Moment of Inertia

Name:

PES 115 Report

Lab

Objective

The purpose of this experiment was to learn how to use logger pro to measure the moments of inertia of a rotating body and then further learn how the moment of inertia changes with a respect to mass and location.

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Data and Calculations

Part A: Moment of inertia of the apparatus (I_0)

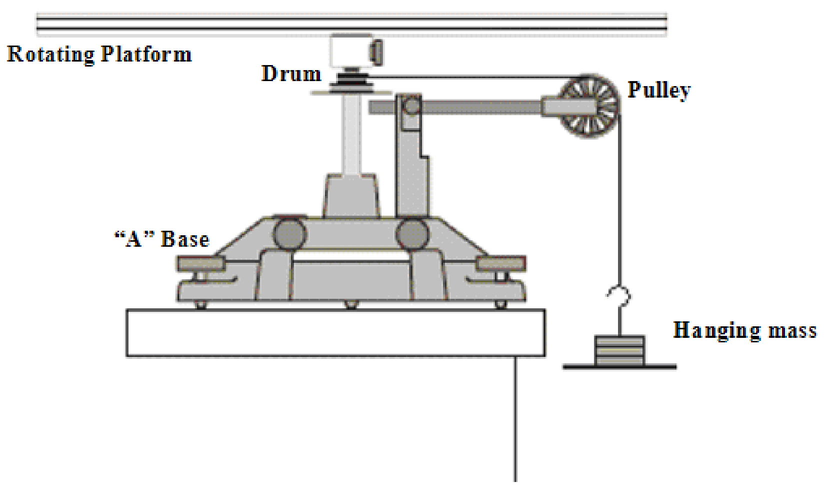

Figure 1: Experimental Setup used to Measure the Moment of Inertia of the Apparatus

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Hanging~~Drop~~ mass = _213.7g = 0.2137__ kg

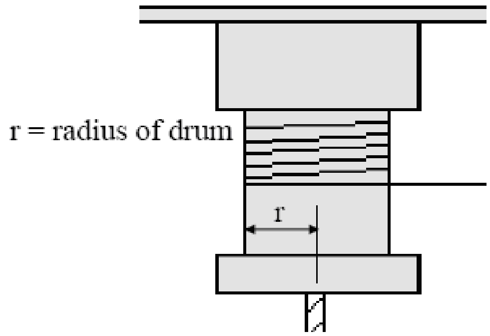

Figure 2: Side view of the Drum, Explicitly Showing the Measured Radius of the Drum

Radius of drum~~pulley~~ = _1.85 cm = 0.0185__ m

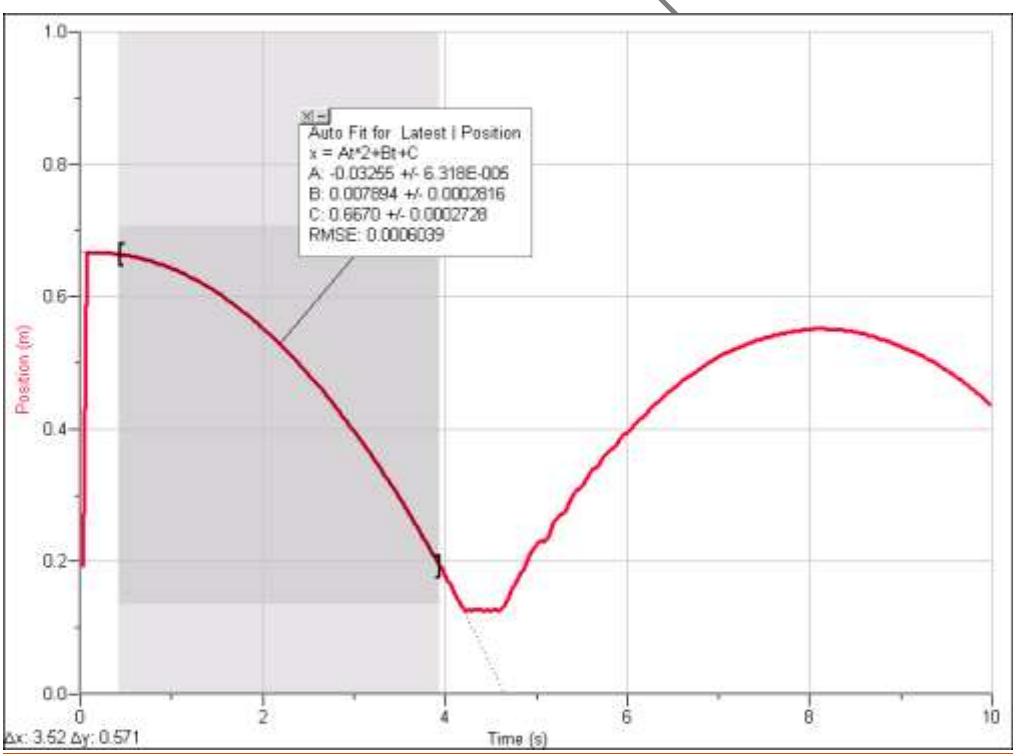

Figure 3: Data Collected by Logger Pro for Just the Apparatus

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Using the trendline feature in Logger Pro, we can get the acceleration from the best fit line with no weights attached to the propeller.

$$z = \left(-0.03255\frac{m}{s^2}\right)t^2 + \left(0.007894\frac{m}{s}\right)t + (0.6670\,m)$$

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

Thus:

a_z [m/s^2]	$v_{o,z}$ [m/s]	z_o [m]
-0.06510	0.007894	0.6670

$$\boxed{\vec{a}_o = -0.06510\frac{m}{s^2}\,\hat{z}}$$

~~$\vec{a}$ = ________________ m/s^2~~

- ~~include a sample graph~~
  - ~~addition trials are not explicitly called for in the manual, but you **know** that averaging over several identical measurements will achieve better results!~~

~~$\vec{a}_{ave}$ = ________________ m/s^2~~

Calculate the Moment of inertia (I_o). Be sure to s~~S~~how your work.

$$I_o = m_{hanging} r_{drum}^2\left(\frac{g}{a_o} - 1\right)$$

$$I_o = (0.2137\,kg)(0.0185\,m)^2\left(\frac{(-9.81)}{(-0.06510)} - 1\right) = 0.0109482\,kg\,m^2$$

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$$\boxed{I_o = 0.0109482\,kg\,m^2}$$

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Part B: Moment of inertia of point-masses (I_{12})

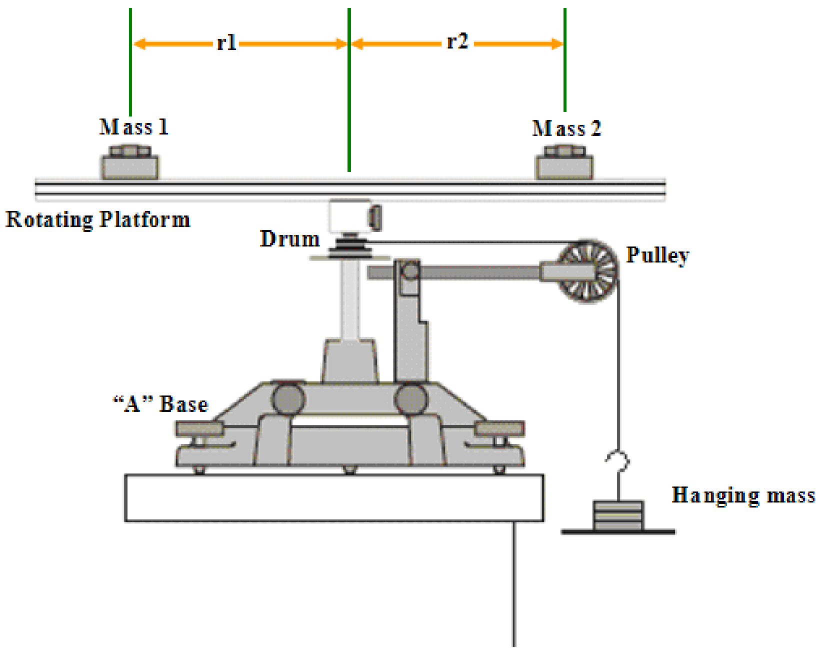

Figure 4: Experimental Setup used to Measure the Moment of Inertia with "Point" Masses

Trial 1:

Mass 1 = _0.2737_ kg Mass 2 = _0.2710_ kg

r~~d~~$_1$ = _0.05_ m ~~d~~r$_2$ = _0.05_ m

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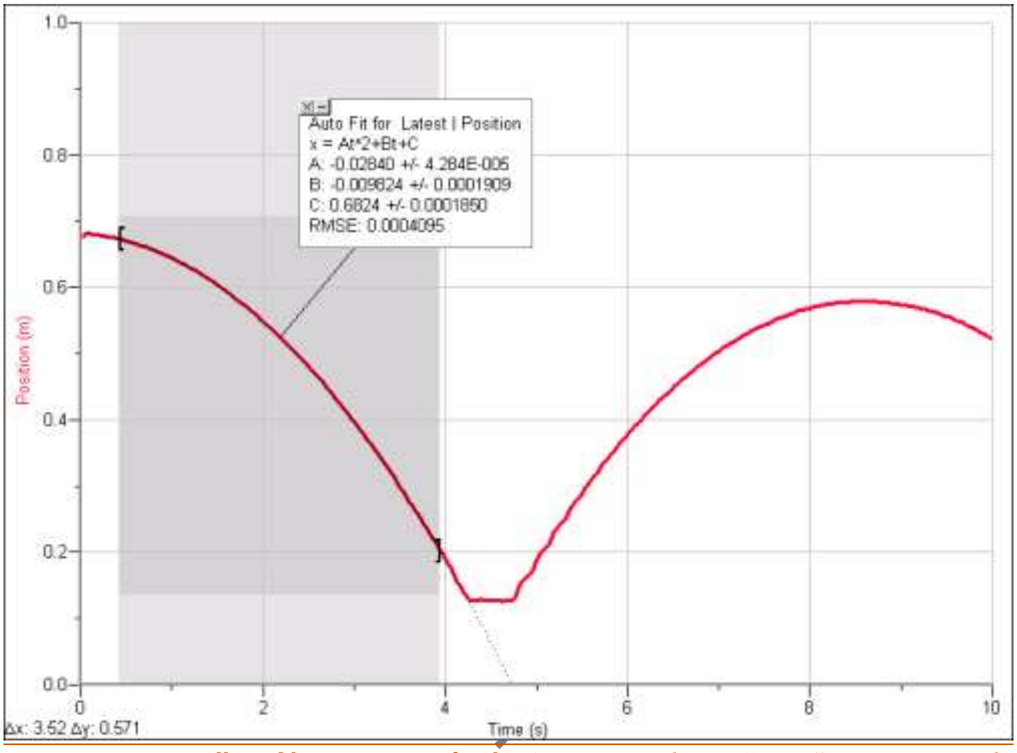

Figure 5: Data Collected by Logger Pro for the Apparatus with Two "Point" Masses Located 5cm from the Pivot Point of the Apparatus

Using the trendline feature in Logger Pro, we can get the acceleration from the best fit line with no weights attached to the propeller.

$$z = \left(-0.02840\frac{m}{s^2}\right)t^2 + \left(-0.009824\frac{m}{s}\right)t + (0.6824\,m)$$

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

Thus:

a_z [m/s^2]	$v_{o,z}$ [m/s]	z_o [m]
-0.05680	-0.009824	0.6824

$$\boxed{\vec{a}_{1,2} = -0.05680\frac{m}{s^2}\,\hat{z}}$$

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Calculate the Moment of inertia ($I_{1,2}$). Be sure to show your work.

$$I_{1,2} = m_{hanging} r_{drum}^2 \left(\frac{g}{a_{1,2}} - 1 \right)$$

$$I_{1,2} = (0.2137\,kg)(0.0185\,m)^2 \left(\frac{(-9.81)}{(-0.05680)} - 1 \right) = 0.012559\,kg\,m^2$$

$$\boxed{I_{1,2} = 0.012559\,kg\,m^2}$$

~~Measure I_{12} = ________________~~

~~Show all work and graph used~~

~~Once again averaging over multiple identical trials would help to improve results~~

Trial 1 - Theoretical values

Calculate the moment of inertia for each mass using the equations in the manual.

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 in the manual:

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

Calculations:

$$I_1 = m_1 (r_1)^2 = (0.2737\ kg)(0.05\,m)^2 = 0.00068425\ kg\,m^2$$

$$\boxed{I_1 = 0.00068425\ kg\ m^2}$$

$$I_2 = m_2 (r_2)^2 = (0.2710\ kg)(0.05\,m)^2 = 0.0006775\ kg\,m^2$$

$$\boxed{I_2 = 0.0006775\ kg\ m^2}$$

Moment of Inertia with out Masses (I_o) [kg m^2] (Measured)	**Moment of Inertia of Mass 1 (I_1) [kg m^2] (Calculated)**	**Moment of Inertia of Mass 2 (I_2) [kg m^2] (Calculated)**	**Moment of Inertia with Masses ($I_{1,2}$) [kg m^2] (Measured)**
0.0109482	0.00068425	0.0006775	0.012559

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

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

$$I_{Total} = \left(0.0109482\ kg\,m^2\right) + \left(0.00068425\ kg\,m^2\right) + \left(0.0006775\ kg\,m^2\right)$$

$$\boxed{I_{Total} = 0.01230995\ kg\,m^2}$$

~~I_o =~~ ______________

~~I_1 =~~ ______________

~~I_2 =~~ ______________

~~Bring it all together~~

~~I_{12} =~~ ______________

It might be better to organize your data into a table.

~~Show all work~~

Error

Calculate the %difference between the experimental and theoretical values for I_{12}

$$\%\ difference = \frac{\left|I_{Theory}\right| - \left|I_{Measured}\right|}{\left|I_{Theory}\right|} x100\%$$

$$\boxed{\%\ difference = \frac{\left|0.01230995\ kg\,m^2\right| - \left|0.012559\ kg\,m^2\right|}{\left|0.01230995\ kg\,m^2\right|} x100\% = -2.023\%}$$

Repeat ~~two~~four more times

Get results for ~~4~~2 more variations on the mass distances.

Trial 2:

Mass 1 = _0.2737_ kg Mass 2 = _0.2710_ kg

r_1 = _0.10_ m r_2 = _0.10_ m

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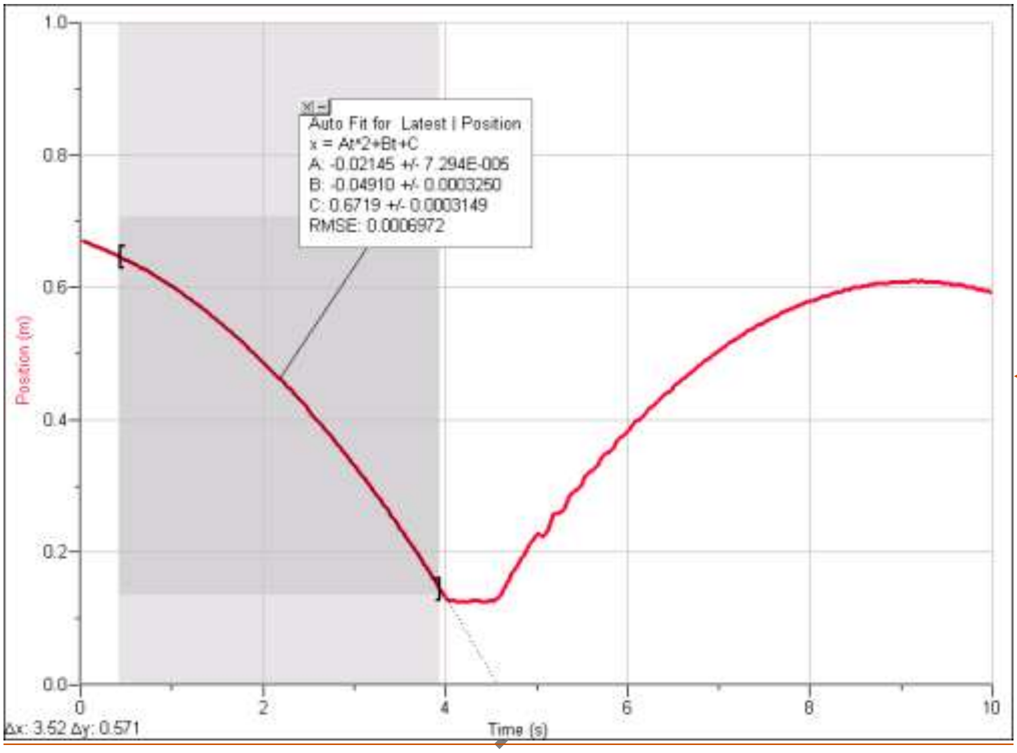

Figure 6: Data Collected by Logger Pro for the Apparatus with Two "Point" Masses Located 10cm from the Pivot Point of the Apparatus

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Using the trendline feature in Logger Pro, we can get the acceleration from the best fit line with no weights attached to the propeller.

$$z = \left(-0.02145\frac{m}{s^2}\right)t^2 + \left(-0.04910\frac{m}{s}\right)t + (0.6819\,m)$$

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

Thus:

a_z [m/s^2]	$v_{o,z}$ [m/s]	z_o [m]
-0.04290	-0.04910	0.6819

$$\boxed{\vec{a}_{1,2} = -0.04290\frac{m}{s^2}\ \hat{z}}$$

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Calculate the Moment of inertia ($I_{1,2}$). Be sure to show your work.

$$I_{1,2} = m_{hanging} r_{drum}^2 \left(\frac{g}{a_{1,2}} - 1 \right)$$

$$I_{1,2} = (0.2137\,kg)(0.0185\,m)^2 \left(\frac{(-9.81)}{(-0.04290)} - 1 \right) = 0.016652\,kg\,m^2$$

$$\boxed{I_{1,2} = 0.016652\,kg\,m^2}$$

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Trial 2 - Theoretical values

Calculate the moment of inertia for each mass using the equations in the manual.

Calculations:

$$I_1 = m_1 (r_1)^2 = (0.2737\ kg)(0.10\,m)^2 = 0.002737\ kg\,m^2$$

$$\boxed{I_1 = 0.002737\ kg\ m^2}$$

$$I_2 = m_2 (r_2)^2 = (0.2710\ kg)(0.10\,m)^2 = 0.002710\ kg\,m^2$$

$$\boxed{I_2 = 0.002710\ kg\ m^2}$$

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Moment of Inertia with out Masses (I_o) [kg m^2] (Measured)	**Moment of Inertia of Mass 1 (I_1) [kg m^2] (Calculated)**	**Moment of Inertia of Mass 2 (I_2) [kg m^2] (Calculated)**	**Moment of Inertia with Masses ($I_{1,2}$) [kg m^2] (Measured)**
0.0109482	0.002737	0.002710	0.016652

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

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

$$I_{Total} = (0.0109482\ kg\,m^2) + (0.002737\ kg\,m^2) + (0.002710\ kg\,m^2)$$

$$\boxed{I_{Total} = 0.0163952\ kg\,m^2}$$

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Error

Calculate the %difference between the experimental and theoretical values for I_{12}

$$\%\ difference = \frac{|I_{Theory}| - |I_{Measured}|}{|I_{Theory}|} x100\%$$

$$\boxed{\%\ difference = \frac{|0.016652\ kg\,m^2| - |0.0163952\ kg\,m^2|}{|0.016652\ kg\,m^2|} x100\% = 1.542\%}$$

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Trial 3:

Mass 1 = _0.2737_ kg Mass 2 = _0.2710_ kg

r_1 = _0.20_ m r_2 = _0.20_ m

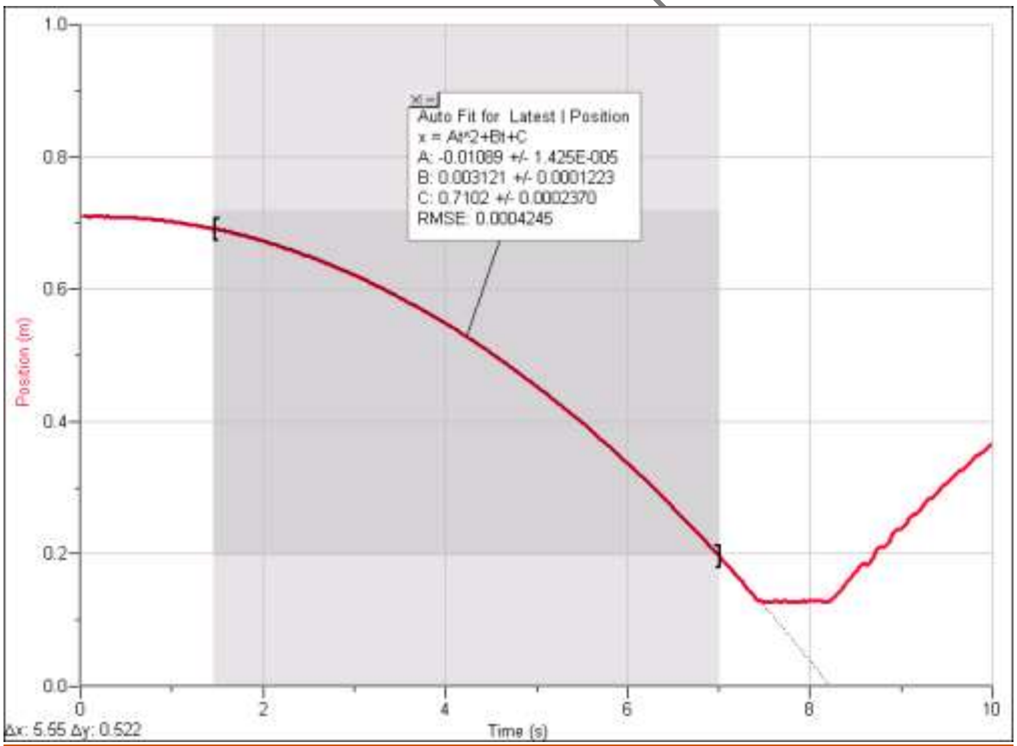

Figure 7: Data Collected by Logger Pro for the Apparatus with Two "Point" Masses Located 20cm from the Pivot Point of the Apparatus

Using the trendline feature in Logger Pro, we can get the acceleration from the best fit line with no weights attached to the propeller.

$$z = \left(-0.01089\frac{m}{s^2}\right)t^2 + \left(0.003121\frac{m}{s}\right)t + (0.7102\,m)$$

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

Thus:

a_z [m/s²]	$v_{o,z}$ [m/s]	z_o [m]
-0.02178	0.003121	0.7102

$$\boxed{\vec{a}_{1,2} = -0.02178\frac{m}{s^2}\,\hat{z}}$$

Calculate the Moment of inertia ($I_{1,2}$). Be sure to show your work.

$$I_{1,2} = m_{hanging} r_{drum}^2\left(\frac{g}{a_{1,2}} - 1\right)$$

$$I_{1,2} = (0.2137\,kg)(0.0185\,m)^2\left(\frac{(-9.81)}{(-0.02178)} - 1\right) = 0.0328696\,kg\,m^2$$

$$\boxed{I_{1,2} = 0.0328696\,kg\,m^2}$$

Trial 2 - Theoretical values

Calculate the moment of inertia for each mass using the equations in the manual.

Calculations:

$$I_1 = m_1(r_1)^2 = (0.2737\;kg)(0.20\,m)^2 = 0.010948\;kg\,m^2$$

$$\boxed{I_1 = 0.010948\;kg\;m^2}$$

$$I_2 = m_2(r_2)^2 = (0.2710\;kg)(0.20\,m)^2 = 0.01084\;kg\,m^2$$

$$\boxed{I_2 = 0.01084\;kg\;m^2}$$

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Moment of Inertia with out Masses (I_o) [kg m^2] (Measured)	Moment of Inertia of Mass 1 (I_1) [kg m^2] (Calculated)	Moment of Inertia of Mass 2 (I_2) [kg m^2] (Calculated)	Moment of Inertia with Masses ($I_{1,2}$) [kg m^2] (Measured)
0.0109482	0.010948	0.01084	0.0328696

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

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

$$I_{Total} = \left(0.0109482\ kg\,m^2\right) + \left(0.010948\ kg\,m^2\right) + \left(0.01084\ kg\,m^2\right)$$

$$\boxed{I_{Total} = 0.0327362\ kg\,m^2}$$

Error

Calculate the %difference between the experimental and theoretical values for I_{12}

$$\%\ difference = \frac{\left|I_{Theory}\right| - \left|I_{Measured}\right|}{\left|I_{Theory}\right|} x100\%$$

$$\boxed{\%\ difference = \frac{\left|0.0327362\ kg\,m^2\right| - \left|0.0328696\ kg\,m^2\right|}{\left|0.0327362\ kg\,m^2\right|} x100\% = -0.408\%}$$

Conclusion

You are intelligent scientists. Follow the guidelines provided and write an appropriate conclusion section based on your results and deductive reasoning. See if you can think of any possible causes of error.

** NOTE: There are several components of error which could significantly modify the results of this experiment. Some of these are listed below:

- Data Selection
- Calibration of Sensors

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- Ignoring String’s Mass and Pulley’s Friction
- The “Pointy-ness” of the “Point” Masses
- Parallax in Measurement
- Center of Mass of “Point” Masses
- Snagging and catching
- Sensor limitation parameters
- Computer processor speed and reading registration
- Sensor Alignment
- Other …

A few of the potential errors listed above may be applicable to YOUR experiment.

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