

$v_t = N \times$ (distance between silver bars) $= N \times$ 2 mm

Once you know v_t, you can use this to find ω. Then, you can use a pair (or the average of several pairs) of these measurements, which happen every 2 seconds, to find angular acceleration, α. Perform the experiment at least 5 times per cylinder to get an estimate of the uncertainty (σ_m).

The rest of the puzzle can be solved by setting up equations that relate the accelerating mass, the tension in the string, and the torque on the large cylinder. Use your understanding of Newton's laws and torque theorem. Solve your equations to find the moment of inertia.

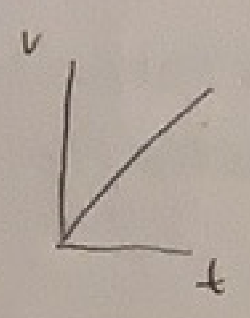
Then, you can use the equations for the moment of inertia of a solid or hollow cylinder ($I = \frac{1}{2} MR^2$ or $I = \frac{1}{2} M(R_1^2 + R_2^2)$) to find a "mathematical" total value for I.

You should report your results in a table that gives, for each cylinder, the mean (μ) and standard deviation of the mean (σ_m) for the "experimental" value of I, the "mathematical" value of I, and the number of σ_m difference between the two. In your discussion, be sure to include the probability that they are drawn from different distributions, and consider whether these values are in statistical agreement with each other.

Hints:

1. Use a free-body diagram in conjunction with your equation for torque and your understanding of the relationship between linear and angular acceleration.
2. Keep track of the radii involved! Use r and R, or r_1 and r_2, etc. to label them, and be sure you're using the *right one* depending on the quantity you're considering.
3. Don't confuse diameter with radius in your equations and measurements!
4. Keep track of your units.

$\omega_f = \omega_i + \alpha t$



$\omega_1 \quad \omega_2$

$\frac{\omega_2 - \omega_1}{\Delta t} = \alpha_{avg}$

$rF = \tau = I\alpha$