Penny Drop Lab - Earth

David Zhukovsky, Section Q — December 5, 2021 — Lab Partners: Erika Lam, Vinayak Rao

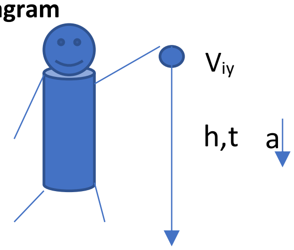
Introduction

The purpose of this lab was to design an experiment using a penny and a stopwatch to determine the acceleration due to gravity based on the curve of best fit from the graphed data. When dropping a penny, how does increasing the height of the penny above the landing surface affect the time for the penny to reach the landing surface? It was hypothesized that as the height of the penny above the landing surface increases, so does the time it takes it to reach the landing surface, with $t \propto \sqrt{h}$, where t is the time it takes the penny to reach the landing surface, and h is the height above the landing surface.

Procedure and Materials

All lab members coordinated to attach scotch tape to the wall at pre-measured heights using a meter stick. Erika held a 2008 penny by the edges at rest, at the designated height, one centimeter away from the wall, so that the bottom of the penny was at the measured height. She let go of the penny and began a MyChron timer simultaneously. Erika stopped the timer when she saw the penny touch the floor. David recorded the time for 10 trials each at 6 different heights.

Diagram



Constants and Equations

m_p = 2.50 g
v_{iy} = 0 m/s
y_i = h
y_f = 0 m
a_T = - 9.8 m/s^2

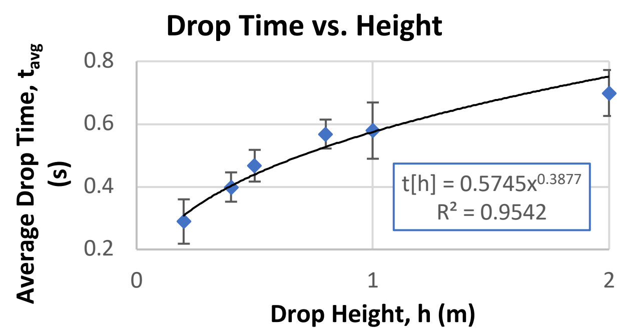
$$y_f = \frac{1}{2}at^2 + v_{iy}t + y_i$$

$$t_T[h] = \sqrt{\frac{-2h}{a_T}}$$

Data Summary

h	t_{avg}	SD	|%RSD|	t_T	|%err|
(m)	(s)	(s)	of t_{avg}	(s)	of t
0.200	0.29	0.07	24.49	0.20	43.05
0.400	0.40	0.05	11.72	0.29	39.65
0.500	0.47	0.05	10.83	0.32	46.19
0.800	0.57	0.05	8.12	0.40	40.57
1.000	0.58	0.09	15.50	0.45	28.17
2.000	0.70	0.07	10.48	0.64	9.41
	Avg	0.06	13.52		34.51

Graph



Analysis

This lab had an average |%RSD| of 13.52%, signifying low precision. The data also showed an average |%err| of 34.51%, signifying low accuracy. The line of best fit for time as a function of height was found as $t[h] = 0.5745x^{0.3877}$. The mathematical model is considered to be a strong fit, given its R^2 value of 0.9542. The line of best fit is a power function, with the power being 0.3877. The known time as a function of height on Earth has a power of 0.5, from which we derive out hypothesis that $t \propto \sqrt{h}$, however, the experimentally determined line of best fit presents a power significantly lower than expected. According to the line of best fit, the drop time at a height of 0m is 0s. Due to the lower power, using the coefficients from the line of best fit, acceleration due to gravity is determined to be -8.354 m/s^2, significantly lower than the know -9.8m/s^2. The data follows a meaningful trend, and the strong fit of the model shows that further experimentation should yield similar results. Although generally lower h values were correlated with higher |%err| values, a height of 0.50m had the highest error, 46.19%, while a height of 2.00m had the lowest error, 9.41%.

Conclusions

In this lab, the acceleration due to gravity was determined to be -8.354 m/s^2. This is lower than the known acceleration due to gravity on Earth, which is -9.8 m/s^2. The hypothesis was partially correct. Although as the height of the penny above the landing surface increases, so does the time it takes it to reach the landing surface, as shown by the line of best fit, the power value shows that t is not proportional to $\sqrt{h}$, but rather $h^{0.3877}$. This is due to multiple sources of error. Aside from human error, air resistance was a factor in lowering the determined acceleration value. This makes logical sense, because air resistance for increase the time it takes the penny to reach the landing surface, thus decreasing the magnitude of the acceleration. In addition, acceleration due to gravity is not constant at every location, and it is possible that a variation in this acceleration skewed time vs height data. Extensions to the penny drop lab should eliminate most sources of error. Future experimentation could be done in a vacuum tube, thus eliminating air resistance. It could also be done without humans, so as to eliminate human error. For example, the penny could land on a sensor that stops the timer, which would be more accurate that a human can.