

Experiment #9 Moment of Inertia Pre-lab Questions

**** Disclaimer: This pre-lab is *not* to be copied, in whole or in part, unless a proper reference is made as to the source. (It is strongly recommended that you use this document *only* to generate ideas, or as a reference to explain complex physics necessary for completion of your work.) Copying of the contents of this web site and turning in the material as “original material” is *plagiarism* and will result in serious consequences as determined by your instructor. These consequences may include a failing grade for the particular pre-lab or a failing grade for the entire semester, at the discretion of your instructor. ****

- This is data taken with the apparatus described in the manual.
 - Hanging mass = 0.1985 kg
 - Diameter of pulley (drum) = 0.0248 m
 - Mass 1: 0.2735 kg out 20 cm from center of arm.
 - Mass 2: 0.271.3 kg out 20 cm from center of arm.
 - Moment of Inertia of the arm I_0 : 0.01200 $\text{kg} \cdot \text{m}^2$ (measured separately)

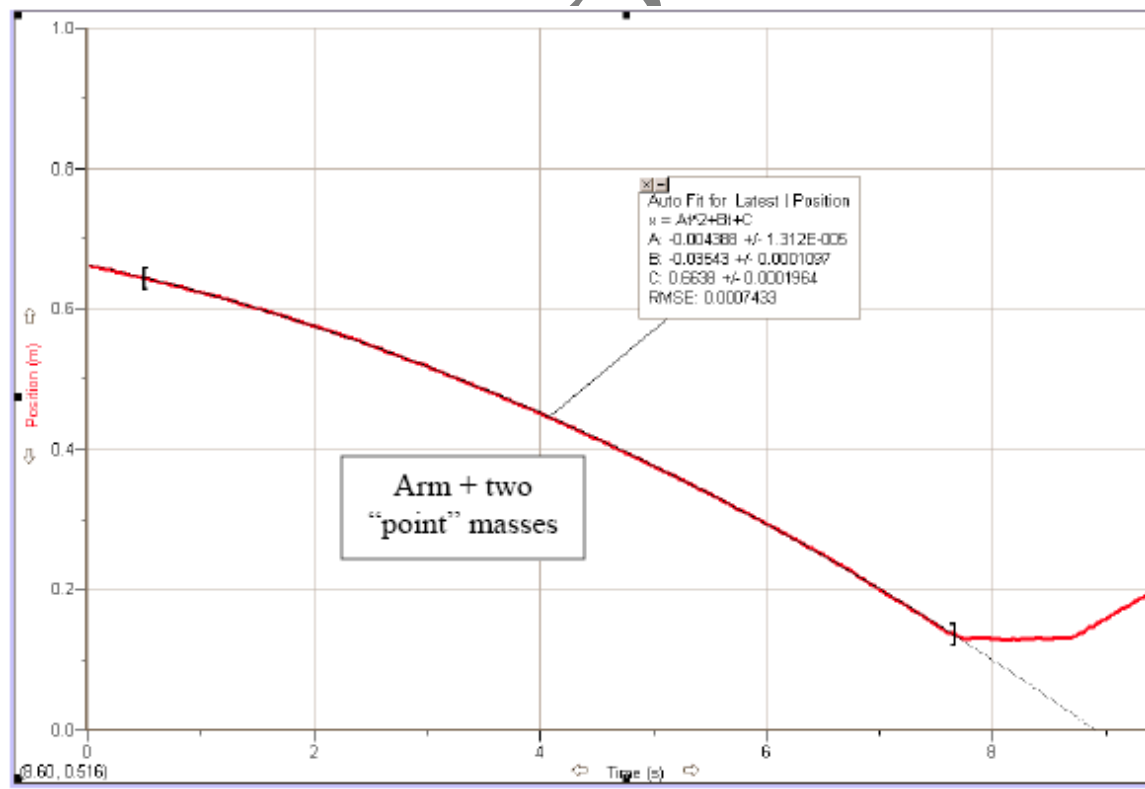


Figure 1: Experimental Data Obtained from Logger Pro for the Moment of Inertia Experiment with Two Masses Attached to the Rotating Platform

- Find the experimental value for the Moment of Inertia of the arm plus the two masses using the information and the graph above.

***** IT IS IMPERATIVE THAT YOU UNDERSTAND THE PHYSICS BEHIND THE EXPERIMENT BEFORE YOU GET STARTED ON THE PRELAB! GO READ THE COMMENTS, THOUGHTS AND SUGGESTIONS PAPER FIRST IF YOU HAVE NOT YET DONE SO! *****

The equation for the moment of inertia from the lab manual and the comments and suggestions paper is given as:

$$I = mr^2 \left(\frac{g}{a} - 1 \right)$$

This means, given the mass of the hanging mass, the radius of the drum, the acceleration due to gravity and the measured acceleration of the falling mass (from a best fit line of position versus time); we can then calculate the moment of inertia for the spinning arm (with zero or more masses attached).

We are given the following information in the problem:

Hanging Mass (m) [kg]	Diameter of Drum (d = 2r) [m]	Mass 1 (m ₁) [kg]	Mass 2 (m ₂) [kg]	Position of Mass 1 (r ₁) [m]	Position of Mass 2 (r ₂) [m]	Moment of Inertia with out Masses (I _o) [kg m ²]
0.1985	0.0248 m	0.2735	0.2713	0.20	0.20	0.01200

(Note: The dark shaded information above is not necessary for this part of the problem.) First, we need to calculate the radius of the drum from the measured diameter. This is a fairly simple and straight forward calculation:

$$r = \frac{d}{2} = \frac{0.0248 \text{ m}}{2} = 0.0124 \text{ m}$$

We are also given the following best fit line with the two bolts attached to the propeller (from figure 1). Using the trendline feature in Logger Pro, we can get the acceleration from the best fit line with the two weights attached to the propeller.

$$z = \left(-0.004388 \frac{\text{m}}{\text{s}^2} \right) t^2 + \left(-0.03543 \frac{\text{m}}{\text{s}} \right) t + (0.6638 \text{ m})$$

$$z = \frac{1}{2} a_z t^2 + v_{o,z} t + z_o$$

Thus:

a_z [m/s ²]	$v_{o,z}$ [m/s]	z_o [m]
-0.008776	-0.03543	0.6638

**** DON'T FORGET ABOUT THE ½ IN FRONT OF THE ACCELERATION IN THE KINEMATIC EQUATION OF POSITION VERSUS TIME!****

Using the equation we just derived for the moment of inertia, we now have all the information we need.

$$I = mr^2 \left(\frac{g}{a} - 1 \right) = (0.1985 \text{ kg})(0.0124 \text{ m})^2 \left(\frac{\left(-9.81 \frac{\text{m}}{\text{s}^2} \right)}{\left(-0.008776 \frac{\text{m}}{\text{s}^2} \right)} - 1 \right)$$

$$I = 0.0341 \text{ kg m}^2$$

This is the experimentally measured total moment of inertia for the arm with the two masses attached.

- **Find the Theoretical value for the two “point” masses. Add the moment of inertia for the “arm” and compare this number to the experimental value calculated above. They should be very close.**

The total moment of inertia of a system is the net sum of all component moments of inertia in the system. This means, if we know the moment of inertia for the rotating bar of our systems, we can calculate what the expected total moment of inertia will be for any masses added to the system – adding to the total moment of inertia. (We can then effectively calculate the total moment of inertia for the system and compare this with the experimentally measured results.) This is mathematically represented using the following equation:

$$I_{Total} = \sum_{j=0}^n I_j = I_o + I_1 + I_2$$

Where I_o is the moment of inertia of the bar without any masses attached (obtained experimentally with Logger Pro). I_1 and I_2 are the calculated moments of inertia from mass 1 and mass 2 (respectively).

The individual moments of inertia for the masses are given by the following equations:

$$I_1 = m_1(r_1)^2 \quad I_2 = m_2(r_2)^2$$

Again, we are given the following information in the first problem:

Hanging Mass (m) [kg]	Diameter of Drum (d = 2r) [m]	Mass 1 (m ₁) [kg]	Mass 2 (m ₂) [kg]	Position of Mass 1 (r ₁) [m]	Position of Mass 2 (r ₂) [m]	Moment of Inertia with out Masses (I _o) [kg m ²]
0.1985	0.0248 m	0.2735	0.2713	0.20	0.20	0.01200

(Note: Again, the dark shaded information above is not necessary for this part of the problem.)

$$I_1 = m_1(r_1)^2 = (0.2735 \text{ kg})(0.20 \text{ m})^2 = 0.01094 \text{ kg m}^2$$

$$I_1 = 0.01094 \text{ kg m}^2$$

$$I_2 = m_2(r_2)^2 = (0.2713 \text{ kg})(0.20 \text{ m})^2 = 0.010852 \text{ kg m}^2$$

$$I_2 = 0.010852 \text{ kg m}^2$$

Thus the total moment of inertia with the two masses attached should theoretically be:

$$I_{Total} = \sum_{j=0}^n I_j = I_o + I_1 + I_2$$

$$I_{Total} = (0.01200 \text{ kg m}^2) + (0.01094 \text{ kg m}^2) + (0.010852 \text{ kg m}^2)$$

$$I_{Total} = 0.033792 \text{ kg m}^2$$

- Use the percent difference to find the error between the two numbers.

$$\% \text{ difference} = \frac{|I_{Theory}| - |I_{Measured}|}{|I_{Theory}|} \times 100\%$$

$$\% \text{ difference} = \frac{|0.033792 \text{ kg m}^2| - |0.0341 \text{ kg m}^2|}{|0.033792 \text{ kg m}^2|} \times 100\% = -0.9115\%$$