# Physics 2019 v1.2

IA2 mid-level annotated sample response

August 2018

## Student experiment (20%)

This sample has been compiled by the QCAA to assist and support teachers to match evidence in student responses to the characteristics described in the instrument-specific marking guide (ISMG).

### Assessment objectives

This assessment instrument is used to determine student achievement in the following objectives:

2. apply understanding of gravity and motion, or electromagnetism to modify experimental methodologies and process primary data
3. analyse experimental evidence about gravity and motion, or electromagnetism
4. interpret experimental evidence about gravity and motion, or electromagnetism
5. investigate phenomena associated with gravity and motion, or electromagnetism, through an experiment
6. evaluate experimental processes and conclusions about gravity and motion, or electromagnetism
7. communicate understandings and experimental findings, arguments and conclusions about gravity and motion, or electromagnetism.

**Note:** Objective 1 is not assessed in this instrument.

# Instrument-specific marking guide (ISMG)

## Criterion: Research and planning

### Assessment objectives

2. apply understanding of gravity and motion, or electromagnetism to modify experimental methodologies and process primary data
5. investigate phenomena associated with gravity and motion, or electromagnetism through an experiment

| The student work has the following characteristics: | Marks |
|---|---|
| • informed application of understanding of gravity and motion, or electromagnetism to modify experimental methodologies demonstrated by<br>– a considered rationale for the experiment<br>– justified modifications to the methodology<br>• effective and efficient investigation of phenomena associated with gravity and motion, or electromagnetism demonstrated by<br>– a specific and relevant research question<br>– a methodology that enables the collection of sufficient, relevant data<br>– considered management of risks and ethical or environmental issues. | 5–6 |
| • adequate application of understanding of gravity and motion, or electromagnetism to modify experimental methodologies demonstrated by<br>– a reasonable rationale for the experiment<br>– feasible modifications to the methodology<br>• effective investigation of phenomena associated with gravity and motion, or electromagnetism demonstrated by<br>– a relevant research question<br>– a methodology that enables the collection of relevant data<br>– management of risks and ethical or environmental issues. | 3–4 |
| • rudimentary application of understanding of gravity and motion, or electromagnetism to modify experimental methodologies demonstrated by<br>– a vague or irrelevant rationale for the experiment<br>– inappropriate modifications to the methodology<br>• ineffective investigation of phenomena associated with gravity and motion, or electromagnetism demonstrated by<br>– an inappropriate research question<br>– a methodology that causes the collection of insufficient and irrelevant data<br>– inadequate management of risks and ethical or environmental issues. | 1–2 |
| • does not satisfy any of the descriptors above. | 0 |

## Criterion: Analysis of evidence

### Assessment objectives

2. apply understanding of gravity and motion, or electromagnetism to modify experimental methodologies and process primary data
3. analyse experimental evidence about gravity and motion, or electromagnetism
5. investigate phenomena associated with gravity and motion, or electromagnetism through an experiment

| The student work has the following characteristics: | Marks |
|---|---|
| • appropriate application of algorithms, visual and graphical representations of data about gravity and motion, or electromagnetism demonstrated by correct and relevant processing of data<br>• systematic and effective analysis of experimental evidence about gravity and motion, or electromagnetism, demonstrated by<br>– thorough identification of relevant trends, patterns or relationships<br>– thorough and appropriate identification of the uncertainty and limitations of evidence<br>• effective and efficient investigation of phenomena associated with gravity and motion, or electromagnetism demonstrated by the collection of sufficient and relevant raw data. | 5–6 |
| • adequate application of algorithms, visual and graphical representations of data about gravity and motion, or electromagnetism demonstrated by basic processing of data<br>• effective analysis of experimental evidence about gravity and motion or electromagnetism, demonstrated by<br>– identification of obvious trends, patterns or relationships<br>– basic identification of uncertainty and limitations of evidence<br>• effective investigation of phenomena associated with gravity and motion or electromagnetism, demonstrated by the collection of relevant raw data. | 3–4 |
| • rudimentary application of algorithms, visual and graphical representations of gravity and motion, or electromagnetism demonstrated by incorrect or irrelevant processing of data<br>• ineffective analysis of experimental evidence about gravity and motion, or electromagnetism demonstrated by<br>– identification of incorrect or irrelevant trends, patterns or relationships<br>– incorrect or insufficient identification of uncertainty and limitations of evidence<br>• ineffective investigation of phenomena associated with gravity and motion, or electromagnetism demonstrated by the collection of insufficient and irrelevant raw data. | 1–2 |
| • does not satisfy any of the descriptors above. | 0 |

## Criterion: Interpretation and evaluation

### Assessment objectives

4. interpret experimental evidence about gravity and motion, or electromagnetism
6. evaluate experimental processes and conclusions about gravity and motion, or electromagnetism

| The student work has the following characteristics: | Marks |
|---|---|
| • insightful interpretation of experimental evidence about gravity and motion, or electromagnetism demonstrated by justified conclusion/s linked to the research question<br>• critical evaluation of experimental processes about gravity and motion, or electromagnetism demonstrated by<br>– justified discussion of the reliability and validity of the experimental process<br>– suggested improvements and extensions to the experiment that are logically derived from the analysis of evidence. | 5–6 |
| • adequate interpretation of experimental evidence about gravity and motion, or electromagnetism demonstrated by reasonable conclusion/s relevant to the research question<br>• basic evaluation of experimental processes about gravity and motion, or electromagnetism demonstrated by<br>– reasonable description of the reliability and validity of the experimental process<br>– suggested improvements and extensions to the experiment that are related to the analysis of evidence. | 3–4 |
| • invalid interpretation of experimental evidence about gravity and motion, or electromagnetism demonstrated by inappropriate or irrelevant conclusion/s<br>• superficial evaluation of experimental processes about gravity and motion, or electromagnetism demonstrated by<br>– cursory or simplistic statements about the reliability and validity of the experimental process<br>– ineffective or irrelevant suggestions. | 1–2 |
| • does not satisfy any of the descriptors above. | 0 |

## Criterion: Communication

### Assessment objective

7. communicate understandings and experimental findings, arguments and conclusions about gravity and motion, or electromagnetism

| The student work has the following characteristics: | Marks |
|---|---|
| • effective communication of understandings and experimental findings, arguments and conclusions about gravity and motion, or electromagnetism demonstrated by<br>– fluent and concise use of scientific language and representations<br>– appropriate use of genre conventions<br>– acknowledgment of sources of information through appropriate use of referencing conventions. | 2 |
| • adequate communication of understandings and experimental findings, arguments and conclusions about gravity and motion, or electromagnetism demonstrated by<br>– competent use of scientific language and representations<br>– use of basic genre conventions<br>– use of basic referencing conventions. | 1 |
| • does not satisfy any of the descriptors above. | 0 |

# Task

| Context |
|---|
| You have completed the following practicals in class:<br>• Conduct an experiment to determine the horizontal distance travelled by an object projected at various angles from the horizontal (mandatory practical).<br>• Conduct an experiment to investigate the force acting on a conductor in a magnetic field (mandatory practical).<br>• Conduct an experiment to investigate the strength of a magnet at various distances (mandatory practical). |
| **Task** |
| Modify (i.e. refine, extend or redirect) an experiment in order to address your own related hypothesis or question.<br>You may use a practical performed in class, a related simulation or another practical related to Unit 3 (as negotiated with your teacher) as the basis for your methodology and research question. |

# Sample response

| Criterion | Marks allocated | Result |
|---|---|---|
| **Research and planning**<br>Assessment objectives 2, 5 | 6 | 4 |
| **Analysis of evidence**<br>Assessment objectives 2, 3, 5 | 6 | 5 |
| **Interpretation and evaluation**<br>Assessment objectives 4, 6 | 6 | 3 |
| **Communication**<br>Assessment objective 7 | 2 | 2 |
| **Total** | **20** | **14** |

The annotations show the match to the instrument-specific marking guide (ISMG) performance-level descriptors.

**Key:** Research and planning | Analysis of evidence | Interpretation and evaluation | Communication

**Note:** Colour shadings show the characteristics evident in the response for each criterion.

| Annotations | Response |
|---|---|
| **Research and planning [3–4]**<br><br>**a relevant research question**<br><br>The research question is connected to the rationale and enables the effective investigation of the topic. However, it does not explicitly state in detail the relationship in question. | # Factors affecting the projectile motion of a sphere<br><br>## Research Question<br><br>What is the relationship between the cross-sectional area of a spherical projectile and its horizontal displacement (range)?<br><br>## Rationale<br><br>An experiment was conducted in class that measured the horizontal distance travelled by an object projected at various angles from the horizontal. It was expected that the data should reflect the theoretical relationship of:<br><br>$$s_x = \frac{v^2 \sin 2\theta}{g},$$<br><br>where $s_x$ is the range (m), $v$ is the initial velocity (m/s), $\theta$ is the angle and $g$ is the acceleration due to gravity (Fitzpatrick, 2011). |
| **a reasonable rationale for the experiment**<br><br>The purpose/reasons for the experiment are sensible but not communicated fully. | In practice, the range is always less than what is theoretically predicted unless air resistance or drag $F_D$ is considered. Initial research revealed that when a projectile is fired, a drag force opposes the object's motion.<br><br>As such, this experiment modifies the original experiment by redirecting it towards determining the relationship between the cross-sectional area of a spherical projectile and its horizontal displacement (range). |

| | |
|---|---|
| | ## Method |
| | ### Original Method |
| **Research and planning [3–4]**<br><br>**feasible modifications to the methodology**<br><br>The modifications can be achieved. However, the response does not justify how the modifications will refine, extend or redirect the original experiment. | The original method measured the horizontal distance travelled by an object projected at various angles from the horizontal.<br><br>**Modifications:**<br><br>1. The angle was kept constant at zero degrees.<br>2. Hollow plastic balls of different radii were used to change the cross-sectional surface area.<br>3. In order to keep the mass constant, mass was added to the inside of the hollow ball using sand to ensure the overall mass remained constant at 1.5 (± 0.05) x $10^{-3}$ Kg.<br>4. 7 different surface areas were tested<br>5. Each surface area was trialled 5 times. |
| **Research and planning [5–6]**<br><br>**considered management of risks and ethical or environmental issues**<br><br>The response shows careful and deliberate identification and planning to handle risks and ethical or environmental issues in the experiment. | **Management of Risk:**<br><br>The most significant risk identified is the potential for injury caused by the moving projectile. This was managed by ensuring that each experimenter wore safety glasses and was not standing in the firing area. |

**Research and planning [5–6]**

**a methodology that enables the collection of sufficient, relevant data**

The methodology shows careful and deliberate thought. It enables collection of adequate data so an informed conclusion to the research question can be drawn.

**Analysis of evidence [5–6]**

**collection of sufficient and relevant raw data**

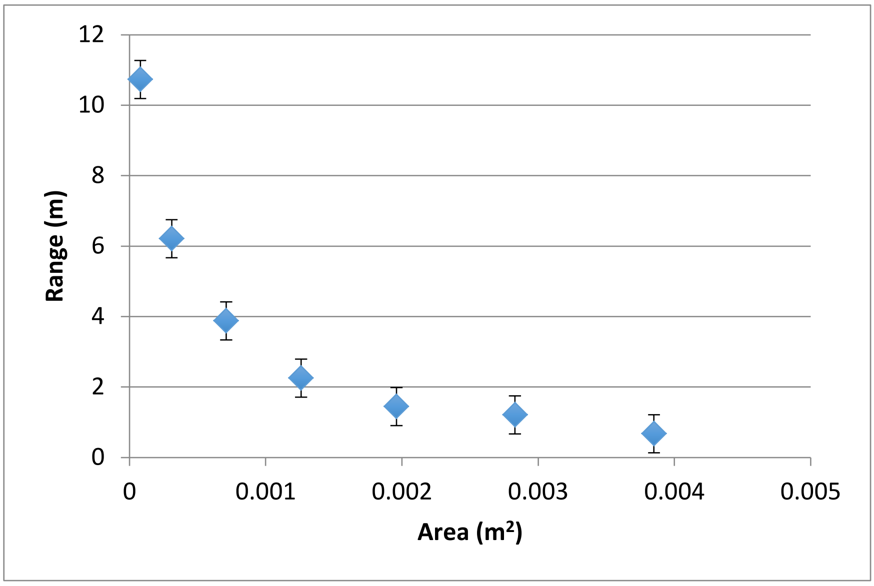
Even when the outliers are removed, there is enough data to find a relationship. The data can be used to respond to the research question.

## Results

Table 1: Effect of ball's radius on range of a projectile (anomalies highlighted in red were ignored for the average)

| Radius r (m) $(\pm 0.0001m)$ | Area ($m^2$) $(\pm 4\%)$ | Range $s_x$ (m) $(\pm 0.01m)$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Trial 1 | Trial 2 | Trial 3 | Trial 4 | Trial 5 | **Mean** | **Absolute uncertainty of the mean (m) $(\pm x)$** | **Percentage uncertainty of the mean (%)** |
| 0.005 | 0.00008 | 11.11 | 13.10 | 10.12 | 11.20 | 10.50 | 10.73 | 0.54 | 5 |
| 0.010 | 0.00031 | 6.32 | 9.12 | 6.11 | 6.52 | 5.90 | 6.21 | 0.31 | 5 |
| 0.015 | 0.00071 | 3.98 | 3.91 | 3.81 | 2.83 | 3.80 | 3.88 | 0.09 | 2.3 |
| 0.020 | 0.00126 | 2.12 | 2.03 | 2.34 | 4.28 | 2.51 | 2.25 | 0.24 | 10 |
| 0.025 | 0.00196 | 1.45 | 1.41 | 1.43 | 1.51 | 1.43 | 1.45 | 0.05 | 3.4 |
| 0.030 | 0.00283 | 1.10 | 1.20 | 1.03 | 2.73 | 1.50 | 1.21 | 0.24 | 20 |
| 0.035 | 0.00385 | 0.71 | 0.74 | 0.81 | 0.67 | 0.45 | 0.73 | 0.07 | 10 |

The values highlighted in red are identified as outliers because they are between 20-80% larger or smaller than the other 4 measurements. During the experiment, it was noticed that some wind gusts effected the flight of the projectiles. Time prevented the repetition of these effected trials. These values were excluded from the calculation of averages and not included in the graphs.

| | |
|---|---|
| **Analysis of evidence [5–6]**<br><br>**correct and relevant processing of data**<br><br>Raw data is manipulated accurately, providing evidence that responds to the research question. | **Sample calculations**<br><br>Cross-sectional area of the 0.005m projectile:<br>$A = \pi r^2$<br>$A = \pi(0.005)^2$<br>$A = 0.000078$<br>(With significant figures taken into account: $A = 0.00008$m$^2$)<br><br>Average range for the 0.00008m$^2$ projectile:<br>$\bar{x} = \frac{\sum_{i=1}^{n} x}{n}$<br>$\frac{11.11+10.12+11.20+10.50}{4} = 10.73$m<br><br>Absolute uncertainty of the mean for the 0.00008m$^2$ projectile:<br>$\pm\frac{x_{max} - x_{min}}{2}$<br>$\pm\frac{11.20-10.12}{2} = \pm 0.54$m<br><br>Percentage uncertainty of the mean for the 0.00008m$^2$ projectile:<br>$\frac{0.54}{10.73} \times 100 = 5\%$ |
| **Communication [2]**<br><br>**appropriate use of genre conventions**<br><br>The response presents data following scientific conventions of graph construction. | The absolute uncertainty of the mean was used for the error bars on the graph.<br><br>Graph 1: Effect of ball's cross-sectional area (m$^2$) on range (m) of a projectile<br><br><br> |

**Communication [2]**

**fluent and concise use of scientific language and representations**

The response is easily understood, avoids unnecessary repetition and meets the required length.

## Analysis of evidence

The plot of the raw data suggests that the relationship between range and cross-sectional area is:

$s_x \propto \frac{1}{A}$, $s_x \propto \frac{1}{A^2}$ , $s_x = e^{-A}$ or some other logarithmic relationship. Theory suggests that relationship is $s_x \propto \frac{1}{A}$ as such, to determine if this relationship is correct, a graph of range (m) vs 1/Area ($m^{-2}$) was plotted.

**appropriate use of genre conventions**

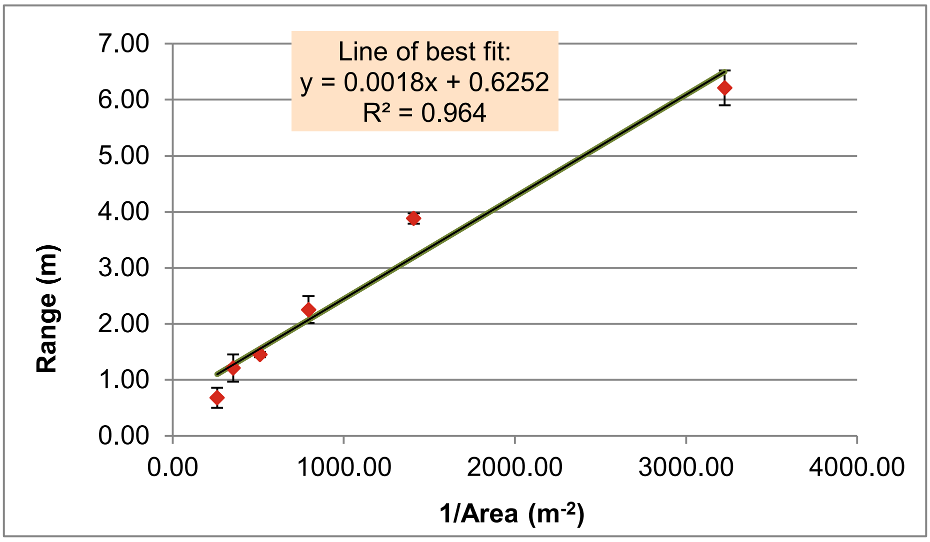
The response presents data following scientific conventions of graph construction.

**Analysis of evidence [5–6]**

**thorough identification of relevant trends, patterns or relationships**

The identification of relationships is not superficial or partial. The relationships are applicable to the research question.

Graph 2: The relationship between 1/cross sectional area ($m^{-2}$) and range (m) of a projectile.




The first data point (radius of 0.005 m) was excluded from Graph 3 because it did not fit with the line of best fit and was tentatively identified as an anomaly. This graph is consistent, within absolute uncertainty of the measurements, with the relationship established in the rationale:

$$s_x \propto \frac{1}{A}$$

In order to confirm this, the gradient of a $s_x \; vs \; \frac{1}{A}$ graph should be equal to $\frac{m}{C_D \rho}$. For a spherical projectile with mass 1.5 x $10^{-3}$ kg this is equal to 0.00297 $m^3$. However experimentally the gradient of the graph was 0.0018 $m^3$ leading to a percentage error of:

$$Percentage\ Error\ (\%) = \left|\frac{0.0018 - 0.00297}{0.00297}\right| x\ 100$$

**Analysis of evidence [3–4]**

**basic identification of uncertainty and limitations of evidence**

The response shows fundamental consideration of the impact of measurement uncertainty. However, measurement uncertainty has only been quantified for some of the evidence.

$$Percentage\ Error\ (\%) = 39\%$$

This is very large suggesting the data does not support the suggested relationship. With this in mind, 0.005m radius projectile may not be an anomaly and may give further insight as to the relationship between $s_x$ and $A$.

The measurement uncertainty is small and the absolute uncertainties of the mean are between 2-20%. When compared to the expected theoretical value, the percentage error is 39%. This suggests uncertainty about the evidence is more than measurement uncertainty of the data.

| | |
|---|---|
| **Analysis of evidence [3–4]**<br><br>**basic identification of uncertainty and limitations of evidence**<br><br>The response identifies a fundamental limitation of the evidence. | The findings and comparison with theoretical expectations must only be considered within the parameters of the experiment, and the associated limitations of the evidence, namely:<br><br>The equation of the line of best fit is only describing the relationship between area and range for the projectiles tested and may not apply to projectiles with different areas. |
| **Interpretation and evaluation [3–4]**<br><br>**reasonable conclusion/s relevant to the research question**<br><br>The conclusion is based on sound judgment and stated in terms of the research question, but does not directly refer to evidence. | **Interpretation of evidence**<br><br>The aim of this investigation was to examine how changing the cross-sectional area of the ball affects the vertical velocity. The results showed that as the cross-sectional area increased, the horizontal displacement, or range, decreased.<br><br>Graph 2 showed an inversely proportional relationship between the cross-sectional area of the projectile and horizontal displacement. However, the gradient of the graph has a percentage error of 39%, suggesting that the following relationship quoted in the rationale is not correct.<br><br>$$s_x \propto \frac{1}{A}$$<br><br>Looking at the original graph a logarithmic line of best fit seems to be a more accurate fit to a 1/x relationship, which suggests there are other factors affecting the range of a projectile in addition to air resistance. Also, although the first data point was left off Graph 2 as an anomaly, if it is included the graph, it might show some other sort of relationship. |
| **reasonable description of the reliability and validity of the experimental process**<br><br>The evaluation of the experiment is consistent with, but has not been explicitly justified using, the uncertainties and limitations identified in the analysis of the evidence. | **Evaluation of experimental process**<br><br>The measurements were relatively precise. This suggests the precision of each individual measurement was high but that the method itself had significant random errors that caused the data to not be reliable<br><br>The main source of error was the wind factor. The experiment was conducted outside and it was almost impossible to control the environmental factors. The most significant of these was the wind, which added a force that was not accounted for in the initial theory. The mass of the projectile was light, which resulted in the range being significantly reduced when the force was towards the launcher and significantly increased when the force was away from the launcher. The method attempted to mitigate these affects by repeating the experiment five times and ignoring any obvious outliers.<br><br>It was assumed that the mass of the projectile was constant and whilst it was initially, during flight the sand sometimes leaked out of the ball, reducing the mass, increasing the horizontal displacement.<br><br>Another factor to mention was that it was assumed that the drag coefficient was 0.42 due to literature findings, however the ball may not have always been a perfect spherical shape. This could have resulted in pressure changes and other factors that would have affected the horizontal displacement.<br><br>It was assumed that the density of air was always 1.2041 kg/m$^3$ as substantiated by scientific literature, however testing was done over a range of days, with varying weather conditions. This may have affected the horizontal displacement. |

**Interpretation and evaluation [1–2]**

**ineffective or irrelevant suggestions**

The suggested improvements do not address the uncertainty identified in the analysis, and the extensions do not address any limitations or provide further insight into the behaviour or phenomena observed during the experiment.

**Interpretation and evaluation [3–4]**

**reasonable conclusion/s relevant to the research question**

The conclusion is based on sound judgment and related to the research question, but is not explicitly justified using the evidence gathered during the experiment.

**Communication [2]**

**acknowledgment of sources of information through appropriate use of referencing conventions**

The use of a referencing system fits the purpose of a scientific report.

Appendixes provide background information and context only. They are not considered when making judgments about the quality of the response.

## Suggestions for improvements and extensions

The experimental process could be improved by collecting more data.

The experiment could be extended by investigating the maximum velocity a ping pong ball can move after being hit with a paddle.

## Conclusion

It is evident that the data suggests that the range and cross-sectional area are related, however, the exact mathematical nature of this relationship is unknown. Therefore, further investigations as outlined previously are recommended.

Word Count: 1920

## Reference List


Fitzpatrick, R (2011). Projectile Motion with Air Resistance, Retrieved from

http://farside.ph.utexas.edu/teaching/336k/Newtonhtml/node29.html


## Appendix

Maximum percentage measurement uncertainty in the range occurs for the 0.030m radius projectile during trial 4:

$$\frac{0.01}{0.67} \times 100\ \% = 1.5\%$$