IB Physics Internal Assessment Report Sample

<u>Design</u>

How does the height from which a ball is dropped affect the time it takes to reach the ground?

In this experiment, the release height of the ball is the independent variable, and the time to reach the ground is the dependent variable. For this experiment, a tennis ball will be dropped from heights ranging from 0.50 m to 4.50 meters, in increments of 0.50 m. The time required for the ball to reach the ground will be timed using a stopwatch. Five trials will be conducted for each release height, and the average time across the five trials will be taken as the time for each height. This will help to ensure that reliable data is captured across an adequate data range.

Below is a list of the variables involved in this experiment:

Variable Name	**Variable Type**	**How measured/controlled**	**Why controlled**
Time	Dependent	Using a stopwatch with precision 0.01 s	N/A
Release height	Independent	Using metric rulers with precision of 0.001 m	To determine what relationship exists with time
Type of ball	Controlled	A single tennis ball will be used	To ensure the dimensions of the dropped ball remain constant

Process steps:

- Using a metric ruler, a height of 0.500 m is measured above the floor and marked on the wall
- The bottom of the tennis ball is held such that the bottom of the ball aligns with the mark on the wall
- Counting down 3, 2, 1, Go, the ball is released as the stopwatch is simultaneously started, and stopped as soon as it is seen/heard hitting the floor
- Process is repeated so that five trials are completed for each release height

Materials:

- Tennis ball
- Metric ruler
- Stopwatch

Data Collection and Processing

Collecting Raw Data

Release height d / m +/- 0.001m	**Trial #**	**Drop time t / s +/- 0.01s**
0.500	1	0.25
	2	0.22
	3	0.29
	4	0.28
	5	0.30
1.000	1	0.34
	2	0.37
	3	0.41
	4	0.37
	5	0.41
1.500	1	0.47
	2	0.46
	3	0.47
	4	0.53
	5	0.54
2.000	1	0.62
	2	0.60
	3	0.63
	4	0.62
	5	0.63
2.500	1	0.75
	2	0.71
	3	0.73
	4	0.72
	5	0.75
3.000	1	0.78
	2	0.79
	3	0.81
	4	0.80
	5	0.79
3.500	1	0.84
	2	0.85
	3	0.85
	4	0.86
	5	0.84
4.000	1	0.91
	2	0.92
	3	0.91
	4	0.90
	5	0.90
4.500	1	0.93
	2	0.93
	3	0.97
	4	0.96
	5	0.96

Raw Data Precision

- **Release height: +/- 0.001m -**
  - Explanation: This is the smallest gradation on the meter stick, and I felt that I was able to decipher to this level with my eyesight
- **Drop time: +/- 0.01 seconds** – This is the smallest gradation on the stopwatches used.

Processing Raw Data

To determine the drop time for each release height, the average drop time is calculated.

Sample Calculations for a release height of 1.00m

- Drop time:
  - $t_{avg} = (t_1 + t_2 + t_3 + t_4 + t_5)/5$
  - $t_{avg} = (0.34 + 0.37 + 0.41 + 0.37 + 0.41)/5$
  - $t_{avg} = 0.38s$

- For the uncertainty in this average time, I used half of the range of the trial times:
  - Range = $t_{max} – t_{min}$
  - Range = 0.41 – 0.34
  - Range = 0.7 s

  - Uncertainty = range/2
  - Uncertainty = 0.7/2 = 0.035 ≈ 0.04 s
  - Since this uncertainty is greater than the smallest precision of the stopwatch, it is acceptable to use for the uncertainty for this measurement.

- Therefore, the drop time measurement for a release height of 1.00m is:

0.38 +/- 0.04 s

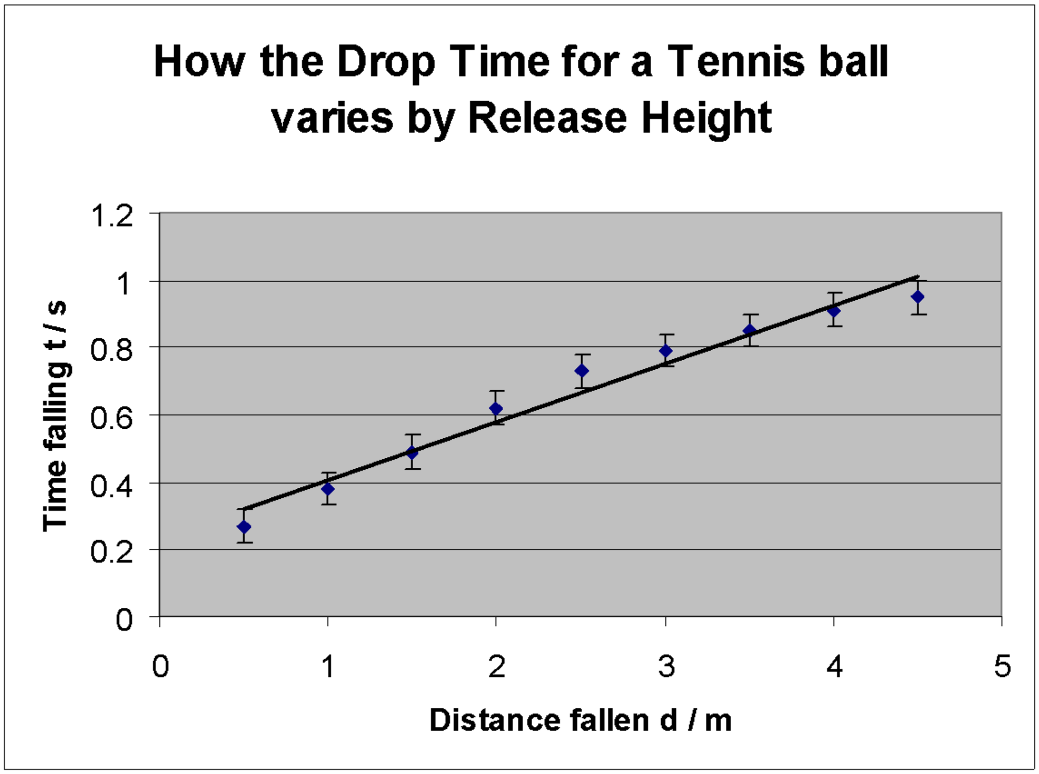
Presenting Processed Data

The table below shows the resulting drop times, with uncertainty, for each of the release heights.

Release height **d / m +/- 0.001m**	**Drop time** **t / s**
0.500	0.27 +/- 0.04 s
1.000	0.38 +/- 0.04 s
1.500	0.49 +/- 0.04 s
2.000	0.62 +/- 0.02 s
2.500	0.73 +/- 0.02 s
3.000	0.79 +/- 0.02 s

3.500	0.85 +/- 0.01 s
4.000	0.91 +/- 0.01 s
4.500	0.95 +/- 0.02 s

To determine the relationship between drop time and release height, I plotted the data from the above table:



Looking at the graph, I interpreted the plotted data to suggest that the relationship between drop time and release height was not linear, since the points do not appear to form a linear pattern. I confirmed this by adding a linear line of best fit, and noticing that the line does not fall within the error bars for all points.

Looking at the shape of the graph formed by the points, I thought that the relationship between the drop time and distance fallen might be either a logarithmic or a square root relationship. As such, to test my hypothesis, I decided to plot time vs. the square root of the distance fallen in an effort to create a linear graph and see if the relationship was of the form:

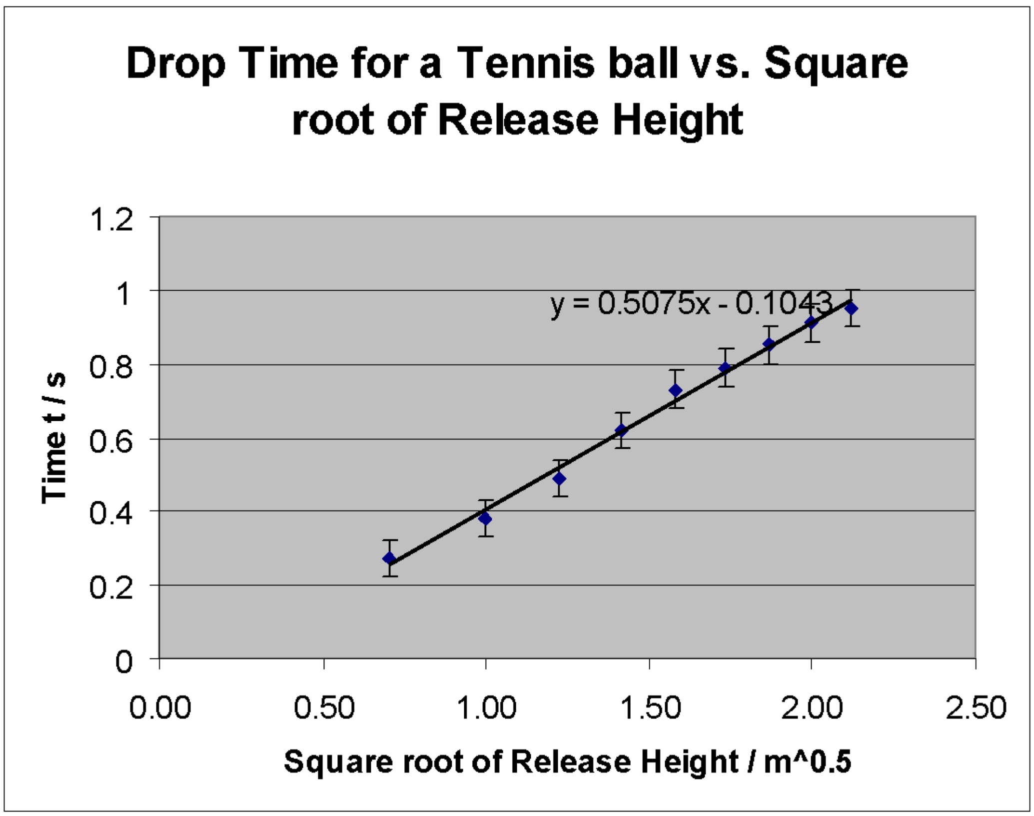
$$\mathbf{t = Cd^{1/2}}$$

where C is some constant.

The table below shows the data values used to plot this graph:

Release height **D / m +/- 0.001m**	**Square root of release height** **$d^{0.5}$ / $m^{0.5}$ +/- 0.001**	**Drop time** **t / s**
0.500	0.707	0.27 +/- 0.04 s
1.000	1.000	0.38 +/- 0.05 s
1.500	1.225	0.49 +/- 0.04 s
2.000	1.414	0.62 +/- 0.02 s
2.500	1.581	0.73 +/- 0.02 s
3.000	1.732	0.79 +/- 0.02 s
3.500	1.871	0.85 +/- 0.01 s
4.000	2.000	0.91 +/- 0.01 s
4.500	2.121	0.95 +/- 0.02 s

Below is the graph showing the resulting data:



As can be seen from the graph, there appears to be a linear relationship between the time taken for a ball to fall and the square root of the release height. The linear line shown goes through the y-axis error bars for all data points.

This linear graph correlates to an equation of the form **y = mx +b**. In this case:

y is the time t

x is the square root of the distance fallen, $d^{0.5}$

m is the gradient of the graph

b is the y-intercept

Using these variables, and the data from the plotted linear graph yields the following equation:

$$\mathbf{t = 0.51d^{0.5} - 0.10}$$

To calculate the uncertainty of the gradient of the graph, I decided to use the uncertainty in the time values for the first and last data points to determine the max and min possible gradients. From those I calculated the range of the gradient, and determined the uncertainty to be half of that range. These calculations are shown below:

Max gradient:

m_{max} = max $\Delta y/\Delta x$ = ((0.95 + 0.02)-(0.27 – 0.04))/(2.121 – 0.707)

m_{max} = 0.74/1.414

m_{max} = 0.52

Min gradient:

m_{min} = min $\Delta y/\Delta x$ = ((0.95 – 0.02)-(0.27 + 0.04))/(2.121 – 0.707)

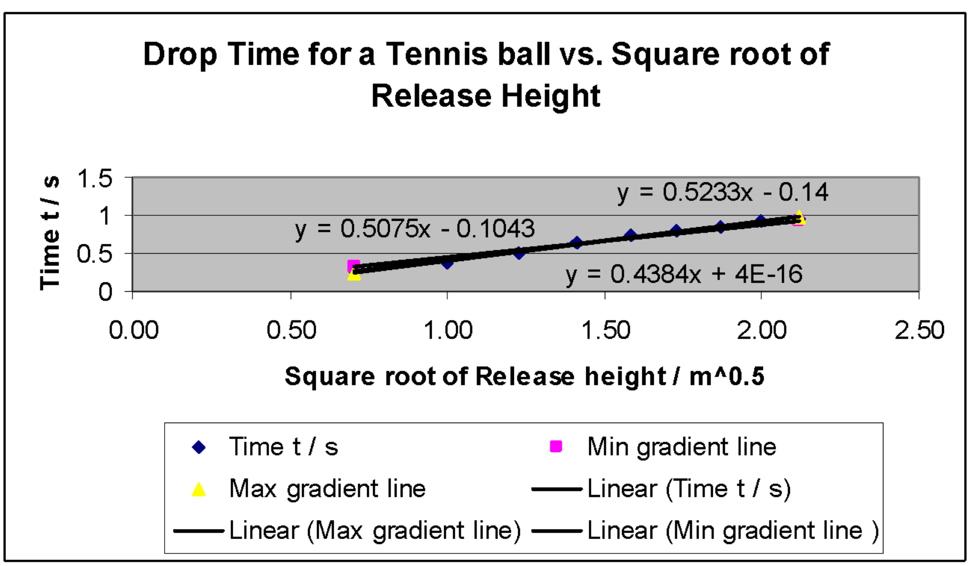
m_{min} = 0.62/1.414

m_{min} = 0.44

Gradient uncertainty = range/2 = (0.52 – 0.44)/2 = 0.04

For this graph, the percentage uncertainty of the gradient is 0.04/0.51 * 100% = 7.8%

The following graph shows the max and min gradients for this graph:



Conclusion and Evaluation

From looking at the results of my plotted data, there seems to be a proportional relationship between the time it takes for an object to fall and the square root of its release height. Thus, the time it takes for the object to fall increased proportionally with the square root of the release height. The data yields a relationship of $\mathbf{t = 0.51d^{0.5} - 0.10}$**.** The uncertainty of the slope was 7.8%.

In a proportional relationship, when one variable is zero, the other should be zero as well. Thus, the y-intercept of the graph between the variables should be zero. Looking at the resulting equation, the y-intercept of -0.10 suggests that there may have been some systematic error in my experimental procedure. In addition, in looking at the plotted line-of-best fit, my data points lie both above and below the line, which suggests that there may have been some random errors during one or more of my trials.

Looking at possible reasons for errors in my data, while I used a stopwatch that has a precision down to 0.01 s, it's possible that my reflex limit prevented me from starting the stopwatch at the instant the ball was released, or from stopping the stopwatch at the instant the ball reached the ground. If my reaction limit is say 0.1s, then starting or stopping the stopwatch 0.1 seconds early or late would have a sizeable impact on my data, since 0.1s would be between 10 and 35% of the total drop time for my trials, depending on the release height.

Also, while I used a metric tape measure with gradations of 1mm, my ability to decipher the exact release point was somewhat limited by my eyesight, and my ability to hold the ball still prior to release. Thus, it's possible that I was releasing the ball from a slightly higher or lower height than I thought either repeatedly, or in occasional trials.

To help mitigate these possible sources of error, and improve the investigation, I could look to use more sophisticated lab equipment for releasing the ball, as well as for distance and time measurement. Specifically, I could use a clamping mechanism that attaches to a gradated column. That way, I could attach the ball to a clamp, rather than having to hold it in place. Also, I could then adjust the height of the clamp along the gradations of the column. This would allow me to fine tune the release height without having to worry about holding the ball still.

To help improve with the timing of the drop, I could implement photogates at both the release point and the ground. Aligning the photogate to the bottom of the ball at its release point, the photogate software could very accurately record its release time. Likewise, placing the photogate along the floor at the landing spot would allow for a very accurate capture of the landing moment. I could then determine the difference in times to calculate the drop time.