Experimental design FRQ /Lab: Acceleration due to gravity

Experimental design: As a student you are to design and describe an investigation, collect and analyze authentic lab data, and make observations to identify patterns and / or explain phenomena.

Make a hypothesis about acceleration due to gravity of free-falling objects at KISJ Physics Class/Lab.

Hypothesis: Acceleration due to gravity of a free-falling object released from rest near the surface of Earth would be constant, at a value of approximately 9.81m/s^2, independent of the object's mass or volume.

Design an experiment to test the hypothesis about *acceleration due to gravity.*

A. Any equipment that would usually be found in a high school physics laboratory is available. If you have any questions about the availability of specific equipment, please ask.

a. What quantities would be measured?

The quantities that should be measured are the initial heights of the free-falling object and the time it takes for the free-falling object to reach the ground.

b. What equipment would be used for the measurements, and how would that equipment be used?

The pieces of equipment used for the measurements are two 1m-length metersticks, a smiley rubber ball, a tennis ball, a marble, and a timer (Video Stopwatch SC Application).

c. Describe the procedure to be used to test the hypothesis. Give enough detail so that another student could replicate the experiment. Include a labeled diagram of the experimental setup.

The experimental procedure to be used to test the hypothesis would be as the following:

i) Prepare pieces of equipment needed for the experiment. The equipment that should be prepared are two 1m-length metersticks, a timer (Video Stopwatch SC Application), and the three free-falling objects: a smiley rubber ball, a tennis ball, and a marble.

ii) Attach the two 1m-length metersticks on the wall vertically to the ground and mark the heights to release the objects. The heights marked are 1.00m, 1.30m, 1.60m, and 1.90m.

iii) Release the object from rest at the marked heights mentioned in step ii .

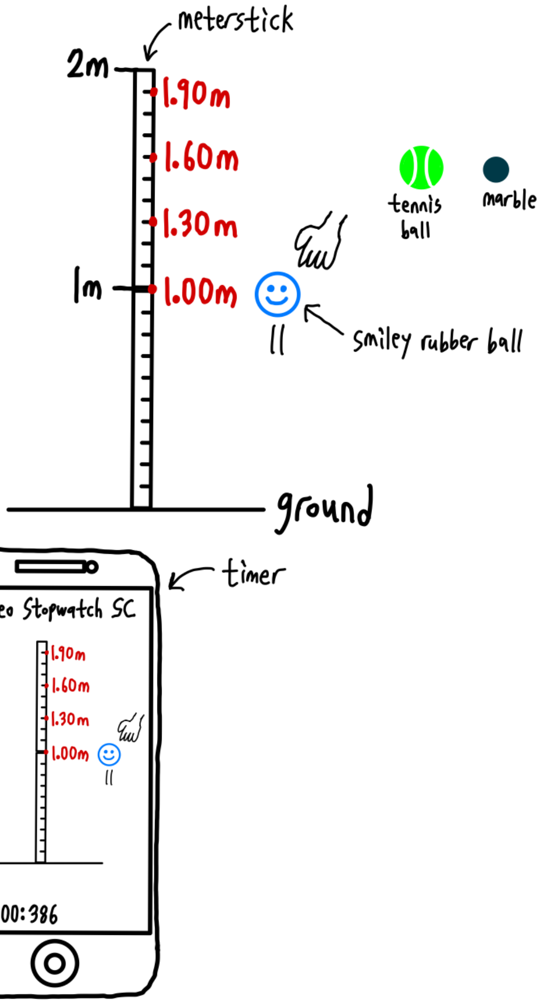
iv) Measure the time between the release and the initial touch of the object to the ground.

v) Repeat steps iii and iv multiple times (about 3 times) for each marked height to obtain data from multiple trials and increase accuracy.

vi) Repeat steps iii, iv, and v for all three objects. (smiley rubber ball, tennis ball, marble)

vii) Record the data obtained after the experiment is done. Then, put the pieces of equipment back where they were.

The Labeled Diagram of the Experimental Setup:



B. Describe how you would represent the data in a graph or table. Explain how that representation would be used to determine whether the data are consistent with the hypothesis.

I would represent the data in a table by setting the (Average time for an object to reach the ground)^2 (s^2) as the independent variable and the height of release of an object (m) as the dependent variable. I would record the time measured, in seconds, for all three trials at each marked height (1.00m, 1.30m, 1.60m, 1.90m) so that I can derive the average time for an object to reach the ground and its squared values. I would have a total of three data tables of such kind, each one including the data of a single free-falling object.

I would represent the data in a graph by putting the values of (Average time for an object to reach the ground)^2 (s^2) as x-coordinates and the values of height of release of an object (m) as y-coordinates in the distance-(time)^2 graph. The graph would be in a linear form.

The representation of this graph would be used to determine the approximate value of acceleration due to gravity for each free-falling object. A distance-(time)^2 should be used to derive the acceleration due to gravity since the unit of acceleration is m/s^2. So, since the slope of the distance-(time)^2 graph is half of the value of acceleration due to gravity, the acceleration due to gravity is equal to two times the slope of the distance-(time)^2 graph for each free-falling object. Then, by comparing the obtained value of acceleration due to gravity and the known value $g = 9.81m/s^2$, it would be possible to determine whether the data are consistent with the hypothesis that acceleration due to gravity of a free-falling object released from rest near the surface of Earth would be constant, at a value of approximately $9.81m/s^2$, independent of the object's mass or volume.

C. Carry out the experiment and analysis described in parts (A) and (B).

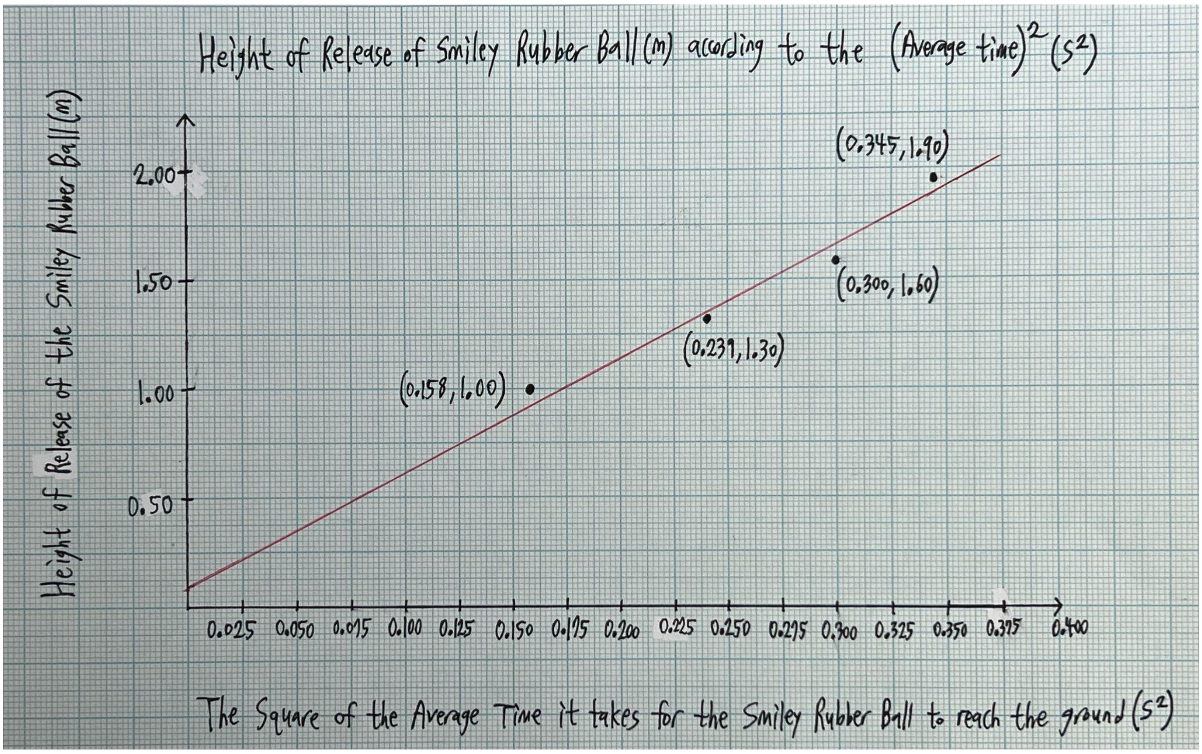
a. Design a data table and collect data for the variables described.

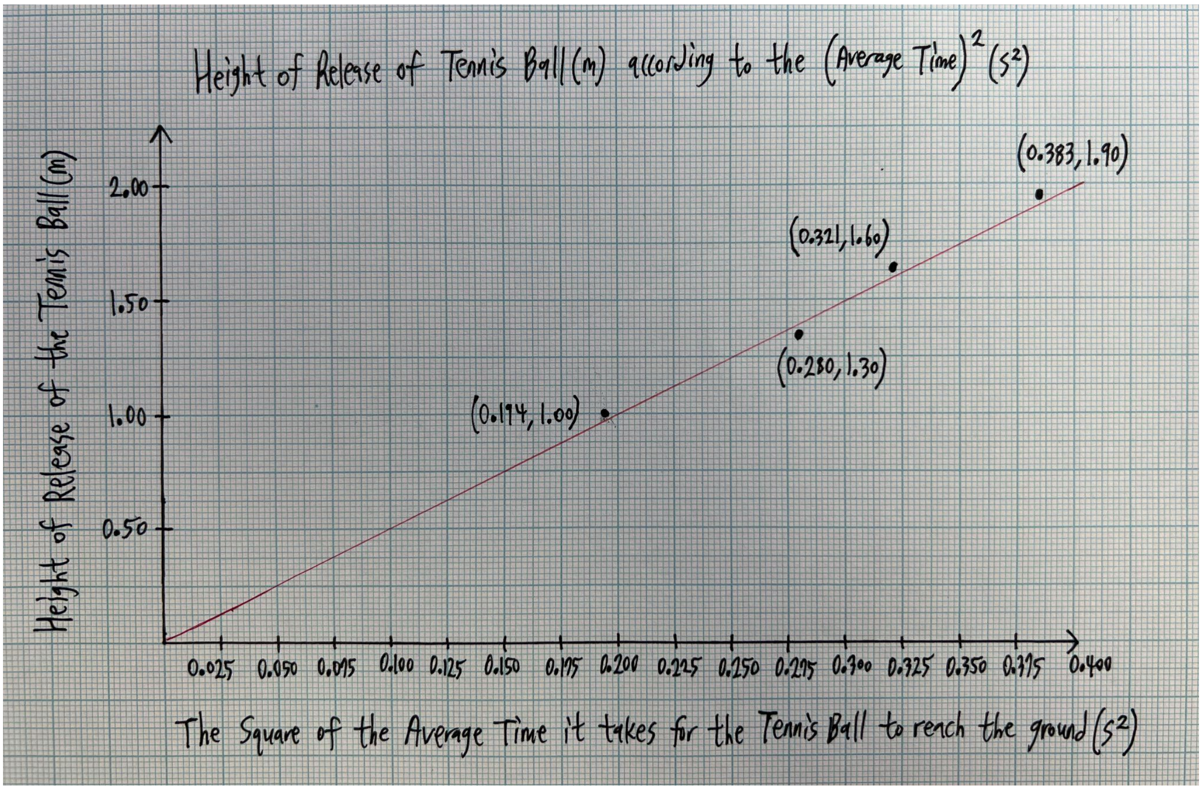
Average Time (s) for **Smiley Rubber Ball** to reach the ground according to the Height of Release (m)					
Height of release (m)	Time taken for the object to drop (s)			Average time (s)	(Average time)^2 (s^2)
	Trial 1	Trial 2	Trial 3		
1.00	0.367	0.394	0.433	0.398	0.158
1.30	0.482	0.466	0.519	0.489	0.239
1.60	0.544	0.548	0.552	0.548	0.300
1.90	0.579	0.596	0.586	0.587	0.345

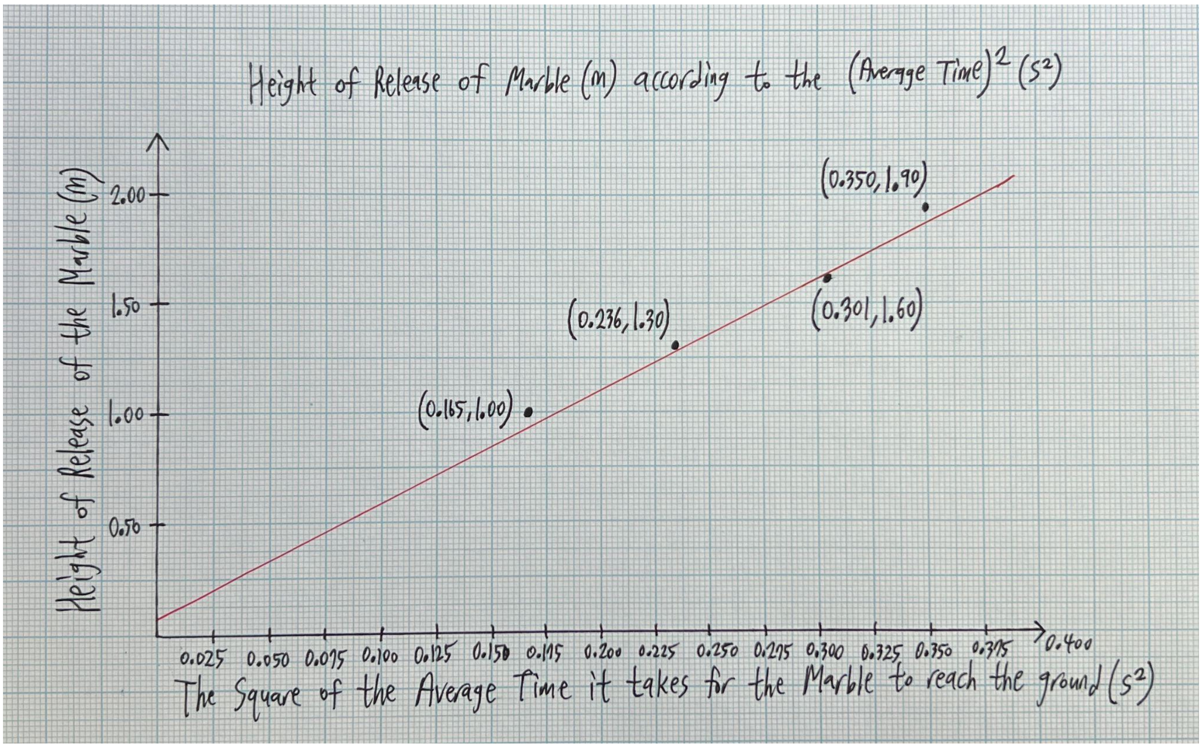
Average Time (s) for **Tennis Ball** to reach the ground according to the Height of Release (m)					
Height of release (m)	Time taken for the object to drop (s)			Average time (s)	(Average time)^2 (s^2)
	Trial 1	Trial 2	Trial 3		
1.00	0.430	0.458	0.435	0.441	0.194
1.30	0.514	0.532	0.541	0.529	0.280
1.60	0.574	0.569	0.558	0.567	0.321
1.90	0.632	0.623	0.602	0.619	0.383

Average Time (s) for **Marble** to reach the ground according to the Height of Release (m)					
Height of release (m)	Time taken for the object to drop (s)			Average time (s)	(Average time)^2 (s^2)
	Trial 1	Trial 2	Trial 3		
1.00	0.397	0.403	0.418	0.406	0.165
1.30	0.477	0.499	0.482	0.486	0.236
1.60	0.521	0.592	0.534	0.549	0.301
1.90	0.584	0.589	0.603	0.592	0.350

b. On a graphing paper, Label and scale the axes, then plot the collected data so that the desired variable can be determined from a best-fit line.







c. Show calculations to determine the desired variable.

The calculations to determine the desired variables are the following:

$$d = \cancelto{0}{V_it} + \frac{1}{2}at^2 \qquad V_i = 0 \text{ (object initially at rest)}$$

$$\underset{y}{d} = \underset{m}{\boxed{\frac{1}{2}a}}\underset{x}{t^2}$$

$$\frac{1}{2}a = m$$

$$a = 2m$$

1) Smiley Rubber Ball

$$m = \frac{1.60 - 1.30}{0.292 - 0.229} = 4.76\ m/s^2 \qquad a = 2m = 9.52\ m/s^2$$

2) Tennis Ball

$$m = \frac{1.30 - 1.00}{0.264 - 0.202} = 4.84\ m/s^2 \qquad a = 2m = 9.68\ m/s^2$$

3) Marble

$$m = \frac{1.30 - 1.00}{0.237 - 0.169} = 4.41\ m/s^2 \qquad a = 2m = 8.82\ m/s^2$$

D. After completing the graph(s) and calculation(s), consider factors that might have produced uncertainties in the experimental results and describe how those factors may have affected the results.

There are mainly three factors that might have produced uncertainties in the experimental results. The three main factors are listed below in the following:

1) Existence of Air resistance

The first main factor that might have produced uncertainty in the experimental results is the existence of air resistance. This is a type of systematic error. The known value of the acceleration due to gravity near the Earth's surface, approximately 9.81m/s^2, is the value under the condition that no air resistance exists. However, the experimental environment of this lab experiment has air resistance. Since air resistance is created by air molecules colliding against the free-falling object, the results obtained through the lab would have possibly underestimated the value of acceleration due to gravity compared to its actual value.

2) Inaccurate Height Measurements

The second main factor that might have produced uncertainty in the experimental results is the possible error in the height measurements. This is a type of human error (random error). If the two metersticks were not completely vertical (90°) to the ground or were not completely attached to the wall, the distance measured would not have been exactly equal to the marked distance (1.00m, 1.30m, 1.60m, 1.90m). Therefore, it could have contributed to producing slightly inaccurate data.

3) Inaccurate Time Measurements

The third main factor that might have produced uncertainty in the experimental results is the possible error in the time measurements. This is also a type of human error (random error). Although we used a smartphone application called "Video Stopwatch SC" to maximize accuracy, the data of the time it took for the object might include some degree of inaccuracy because deriving the time using the "lap" function in the application also has technical limitations. Therefore, the inaccurate time measurements might have contributed to producing slightly inaccurate data.

E. What conclusions can you draw from the results of your experiment to either support or contradict the hypothesis?

The conclusion that I can draw is that the results of this experiment support the hypothesis that acceleration due to gravity of a free-falling object released from rest near the surface of Earth would be constant, at a value of approximately 9.81m/s^2, independent of the object's mass or volume. The experiment tested a smiley rubber ball, tennis ball, and marble, which are three different objects made of different ingredients that led them to all have distinctive masses and volumes. However, regardless of the different masses or volumes of the three objects, the values of the acceleration due to gravity calculated by the equation g = 2 × (slope of the distance-time^2 graph) were all similar and close to 9.81m/s^2. Therefore, according to the experimental results that the acceleration due to gravity is constant and approximately 9.81m/s^2 in value regardless of the object's mass or volume, the hypothesis is supported and confirmed as true. Although the experiment results did not derive exactly the value of 9.81m/s^2, the results and the conclusion are still valid. It is because the experimental conditions contain some factors that could lead to an inaccurate calculation of the acceleration due to gravity, such as air resistance (collision between the air molecules and the object), inaccurate height measurements (meterstick not exactly vertical to ground or not completely attached to the wall), and inaccurate time measurements (technical limitations). Furthermore, since the graph is drawn by hand with estimation, the slope of the distance-time^2 graph is also not exactly accurate, leading to some degree of systematic error in the value of acceleration due to gravity. Nevertheless, since these factors are inevitable in experiments conducted in real-life situations, the conclusion that the hypothesis is supported would still be valid.

Lab Title		
Points: Complete=3 Partial=2 Minimal=1 None=0		
Presentation	1. Underline headings 2. Tabulate data 3. Entire lab is neat	
Procedure	1. All materials used listed 2. Complete, specific procedure steps 3. Clear diagram showing the setup	
Data	1. All data recorded 2. Record to correct precision 3. Use sig figs and units	
Analysis	1. Complete and correct 2. Graphing guidelines followed 3. Use sig figs and units	
Conclusion	1. Use complete sentences 2. Correctly interpret analysis 3. All questions answered	
Total		