☐PHYS115 ☑PHYS121 ☐PHYS123
☐PHYS116 ☐PHYS122 ☐PHYS124
Lab Cover Letter

Author (*You*) Trevor Nichols Signature: Trev N.

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Lab Partner(s) Katherine

Date Performed 27/03/2024 Date Submitted 02/04/2024

Lab (*such as #1: UNC*) 4: RKE

TA: Phillip

GRADE (*to be filled in by your TA*) See your TA for detailed feedback.
An '*x*' next to a subcategory means you need to improve this aspect of your work.

Paper Subtotals (points)

( ) ***General* (6)**
____ Sig. figs.
____ Units
____ Clarity of Presentation
____ Format

( ) ***Abstract* (4)**
____ Quantity or principle
____ How measurement was made
____ Numerical Results
____ Conclusion

( ) ***Intro & Theory* (9)**
____ Basic principle
____ Main equations to be used
____ Apparatus
____ What will be plotted
____ Fitting parameters related

( ) ***Exp. Procedures* (15)**
____ Description
____ Stating and justifying uncertainties
____ Data Record
____ Quality of Lab Work

( ) ***Analysis & Error Analysis* (20)**
____ Discussion
____ Equations & Calculations
____ Presentation inc. Graphs, Tables
____ Results Reported & Reasonable
____ Underlined items addressed

( ) ***Discussion & Conclusions* (6)**
____ Numerical comparison of results
____ Logical conclusions
____ Discussion of pos. errors
____ Suggestions to reduce errors

( ) **Paper Total (60 points)**
(30 points for CME or EPF)

( ) **Notebook (10 points)**
____ Format (*proper style, following directions*)
____ Apparatus (*brief description of equipment, including sketches*)
____ Data (*including computer file names and manually recorded data*)
____ Experimental Technique (*describing your procedures; stating & justifying uncerts.*)
____ Analysis (*results and errors*)

( ) **Worksheet(s)/Fill-in-the-Blank-Report (30 points)** *if applicable*

( ) **Adjustments** – late submissions, improper procedures, etc. – or bonus points for exceptional work.

( ) Total Grade

Graded by ___________ (TA's initial)

1 Abstract

The purpose of this lab is to establish whether the formulas of inertia for point masses are consistent with both Monte-Carlo simulation data and experimental data.

$I_{Lpredicted} = 0.034\ kgm^2$
$I_L = 0.02 \pm 0.01\ kgm^2$

Our predicted values for inertia and the experimental values do line up fairly well, and thus is insufficient to reject the theoretical values of inertia for point masses.

Additional sources of error could be inaccuracy in measurement of the radius of the masses, additional friction in the system, inertia and drag of the flywheel, and the masses not truly being point masses.

2 Theory

2.1 Variables

2.1.1 Constants

$\Delta S = 0.015\ m$
$R_{wheel} = 0.200 \pm 0.002\ m$
$m_w = 1.5\ kg$
$m_h = 0.060\ kg$
$m_L = 0.9223 \pm 0.0001\ kg$
$r = 0.1845 \pm 0.0005\ m$

2.1.2 Measured Values

2.1.2.1 Simulated

$\delta_{\Delta T} = 0.0002$
$y_L(t)$: Position as a function of time

2.1.2.2 Experimentally

$\delta_{\Delta T} = 0.00005$
$y_W(t)$: Position as a function of time
$y_{W+L}(t)$: Position as a function of time

2.2 Formulae

2.2.1 Calculation of velocity and position and expected inertia

$y = i\Delta S$
$v = \frac{\Delta S}{\Delta T}$
$I = mr^2$
$\delta_I = \sqrt{(\delta_m r^2)^2 + (\delta_r 2mr)^2}$

2.2.2 Uncertainty in velocity squared

$\delta_{v^2} = \delta_{v^2 \Delta T}$ as ΔS has negligible variance
$= 2\frac{\Delta S^2}{\Delta T^3}\delta_{\Delta T}$ from formula for velocity
$= \frac{2v^3}{\Delta S}\delta_{\Delta T}$

2.2.3 Measurement of Inertia

$$\begin{aligned}
\text{Separation of weights} \quad & \Delta U_W = \Delta U_{M_h} + \Delta U_{m_h} \\
\text{Conservation of energy} \quad & \Delta U_W + K_t + K_r - W_f = 0 \\
\text{Cancellation of friction} \quad & \Delta U_{M_h} + K_t + K_r = 0 \\
& M_h g y = \frac{1}{2} M_h v^2 + \frac{1}{2} I\omega^2 \\
& M_h g y = \frac{1}{2}\left(M_h + \frac{I}{r^2}\right)v^2 \\
\text{Measurable values vs. constants and Intertia} \quad & \frac{v^2}{y} = \frac{2g}{\left(1 + \frac{I}{M_h r^2}\right)} \\
\text{Intertia} \quad & I = M_h r^2 \left(\frac{2g}{\frac{v^2}{y}} - 1\right)
\end{aligned}$$

2.2.4 Difference in Inertia for experimental setup

$$\begin{aligned}
\text{Initial Equation} \quad & I = M_h r^2 \left(\frac{2g}{\frac{v^2}{y}} - 1\right) \\
\text{Inertia of just the wheel} \quad & I_W = M_h r^2 \left(\frac{2g}{\frac{v_W^2}{y_W}} - 1\right) \\
\text{Inertia of the wheel and weights} \quad & I_{W+L} = M_h r^2 \left(\frac{2g}{\frac{v_{W+L}^2}{y_{W+L}}} - 1\right) \\
\text{Inertia of the weights} \quad & I_L = 2gM_h r^2 \left(\frac{1}{\frac{v_{W+L}^2}{y_{W+L}}} - \frac{1}{\frac{v_W^2}{y_W}}\right)
\end{aligned}$$

2.2.5 Uncertainty in Inertia of weights

$$\text{Initial Equation} \quad I_L = 2gM_hr^2\left(\frac{1}{\frac{v_{W+L}^2}{y_{W+L}}} - \frac{1}{\frac{v_W^2}{y_W}}\right)$$

$$\text{Combination of sources of variance} \quad \delta_{I_L} = \sqrt{\delta_{I_Lr}^2 + \delta_{I_L\frac{v_{W+L}^2}{y_{W+L}}}^2 + \delta_{I_L\frac{v_W^2}{y_W}}^2}$$

$$\text{Let} \quad b_{W+L} = \frac{v_{W+L}^2}{y_{W+L}}$$

$$\text{Let} \quad b_W = \frac{v_W^2}{y_W}$$

Combination of sources of variance:

$$\delta_{I_L} = \sqrt{\left(\delta_r 4gM_hr\left(b_{W+L}^{-1} - b_W^{-1}\right)\right)^2 + \left(\delta_{b_{W+L}}2gM_hr^2b_{W+L}^{-2}\right)^2 + \left(\delta_{b_W}2gM_hr^2b_W^{-2}\right)^2}$$

$$\delta_{I_L} = 2gM_hr\sqrt{\left(2\delta_r\left(b_{W+L}^{-1} - b_W^{-1}\right)\right)^2 + \left(\delta_{b_{W+L}}rb_{W+L}^{-2}\right)^2 + \left(\delta_{b_W}rb_W^{-2}\right)^2}$$

2.2.6 Uncertainty in Inertia of weights for MC

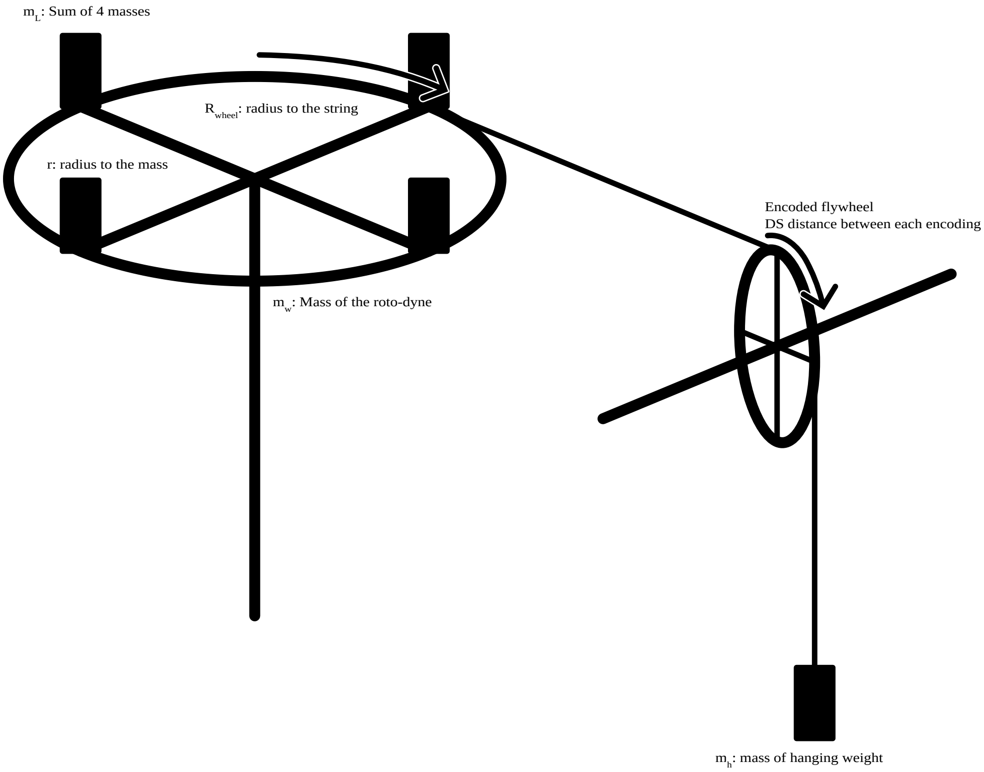
$$\text{Let} \quad b = \frac{v^2}{y}$$

Combination of sources of variance:

$$\delta_{I_L} = \sqrt{\left(\delta_r 4gM_hr\left(b^{-1} - 1\right)\right)^2 + \left(\delta_b 2gM_hr^2b^{-2}\right)^2}$$

$$\delta_{I_L} = 2gM_hr\sqrt{\left(2\delta_r\left(b^{-1} - 1\right)\right)^2 + \left(\delta_b rb^{-2}\right)^2}$$

3 Procedure



1. Set up the diagram above without the 4 masses on the roto-dyne or the hanging weight
2. Add paperclips to the end of the string until the system is in equilibrium moving downward, this is to account for the friction in the system
3. Add the mass of m_h to the end of the string
4. Release the mass and record the data as it falls with the encoded flywheel
5. Reset the system and add the 4 masses to the roto-dyne
6. Release the mass and record the data as it falls with the encoded flywheel

4 Analysis

4.1 Monte Carlo Pre-setup

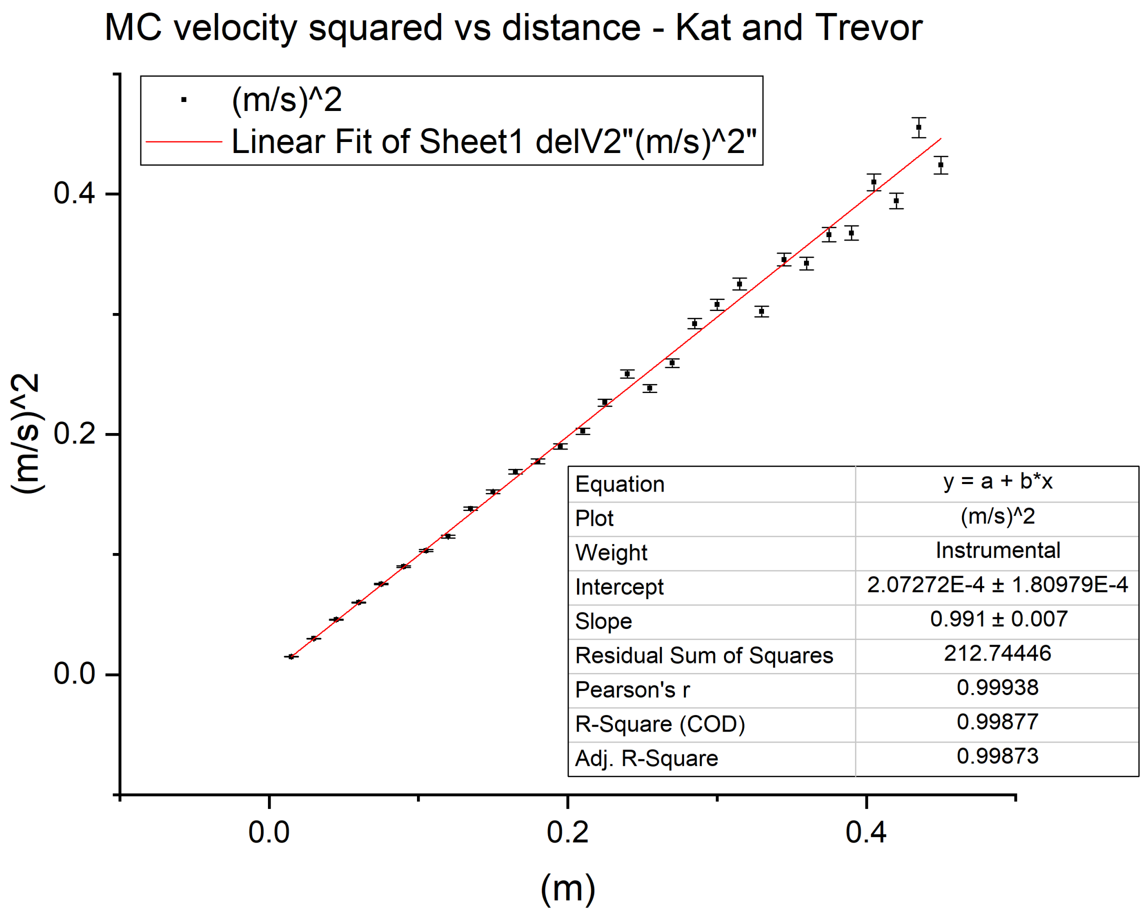
1. Estimate the inertia of the roto-dyne
2. Use seed data to generate the data

$I_{predicted} = \frac{3}{4}MR^2 = 0.045\ kgm^2$
$\text{Seed} = 0201$

4.2 Analysis

1. After collecting all the data, we first derived the velocity and position through the formulae derived in section 2.2.1.
2. Then we calculated the variance in v^2 by the formulae given in section 2.2.2.
3. We then graphed a position vs. velocity squared graph and used linear regression to obtain the slope with its uncertainty in *Origin*
4. From that, we obtained our estimated Inertia of the weights through the formulae given in sections 2.2.4 and 2.2.3 for the experimental and Monte-Carlo data respectively
5. We also calculate the variance in the Inertia value via the formulae in sections 2.2.5 and 2.2.6.
6. Then we compared our found inertia value with the expected value calculated by the formula given in section 2.2.1

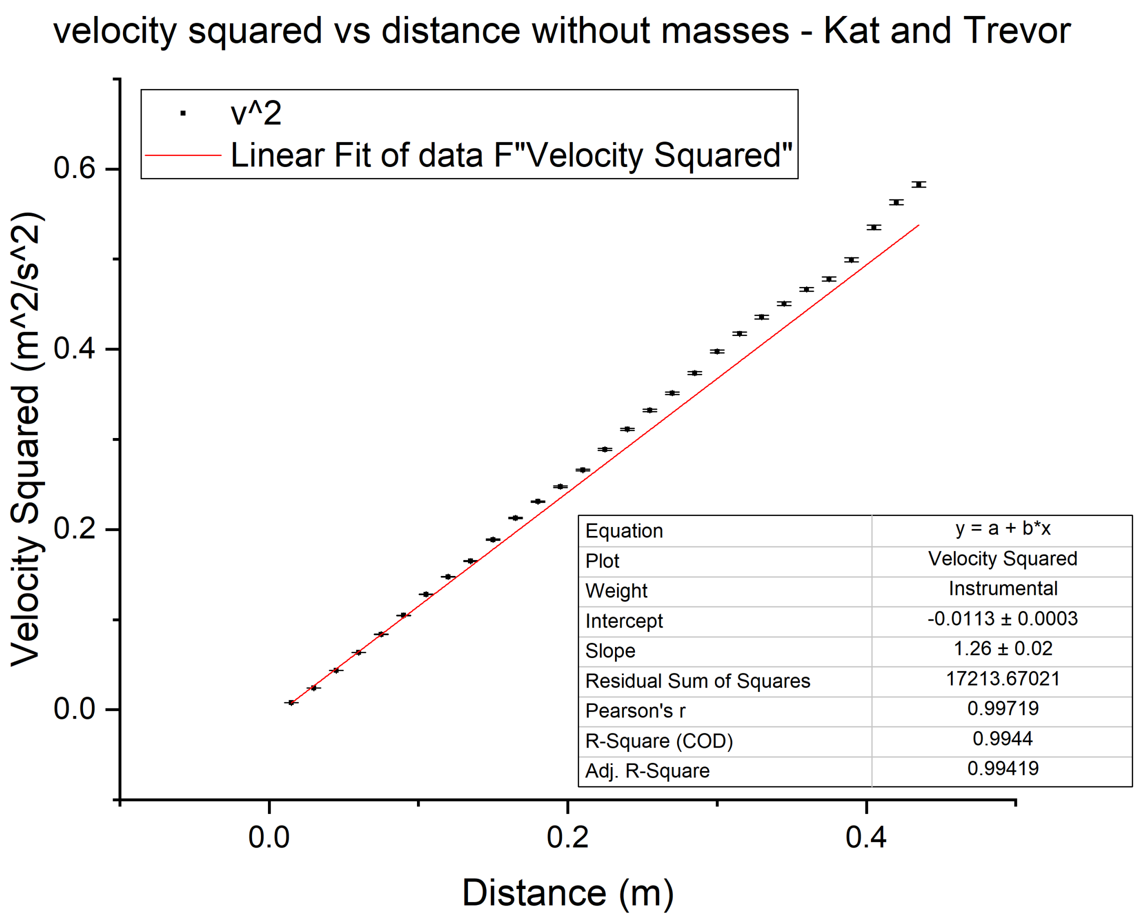
4.3 Monte Carlo

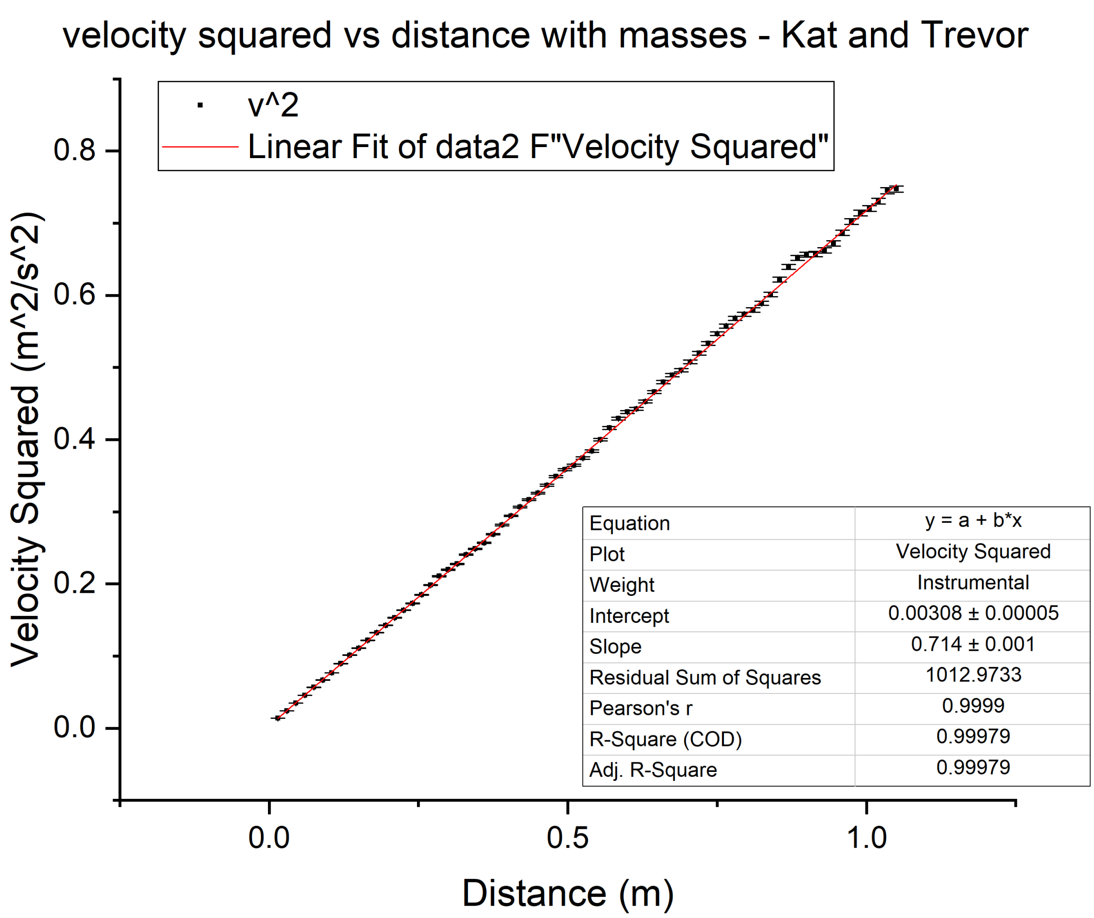


$b = 0.991 \pm 0.007\ \frac{m}{s^2}$
$I = 0.4512 \pm 0.0003\ kgm^2$

We found our experimental inertia to be within 3 SD of the predicted value. Additional variance is due to a large spread chosen for the random number generation.

4.4 Experimental


velocity squared vs distance without masses - Kat and Trevor
v^2
Linear Fit of data F"Velocity Squared"
Velocity Squared (m^2/s^2)
Distance (m)
0.0
0.2
0.4
0.6
Equation
y = a + b*x
Plot
Velocity Squared
Weight
Instrumental
Intercept
-0.0113 ± 0.0003
Slope
1.26 ± 0.02
Residual Sum of Squares
17213.67021
Pearson's r
0.99719
R-Square (COD)
0.9944
Adj. R-Square
0.99419


velocity squared vs distance with masses - Kat and Trevor
v^2
Linear Fit of data2 F"Velocity Squared"
Velocity Squared (m^2/s^2)
Distance (m)
0.0
0.2
0.4
0.6
0.8
0.5
1.0
Equation
y = a + b*x
Plot
Velocity Squared
Weight
Instrumental
Intercept
0.00308 ± 0.00005
Slope
0.714 ± 0.001
Residual Sum of Squares
1012.9733
Pearson's r
0.9999
R-Square (COD)
0.99979
Adj. R-Square
0.99979

$b_W = 1.26 \pm 0.02 \ \frac{m}{s^2}$
$b_{W+L} = 0.714 \pm 0.001 \ \frac{m}{s^2}$
$I_L = 0.02 \pm 0.01 \ kgm^2$

$I_{Lpredicted} = 0.034 \ kgm^2$

Our experimental finding is within 1.5 SD of the predicted value.

5 Conclusion

We concluded that our experimental data is consistent with the theoretical values of inertia for point masses. Our experimental values landed within 1.5 SD of the predicted value. Additional variance could be explained by inaccuracy in measurement of the radius of the masses, additional friction in the system, inertia and drag of the flywheel, and the masses not truly being point masses.

6 Acknowledgements and info

- Lab #5
- 27/03/2024
- Station 14 Rockefeller 404
- PHYS 121

Lab Partner: Katherine Chen
Lab Manual: Lab 5 RKE PHYS 121