PHYS115 PHYS121 PHYS123
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Lab Cover Letter

Author (*You*) Trevor Swan Signature: Trevor Swan

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Lab Partner(s) Adi Mallik

Date Performed 2/14/24 Date Submitted 2/19/24

Lab (*such as #1: UNC*) #3: CME

TA: Philip Dudones

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)

Conservation of Mechanical Energy

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Abstract:

I have tested the conservation of mechanical energy using a cart and a mass block on a track pulled by a counterweight along with a spring in a similar manner. After releasing the cart at rest with a counterweight at the end of a string hanging off the table, I measured the distance and velocity of the cart as a function of time using *Logger Pro*. According to the conservation of mechanical energy, the total change in energy, $\frac{\Delta E}{\Delta y}$, should be 0. The data I have collected does not agree with this theory, yielding $\frac{\Delta E}{\Delta y} = -\ 87\ \pm\ 3$ mJ. Likewise, I released a spring connected to a string holding a counterweight in a similar manner, this time with varying counterweight masses. I plotted the spring's displacement against the mass used using *Origin* and reported the appropriate spring constant. Using these data , I determined a value for ε, the total change in energy for the system. According to the conservation of mechanical energy, this value should be 0. My measured value does not agree, however, yielding $\varepsilon\ =\ 0.78\ \pm\ 0.02$. Based on the aforementioned data, I could not conclude that mechanical energy is conserved in these systems, and that external forces played a significant role in my data collection.

Conservation of Mechanical Energy

Analysis

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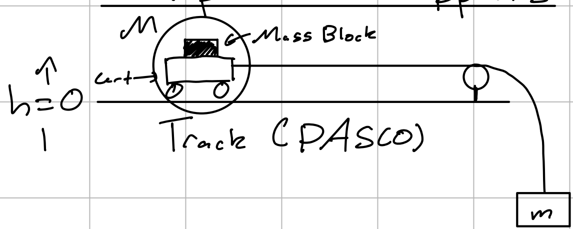
Gravitational Potential Energy:

Experiment Apparatus



Procedure

① Weigh Mass of Cart + Mass Block
Mass (M) = 994.0 ± 0.1g

② Adjust Track to be level with the table

③ Allow the Cart to move at a constant speed by placing paperclips on the rope (adding to mass m). Use Logger pro to determine actual constant speed

Number of Paper Clips: 9 Measured Mass w/ UNC: 2.7±0.3g

About the paperclips mass UNC: I estimated 0.3g (greater than scale's resolution) as the Number of paperclips was uncertain → higher mass UNC.

④ Replace Paperclips with 50g Hanger and use Logger Pro to measure: position, time, velocity, and acceleration. ← Export to Origin

Kinetic and Potential Energy were calculated in origin using the equations:

$KE = \frac{1}{2}m_1v^2 = \frac{1}{2}(994.0)(\text{velocity})^2$, where m_1 = mass of cart + mass block

$PE = -m_2gy = -(52.7)(9.81)(\text{position})$, where m_2 = mass of hanger + mass of paperclips

$\text{Total Energy} = KE + PE = \frac{1}{2}(994.0)(\text{velocity})^2 - 52.7(9.81)(\text{position})$

Plotting these data on the same plot, as seen in Figure 1, revealed a slightly negative slope for $\frac{\Delta E}{\Delta y}$. $\frac{\Delta E}{\Delta y} = {}^*-86.84 \pm 2.84\ mJ$

*Although this value may seem large, it is relatively small, being measured in milijoules instead of joules.

UNC: $\delta_{m_2} = 0.1$ $\delta_{slope} = 2.84$ ∴

$\Rightarrow \delta_{\frac{\Delta E}{\Delta y}} = \sqrt{0.1^2 + 2.84^2} = 2.842$

$\boxed{\frac{\Delta E}{\Delta y} = -87 \pm 3\ mJ}$

Interval
[-84, -90]

Conservation of Mechanical Energy

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Spring Constant Experiment

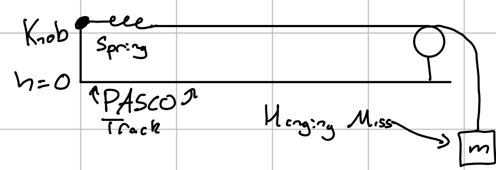
Procedure: ① Measure the distance the tip of the spring gets to.

② Subtract a starting position of 4.15 cm from the distance in step ①

③ Record this value as displacement, increment the mass by 5, and repeat until 100 g on Hanger

grams Mass on Hanger	cm Starting Pos	cm Final Pos	cm Displacement
50 g	4.15 cm	18.61	4.46
55 g	↓	20.09	10.44
60 g		21.47	12.32
65 g		23.05	13.90
70 g		24.75	15.60
75 g		26.29	17.14
80 g		28.32	19.17
85 g		29.24	20.09
90 g		30.76	21.61
95 g	↓	31.43	22.78
100 g	4.15 cm	34.31	25.16

Apparatus:



Note: All Displacement Uncertainties were estimated to be ±0.01 cm

} Plot in Origin → Fit Line to Determine K

Plotting displacement vs. mass, as seen in Figure 2, reveals a slope of $0.309 \pm 0.005 \ \frac{cm}{g}$

Making use of the equation $x = \frac{mg}{K} + x_0$, we see that $\text{Slope} = \frac{g}{K}$

$$\therefore K = \frac{g}{\text{Slope}} = \frac{4.81}{0.309} = 32.2 \ \frac{m/s^2}{cm/g} = \boxed{31.75 \ \frac{g \cdot m}{cm \cdot s^2}}$$

For UNC in K, I will treat δ_g as negligible as well as δ_m. δ_g is negligible as it is a constant. δ_m is negligible because m is the mass of pre-weighed weights.

If... $x = \frac{mg}{K} + x_0$, Then... $K = \frac{mg}{x - x_0}$

Let $\Delta x = 17.11$ cm ← Mean Displacement from Origin and $m = 100$ g Final Mass

Let $x - x_0 = \Delta x$ $\therefore \Delta x = 17.11$

$$\delta_{K_{\Delta x}} = \left| \frac{\delta K}{\delta x} \right| \delta_x = \frac{mg}{(\Delta x)^2} \delta_x = \frac{100(9.81)}{(17.11)^2}(0.01)^* = 0.0335$$

$^*\delta_{\Delta x} = 0.01$ From Original Calculations

From Slope $\delta_{\text{Slope}} = 0.005$ $\therefore \delta_K = \sqrt{.0335^2 + 0.005^2} = 0.03$ → $\boxed{K = 31.75 \pm 0.03}$

Units are $\frac{g \cdot m}{cm \cdot s^2}$

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Analyzing Total Energy

$$\mathcal{E} = \frac{\Delta U_k + \Delta U_g}{|\Delta U_g|} = \frac{\frac{1}{2}k(\Delta x)^2 + mg(\Delta h)}{|\Delta h m g|}$$ where $\Delta x = \Delta h$, $x_p = 17.11$ (Avg. from Origin), and $\Delta_i = 9.15g$.

$\therefore \Delta x = 17.11\text{cm} = \Delta h$

☆ For UNC, δ_m is negligible because the mass is determined by summing pre-weighed blocks! g is negligible in its uncertainties as it is a constant.

$$\delta_{\mathcal{E}_k} = \left|\frac{\delta \mathcal{E}}{\delta_k}\right| \delta_k = \frac{\frac{1}{2}(\Delta x)^2 + mg\Delta h}{|\Delta h m g|}\delta_k = \frac{(17.11)^2 + 17.11(9.81)(100)}{2|17.11 \times 9.81 \times 100|}(0.03) = 0.01526$$

$$\delta_{\mathcal{E}_{\Delta x}} = \left|\frac{\delta \mathcal{E}}{\delta \Delta x}\right| \delta_{\Delta x} = \frac{\frac{1}{2}k 2\Delta x + mg\Delta h}{|\Delta h m g|}\delta_{\Delta x} = \frac{(32.2)2(17.11) + 17.11(9.81)(100)}{2|17.11 \times 9.81 \times 100|}(0.01) = 0.005328$$

$$\therefore \delta_{\mathcal{E}} = \sqrt{0.01526^2 + .00533^2} = 0.02$$

$$\mathcal{E} = \frac{\frac{1}{2}k\Delta x^2 + mg\Delta h}{|\Delta h m g|} = \frac{\frac{1}{2}(32.2)(17.11)^2 + 100(9.81)(17.11)}{|17.11(100)(9.81)|} = 0.78$$

$$\therefore \boxed{\mathcal{E} = 0.78 \pm 0.02}$$

Conclusion:

The expected value of the change in energy in the system was $\frac{\Delta E}{\Delta y} = 0$.The measured value of the change in energy in the system was $\frac{\Delta E}{\Delta y} =- 87 \pm 3$ mJ. These two values do not agree. This is potentially the result of the track not being level with the table. Since the PASCO tracks in the lab have been being used for long periods of time, they are no longer flat and the warping results in inaccurate data. Newer tracks or more extensive leveling of the tracks could have reduced this systematic error. The expected value of the Spring's energy conservation was $\varepsilon = 0$, but the measured value of the spring's energy conservation was $\varepsilon = 0.78 \pm 0.02$. These values do not agree either. A possible cause of this may have been an old spring or a slow *Logger Pro* wheel. If the spring was not in pristine condition with unwavering endpoints, then the measured value may have been closer to 0. We observed slight stretches towards the end of the spring, which would introduce systematic error. The *Logger Pro* wheel at the end of the track, in combination with the possible error discussed in $\frac{\Delta E}{\Delta y}$, may also play a role in introducing variables that systematically corrupt our data. We **cannot** conclude that mechanical energy is conserved because $\frac{\Delta E}{\Delta y} \neq 0$ and $\varepsilon \neq 0$.

Acknowledgements:

I would like to thank Adi Mallik, Case Department of Physics, for helping me obtain the data used in this experiment as well as for helping with the generation of the figures.

References:

1. Driscoll, D., General Physics I: Mechanics Lab Manual, "Inclined Plane," CWRU Bookstore, 2014.

FIGURE 1

Conservation of Mechanical Energy
Gravitational Potential Energy

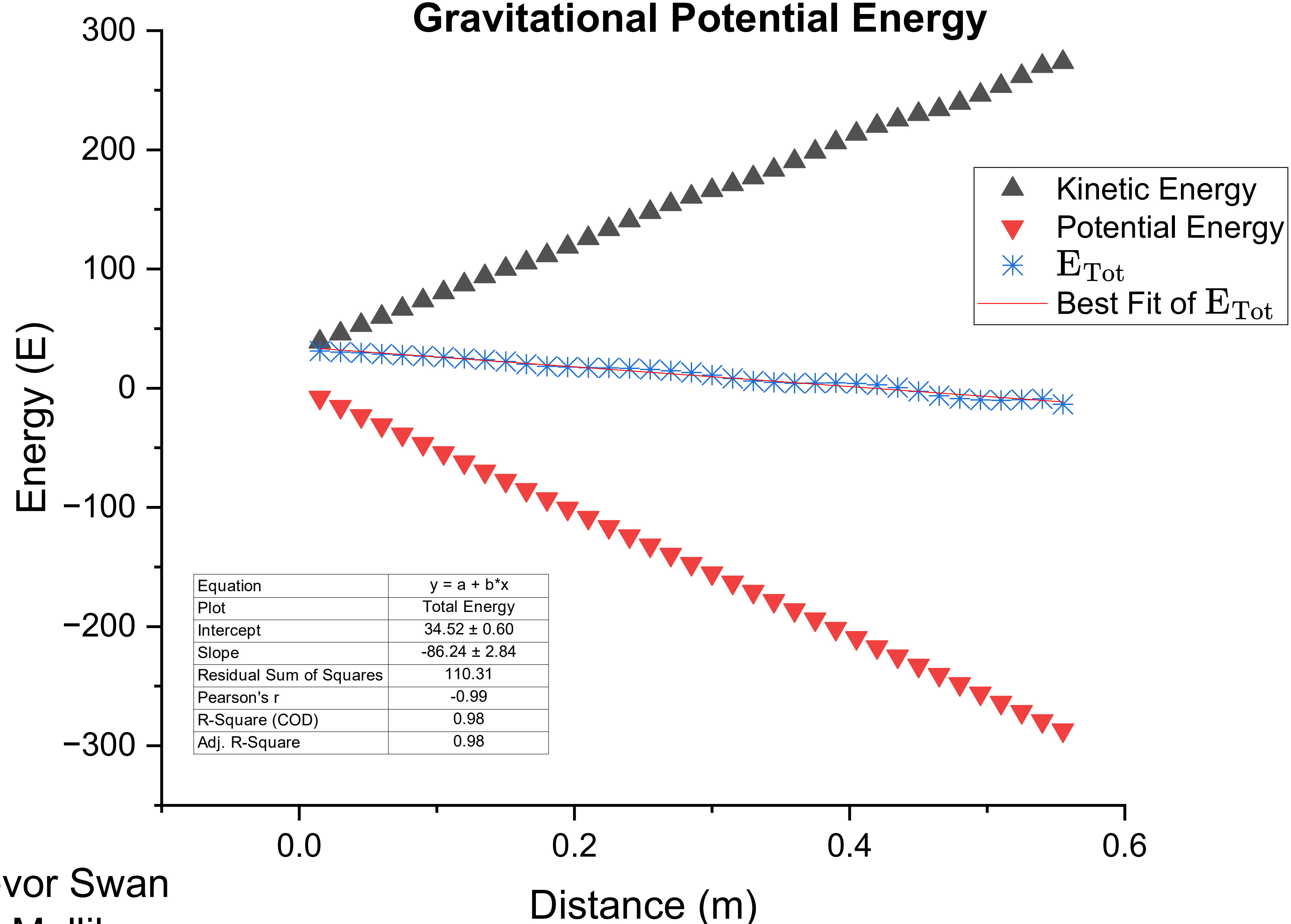

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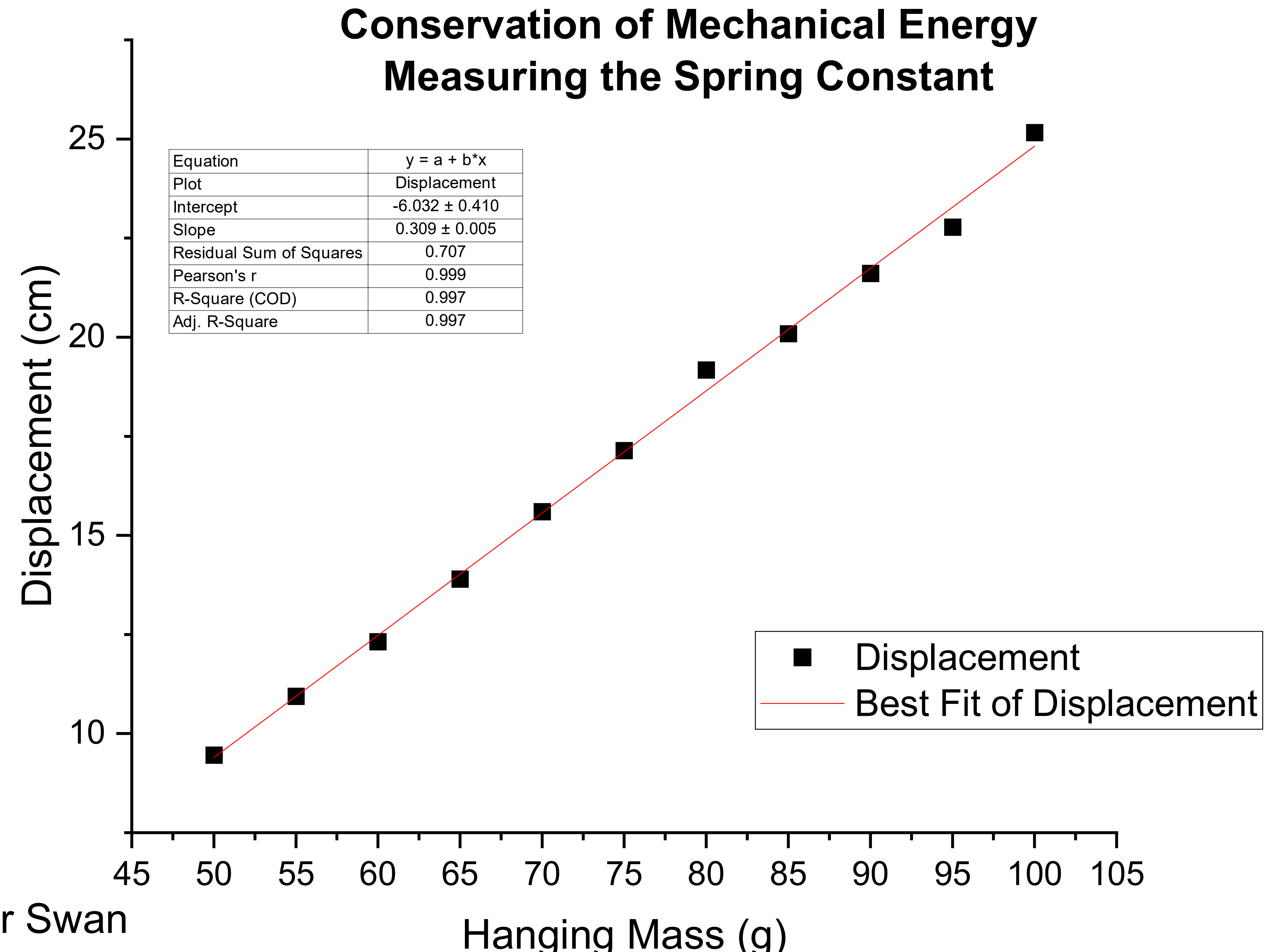
FIGURE 2



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