Experiment 1 : Uniform Acceleration

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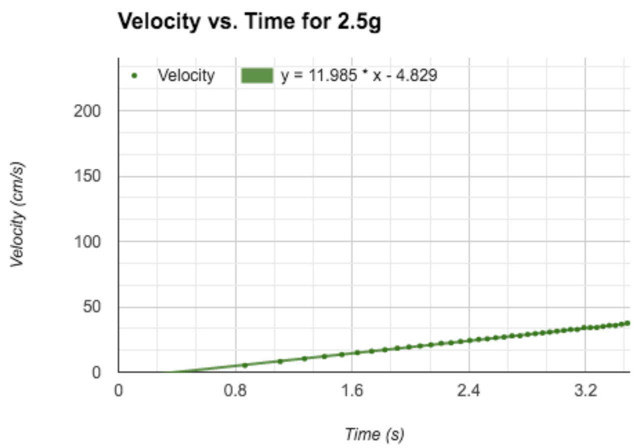
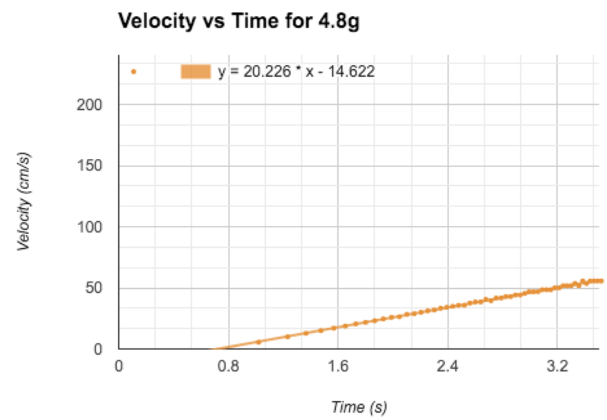
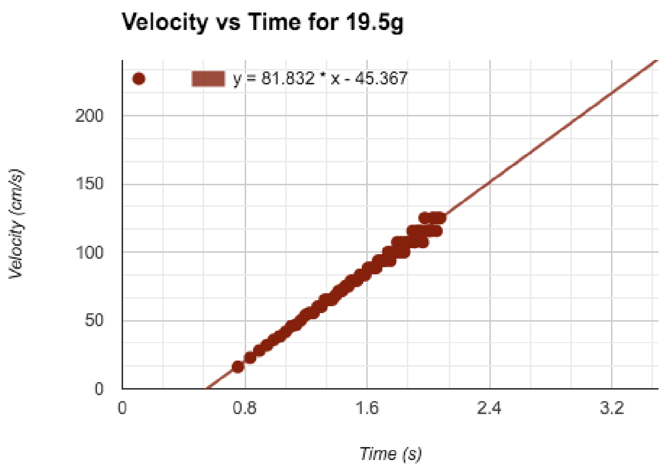
Plots



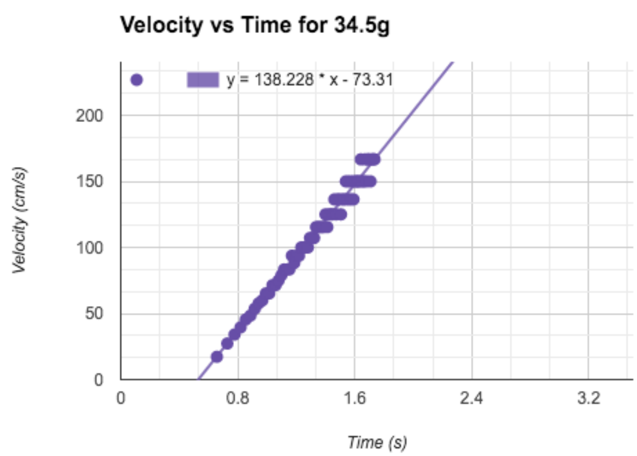
a) Slope = 11.98 $\pm$ .05 cm/s^2



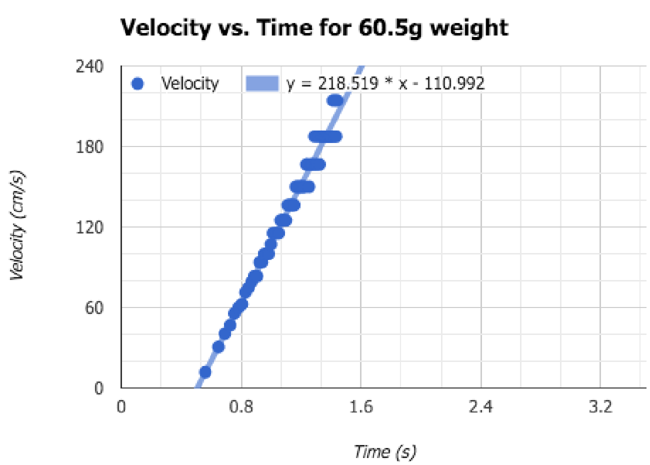
b) Slope = 20.22 $\pm$ .09 cm/s^2



c) Slope = 81.8 $\pm$ .9 cm/s^2



d) Slope = 138 $\pm$ 2 cm/s^2



e) Slope = 218 $\pm$ 3 cm/s^2

Plots a) - e) show the relationship between Velocity (cm/s) and Time (s) on y-axis and x-axis respectively. The slope gives the acceleration (cm/s^2).

Data Table

The following results were obtained after performing the experiment, analyzing and using linear regression on Excel. The fit acceleration was obtained from the plots by converting cm/s^2 to m/s^2. The predicted acceleration was found by using equation 1.1 : $a = \frac{mg}{M+m}$. Uncertainties were found using the formulas for uncertainty propagation, that are derived later.
$g=9.7955 \pm 0.0003 m/s^2$

Trial	Hanging Mass m (g)	Glider Mass M_t(g)	Fit acceleration $a_{fit}(m/s^2)$	Predicted acceleration $a_{predict}(m/s^2)$
1	2.50 ± .05	200.10 ± .05	.1198 ± .0005	.120 ± .003
2	4.80 ± .05	200.10 ± .05	.2022 ± .0009	.220 ± .005
3	19.50 ± .05	200.10 ± .05	.818 ± .009	.87 ± .01
4	34.50 ± .05	200.10 ± .05	1.38 ± .02	1.44 ± .02
5	60.50 ± .05	200.10 ± .05	2.18 ± .03	2.27 ± .04

Derivation

Derivation of equation 1.1

We have,
M=mass of glider
m=hanging mass
T= tension in the string

By the free body diagram and Newton's second law,

$$mg - T = ma$$

$$Ma = T$$

Substituting T,

$$mg - Ma = ma$$

$$mg = a(M + m)$$

$$a = \frac{mg}{M+m}$$

Derivation of uncertainty propagation:

We know that,
for any f related to x as $f = Ax$ the uncertainty in f,

$$\delta f = |A|\delta x$$

For $f = x + y$,

$$\delta f = \sqrt{(\delta x)^2 + (\delta y)^2}$$

For $f = \frac{x}{y}$,

$$\delta f = |f_{best}|\sqrt{(\frac{\delta x}{x_{best}})^2 + (\frac{\delta y}{y_{best}})^2}$$

Now, $a = \frac{mg}{M+m}$

By using the aforementioned relations,

$$\Rightarrow \delta a = |a| \sqrt{(\frac{\delta g}{g_{best}})^2 + (\frac{\delta m}{m_{best}})^2 + (\frac{\sqrt{\delta m^2 + \delta M^2}}{m_{best} + M_{best}})^2}$$

For obtaining the uncertainties in the data table above, the following uncertainties were used:

1) uncertainty in block count measurement = .05cm
2) the uncertainty in masses = .05g
3) uncertainty in g = .0003m/s^2

Conclusions

After performing the experiment with five masses, and plotting the graph of velocity vs. time, it is seen that the system (weight + glider) has constant acceleration, since the graph is linear. The force that is acting on the system is the weight of the hanging mass. Moreover, it can be seen from the results that the magnitude of the constant acceleration increases as the weight is increased.

The acceleration as measured from the plots and from the formula (equation 1.1) agree within a little margin of error. The predicted value is not exactly the same as the calculated (fit-line) value because we assume that there is 0 friction. However, there is some friction in the air track and the pulley that causes slight error. Error may also creep in because measuring instruments are not completely accurate. Due to these errors, there is slight difference in measured and calculated values of acceleration.

A way to improve the agreement is to use an advanced air-track that has 0 friction and to use instruments that can measure the data extremely accurately with high precision.

Presentation Mini Report
Modern Accelerometers

Accelerometers are devices that are used for the measurement of acceleration of motion. The earliest commercial accelerometers (resistance bridge type) were created by McCollum and Peters[1]. These accelerometers found applications in measuring the acceleration of airplanes, vibrations of turbines or industrial and civil engineering applications. Accelerometers can be made by utilizing different principles of physics. Some types are piezoelectric accelerometers, laser accelerometers and capacitive accelerometers. With advancement in physics and technology, modern accelerometers have significantly reduced in size and increased in accuracy and precision. Due to these factors, accelerometers enable numerous uses in a lot of fields.

Accelerometers are nowadays present in laptops and smartphones because of their small size. The compass in smartphones or games that require tilting the phone are possible because of small accelerometers inside the phone. Apple integrates accelerometers into laptops to protect hard drives. The usage of this is that when a sudden and sharp increase in acceleration is detected by the accelerometers, the hard-drives are shut off so that it does not crash and there is no data loss. Accelerometers in computers are also helping in seismology by detecting the motion of the tectonic plates. The Quake Catcher Network(QCN) is a collaborative community system that utilizes distributed computing and detects earthquakes using the in built accelerometers of Apple Macs and IBM Thinkpads [2]. Another application of accelerometers is in image stabilization and video capturing from cameras. Furthermore with the emergence of Internet of Things, accelerometers are now present in smart watches and other wearable devices and have a lot of applications too. A recent research has identified a method to authenticate users by analyzing their arm motion patterns. The accelerometers provide accurate acceleration of the arms and this information combined with the rotation angles can uniquely identify people with extremely low error rates[3]. Accelerometers are also used extensively in image stabilization in cameras for video capturing. Another field where accelerometers are starting to be used is medicine. A research showed that accelerometers in helmets of NFL players made it possible to do concussion analysis easily[4]. Thus accelerometers have applications in numerous fields.

Modern accelerometers use a variety of different technologies to measure acceleration. One common principle used in accelerometers is the piezoelectric effect–the development of electric charge in certain materials due to the applied mechanical stress. Piezoelectric accelerometers use a system containing a mass and a spring and convert force to signals, to detect acceleration. Quartz is used in such accelerometers since it has high temperature capability[1]. However, Piezoelectric accelerometers have some disadvantages too. They are unsuitable for measurement in some conditions like high temperatures[5]. Another type of accelerometers are capacitive based displacement accelerometers. The basic principle used in these accelerometers is that electric field is created due to separation of positive and negative charges on certain objects. The movement of charges creates alternating current that can be measured. A transducer is also present. These type of accelerometers have a very good lifespan and work well in all temperatures. However the disadvantage of these types of accelerometers is that they are not very accurate in situations where there is a change in the electromagnetic field[4]. Yet another type of accelerometer is laser accelerometer which is ultra sensitive and produces great results. These devices use reflection of laser light and are able to detect movement as small as femtometers. These are extremely small in size and can operate in a wide range of frequencies. All these different accelerometers differ in costs and have varying pros and cons.

The aforementioned discussion illustrates that accelerometers are important devices not just in physics but in a lot of other fields like seismology, wearable technology, medicine etc. The multiple types of accelerometers are suited for different scenarios and thus accelerometers are carefully chosen for tasks depending on the constraints and limitations. Furthermore, with advancement in technology the accuracy and precision of the accelerometers has increased significantly since the first resistance bridge type accelerometer. Due to extensive research and progress in microsensor technology, the accelerometers would continue to become more advanced.

Bibliography

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