Experiment 1: Uniform Acceleration

Deborah Liu UID:205140725

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TA:Jingwen Zhang

Lab Partner: Benjamin Ming Hoe Koh

2. Plots

In experiment one, we did 5 experiment runs, each for a different hanging mass m. The glider mass M stays the same for all trials. The slope of each graph is calculated through Excel's data analysis tool, representing the acceleration in cm/s^2. Here is the plot for the five runs:

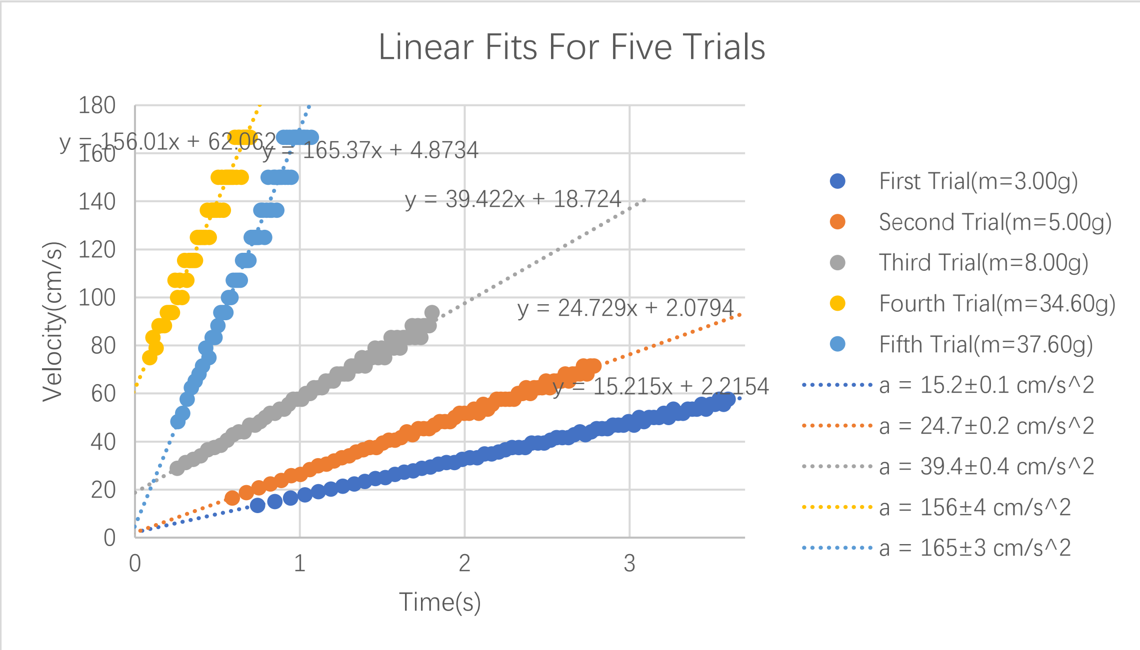

Figure 1: All five sets of data shows linear correlation between time and velocity, indicating constant acceleration. As the hanging mass increases from 3.00g to 37.60g, the slopes of best fit lines increase accordingly.

3. Data Table

Trial	Hanging mass m_{best} (g)	Glider mass M_{best} (g)	Fit acceleration a_{fit} (cm/s^2)	Predicted acceleration $a_{predict}$ (cm/s^2)
1	3.00 ± 0.05	179.50 ± 0.05	15.2 ± 0.1	16.1 ± 0.3
2	5.00 ± 0.05	179.50 ± 0.05	24.7 ± 0.2	26.6 ± 0.3
3	8.00 ± 0.05	179.50 ± 0.05	39.4 ± 0.4	41.9 ± 0.3
4	34.60 ± 0.05	179.50 ± 0.05	156 ± 4	158.5 ± 0.2
5	37.60 ± 0.05	179.50 ± 0.05	165 ± 3	170.0 ± 0.2

4. Derivations

According to Newton's second law, we have formula:

$$F = ma$$

Notice the m in the above formula is not the mass the hanging mass, but the total mass of the object which the force is applied on. In our experiment, as we are ignoring all the friction and the mass of the pully, the F for the whole system of hanging mass and glider mass is only the gravity of the hanging mass, which is

$$G = mg$$

Here we use $g=9.81m/s^2=981cm/s^2$ and treat it as a constant without error. And the mass is the total mass of the glider and the hanging mass, which is M+m. We can substitute these two equations into our first formula. We get:

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

To solve for a, we divide both sides of the equation by m+M, then we get:

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

which is equation 1.1 in the lab manual.

To get the uncertainty of a, we should apply the formula:

$$\delta\mathrm{a} = |a_{best}|\sqrt{\left(\frac{\delta(mg)}{(mg)_{best}}\right)^2 + \left(\frac{\delta(m+M)}{(m+M)_{best}}\right)^2}$$

The value of $\delta(mg)$ and $\delta(m+M)$ can be obtained by:

$$\delta(mg) = |g|\delta m$$

$$\delta(m+M) = \sqrt{(\delta m)^2 + (\delta M)^2}$$

The value of $(mg)_{best}$ and $(m+M)_{best}$ can be obtained by:

$$(mg)_{best} = g \times m_{best}$$

$$(m+M)_{best} = m_{best} + M_{best}$$

Substituting back to the original formula for $\delta\mathrm{a}$, we get:

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

where δm and δM both equal to 0.05g.

5. Conclusions

In all five runs of the experiment, we obtained linear correlation between the velocity and time. Since $\mathrm{a}_{fit} = \frac{\mathrm{dv}}{\mathrm{dt}}$ is the slope of the velocity vs time graph, a linear relation indicates that the acceleration is uniform in our experiment. Also, as we increase the hanging mass, the acceleration of the system is also increased, showing a positive correlation between them.

As we compare the fit acceleration and the predicted acceleration in part 3's data table, it's not hard to find that the two sets of values are very close. The differences between a_{fit} and $a_{predict}$ are within 5 cm/s^2. So, we can conclude that although the two sets of data do not agree, they are reasonably close.

There are several possible causes of the disagreement. First, when we are predicting the acceleration, we assume that there is no friction in the whole system. However, in the actual experiment, even though the air track does its best to minimize the friction, friction still exists. This results the net force being smaller than the net force (mg) we assumed in equation 1.1 in the lab manual. Therefore a_{fit} is smaller than $a_{predict}$, which is true in our data table.

Another cause of the disagreement may come from the unprecise measurement. None of the measurement instrument we used in this experiment is completely accurate. Thus, the measured values deviate from the real values. We try to eliminate such uncertainty by fitting a series of data points. However, as we can see from the data table, as we increase the hanging mass, the glider runs faster, resulting fewer data points and larger error.

To improve the experiment, we should consider the effect of friction and re-write equation 1.1 in the lab manual to yield a better prediction. To reduce the uncertainty from measurement instrument, we can use instruments with higher precision and run more trials to yield more data points.

Mini Report

In the past decade, quantum computers have become a hot research topic as they demonstrate the potential to surpass classical computers. The current building blocks of computers are called bits, which can only hold the state of 0 or 1. The quantum computers, however, use qubits as their building block, which can hold the superposition of the 0 and 1 states. This feature, together with another quantum phenomena called entanglement, allows quantum computers to perform faster and more complex computations than classical computers. Scientists have seen its potential in cryptography, searching and simulation. However, building a reliable and scalable quantum computer is no easy task.

The two major challenges in building quantum computers are decoherence and scaling problem. Decoherence means that qubits can be easily disturbed through interacting with the environment, causing the whole computing system to crash. So far, the most successful attempt to isolate the quantum computing system from environmental interactions and suppress decoherence is made by Kamyar Saeedi *et al.*[1]. They managed to maintain the coherence time of qubit to 39 minutes at room temperature and 3 hours at cryogenic temperature, while 62% of coherence signal survived this process. This is achieved by using ionized donors(D^+) and highly enriched ^{28}Si. Another challenge is scaling, meaning the difficulty to add qubits increases as the number of qubits in the system increases. This prevents us from building a system that is complex enough to perform the computation we need. In 2013, Kae Nemoto *et al*. proposed a model for building large scale quantum computing system[2]. This model is consisted of modules made by diamond with a single NV^- at its center and connected by optical fibers. Right now, this model is still theoretical. But with current technology, this model is realizable. We can imagine that in the future, researchers will continue to work on longer coherence time and more scalable structure, which will in the end allow us to build a powerful quantum computer.

With the breakthroughs in the past decades, scientists have start using quantum computer to run some basic simulations. In 2017, a research group used a quantum computer to simulate the energy surface of hydrogen molecules with high accuracy[3]. The computation is done by an array of superconducting qubits, and two quantum algorithms are used in the process. The result of this research shows that, in the future, quantum computers may be applied to simulate more complicated molecules, such as large protein structure, to enhance our understanding of the microscopic structures of matters and help us develop more efficient medicine. Another possible application of quantum computer is quantum teleportation. The quantum entanglement phenomenon allows immediate teleportation of information, regardless of distance. In 2014, Wolfgang Pfaff *et al*. has realized quantum teleportation between diamond spin qubits separated by 3m[4]. Despite the successful result, the whole experiment was conducted near absolute temperature (at T=8K and T=4K), which means we still have a long way to go before we could build an efficient and reliable quantum network at room temperature.

From the above discussion, we can tell that quantum computers have great potentials in executing faster calculation, more accurate simulation and more efficient teleportation, which can bring our knowledge in many different areas to the next level. The researchers have made great progress in bringing quantum computers to reality, through lengthen the coherence time and designing better structure. Still, our achievements today in quantum computing is not yet enough to bring quantum computers out of the lab. Most results in this area are obtained either under low temperature or require very precise manipulation. To create a commonly accessible quantum computer, there are still many technical difficulties to overcome.

(word count: 609)

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