Experiment 1:
Uniform Acceleration

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Lab performed on: April 17, 2018
Lab section: Lab 6- Tuesday 11am
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Partners' names:

Worksheet

2) **Plots**:

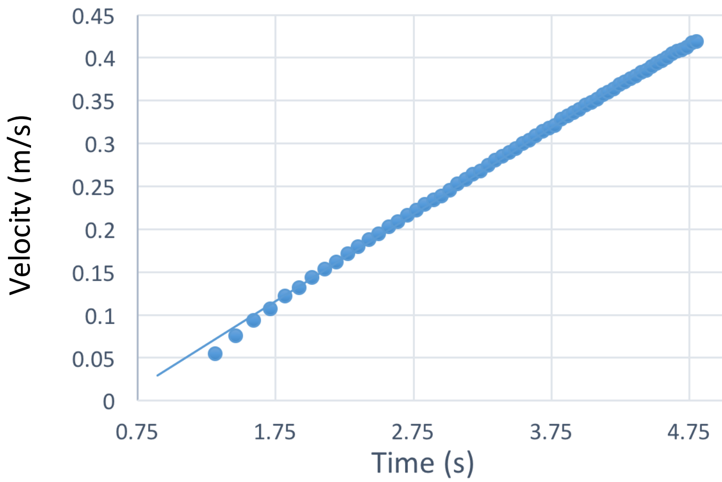

Figure 1— Velocity vs. Time: Data Set 1 This graph shows the linear relationship between velocity (m/s) and time (s) where m (hanging mass) = 2.9g and M (glider with total mass) = 290.0g. The acceleration of the object is the slope of the fit line.

$y = (0.1012 \pm 0.0001)x - (0.061 \pm 0.005)$

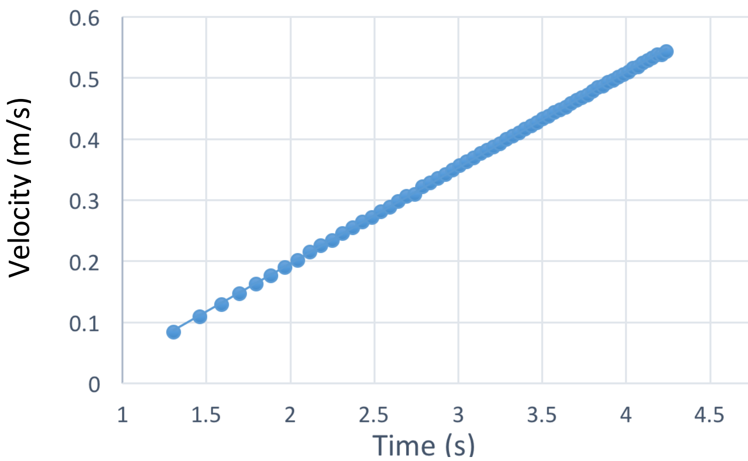

Figure 2— Velocity vs. Time: Data Set 2 This graph shows the linear relationship between velocity (m/s) and time (s) where m (hanging mass) = 4.8g and M (glider with total mass) = 290.0g. The acceleration of the object is the slope of the fit line.

$y = (0.1568 \pm 0.0008)x - (0.1173 \pm 0.0003)$

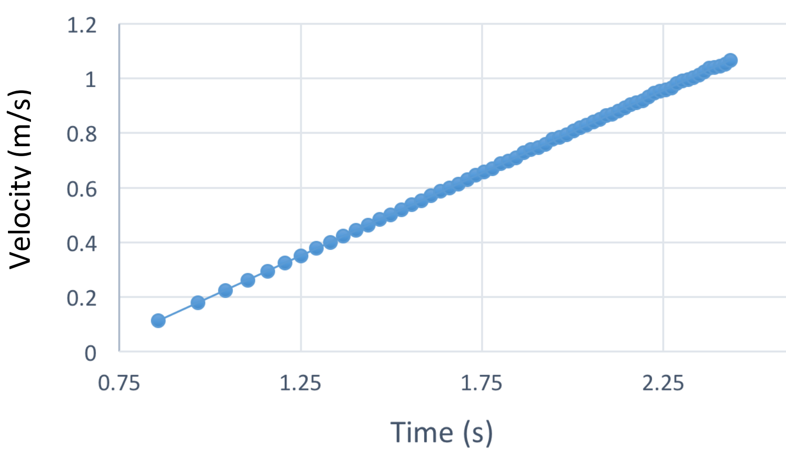

Figure 3— Velocity vs. Time: Data Set 3 This graph shows the linear relationship between velocity (m/s) and time (s) where m (hanging mass) = 19.7g and M (glider with total mass) = 290.0g. The acceleration of the object is the slope of the fit line.

$y = (0.6041 \pm 0.0008)x - (0.4033 \pm 0.0001)$

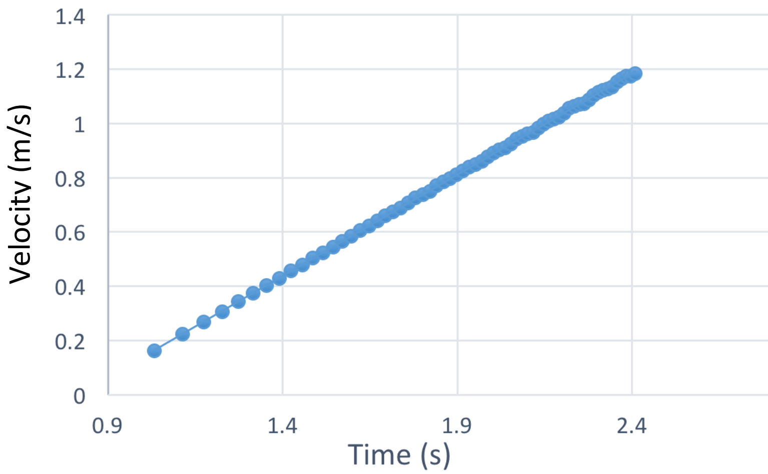

Figure 4— Velocity vs. Time: Data Set 4 This graph shows the linear relationship between velocity (m/s) and time (s) where m (hanging mass) = 24.5g and M (glider with total mass) = 290.0g. The acceleration of the object is the slope of the fit line.

y = (0.7457±0.0001)x – (0.6056±0.0002)

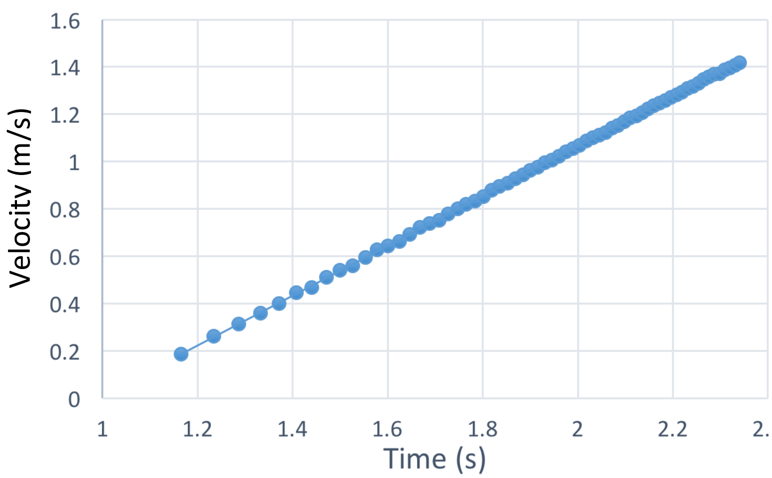

Figure 5— Velocity vs. Time: Data Set 5 This graph shows the linear relationship between velocity (m/s) and time (s) where m (hanging mass) = 36.0g and M (glider with total mass) = 290.0g. The acceleration of the object is the slope of the fit line.

y = (1.0515±0.0001)x – (1.0387±0.0003)

3) **Data Table**:

Data Set	Hanging mass m_{best} (g)	Glider with total mass m_{best} (g)	Measured acceleration $a_{measured}$ (m/s^2)	Predicted acceleration $a_{predicted}$ (m/s^2)
1	2.90 ± 0.05	290.00 ± 0.05	0.1012 ± 0.0001	0.097 ± 0.002
2	4.80 ± 0.05	290.00 ± 0.05	0.1568 ± 0.0008	0.160 ± 0.003
3	19.70 ± 0.05	290.00 ± 0.05	0.6041 ± 0.0008	0.623 ± 0.002
4	24.50 ± 0.05	290.00 ± 0.05	0.7457 ± 0.0001	0.763 ± 0.002
5	36.00 ± 0.05	290.00 ± 0.05	1.0515 ± 0.0001	1.082 ± 0.001

Table 1— The table above shows the results conducted from the experiment. The measured acceleration is obtained from the slope of each of the fit lines and the predicted acceleration is obtained from the formula 1.1, with uncertainties calculated from the formulas derived below.

4) **Derivations**:

Deriving equation 1.1:

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

From Newton's Second Law:
mg – T = ma
T = ma

Substitute (T = Ma) into (mg – T = ma):
mg – Ma = ma
mg = a(M + m)

Solving for a, we get:

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

Deriving propagation of uncertainties:
For f = x + y:

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

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

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

With $a = \frac{gm}{m+M}$,
From the equations above:

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

5) **Conclusions**:

From the velocity vs. time graph, it can be concluded that the mass and glider system has a constant acceleration because the plots show a linear relationship. The measured acceleration from the plots and the predicted acceleration calculated from the formula agree despite not being exactly the same, due to a compact marginal error. This margin of error may be the result of some friction between the air track and the glider with mass because we assumed that there was no friction throughout the experiment.

6) **Extra Credit**:

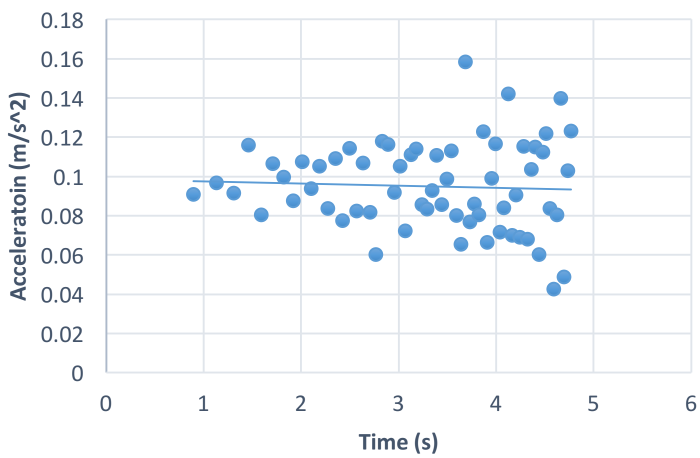

Figure 6— Acceleration (m/s^2) vs. Time: Data Set 1
This graph shows the linear relationship between acceleration (m/s) and time (s) where m (hanging mass) = 2.9g and M (glider with total mass) = 290.0g. The acceleration is the fit line, which is constant, however there is a large amount of noise due to the limited precision of instruments used.

y = (-0.0012$\pm$0.0030)x+(0.098$\pm$0.009)

The acceleration measured using first method is 0.1012$\pm$0.0001. As illustrated in Figure 6, the acceleration value obtained using the second method is 0.098$\pm$0.009. Both of the methods produced similar values, but the acceleration measured using the first method would be better because the uncertainty is reduced and gives the value a better precision with more significant figures. In the first method, acceleration is the slope of the fit line on the velocity vs. time graph. In the second method, acceleration is the y-intercept, which is the average of accelerations that have been calculated.

<u>Presentation Mini-Report</u>

Radiation therapy utilizes high-energy radiation to kill cancerous cells in the human body. Most people who undergo radiation therapy are hoping to eliminate a malignant tumor or prevent reoccurring cancer. The two ways radiation therapy effectively kills cancerous cells are through external machines or radioactive materials placed internally. The benefits of this practice is that it is extremely effective in targeting and damaging the DNA of cancerous cells[1] . However, the downside of this practice is that other non-cancerous human cells are damaged in this process. To optimize radiation therapy, doctors look to decrease harm to normal cells by increasing the precision and accuracy of the amount of radiation they deliver to the patient's body, specifically the malignant tumor [2].

The field of physics is vital in the current development of radiotherapy. Specifically, calculating the amount of radiation absorbed by the human body[2] (measured in energy transmitted per unit) and determining the necessary dosages for effectiveness are part of what physicists contribute in radiation therapy. In addition, the scientific and research approaches of physics are the guiding aspects that make radiation therapy effective. This is not possible with the clinical trials that are carefully experimented to perfect dose localization.

Although physics contribute significantly to the usefulness of radiotherapy, its contributions are bettered through the practices of other fields. For instance, physicists use resources that tie in with the field of computer science, such as the Monte Carlo method, which is a computational algorithm that depends on random sampling, in order to determine how much radiation should be administered. In addition, physicists use engineering methods [2] and solutions such as motion related imaging that reduce the inaccuracies of snapshots of instant time of the human body. Lastly, mathematical models contribute to how doctors and physicists analyze the human response to radiation. For instance, physicists directly use mathematical equations that determine the least amount of radiation exposure necessary to get the best image quality when it comes to diagnosing a patient[3]. Mathematical equations regarding the correlation between an individual's body size, dosage levels, and image quality for clinical X-ray imaging are almost directly used to understand radiotherapy practices. How the human body changes over time or how the human body responds to the amount of radiation variation are all aspects that are analyzed through the lens of these four fields. Without using the developments of other fields, physicists would be limited to understanding different radiation volumes based on CT imaging techniques[4,5].

The future of radiation therapy lies in how physicists and engineers can modify and optimize technology in order to lower the costs of providing radiotherapy as well as decreasing the percentage of normal cells that are damaged in the process. In the modern world where technological innovations are always improving[6], it is potentially possible to increase the accuracy of imaging so that doctors are well-informed of the target area before administering a specific dose. This includes the use of 4D imaging in order to capture instant movement of organs in response to a specific dosage[7]. Lastly, better optimizing the computer science, mathematical, and engineering techniques would be an area that physicists can focus on. For instance, instead of just focusing on the ties between physics and a specific field, physicists can research how the mathematical models intertwine with engineering and form a better understanding of how to lower the side effects of exposure to radiation but also reaping the benefits of killing harmful cells that are detrimental to the human.
(577 words)

References:

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[2] Bortfeld T. & Jeraj R. The physical basis and future of radiation therapy. Br J Radiol. pp 84, 485–498 (2011)

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[6] Purdy JA. Oncology (Williston Park). (Supply 5): pp 155-168 (1999)

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