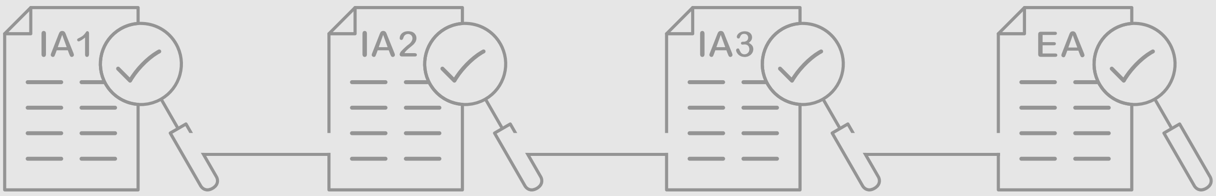
# Physics subject report

2025 cohort

January 2026





Queensland Government

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For all Queensland schools

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# Contents

# Introduction

The annual subject reports seek to identify strengths and opportunities for improvement of internal and external assessment processes for all Queensland schools. The 2025 subject report is the culmination of the partnership between schools and the QCAA. It addresses school-based assessment design and judgments, and student responses to external assessment for General and General (Extension) subjects. In acknowledging effective practices and areas for refinement, it offers schools timely and evidence-based guidance to further develop student learning and assessment experiences for 2026.

The report also includes information about:

- how schools have applied syllabus objectives in the design and marking of internal assessments
- how syllabus objectives have been applied in the marking of external assessments
- patterns of student achievement
- important considerations to note related to the revised 2025 syllabus (where relevant).

The report promotes continuous improvement by:

- identifying effective practices in the design and marking of valid, accessible and reliable assessments
- recommending where and how to enhance the design and marking of valid, accessible and reliable assessment instruments
- providing examples that demonstrate best practice.

Schools are encouraged to reflect on the effective practices identified for each assessment, consider the recommendations to strengthen assessment design and explore the authentic student work samples provided.

## Audience and use

This report should be read by school leaders, subject leaders, and teachers to:

- inform teaching and learning and assessment preparation
- assist in assessment design practice
- assist in making assessment decisions
- help prepare students for internal and external assessment.

The report is publicly available to promote transparency and accountability. Students, parents, community members and other education stakeholders can use it to learn about the assessment practices and outcomes for senior subjects.

## Subject highlights

**418**
schools offered Physics

**85.67%**
of students completed 4 units

**12.86%**
increase in enrolment since 2024

# Subject data summary

## Unit completion

The following data shows students who completed the General subject or alternative sequence (AS).

**Note:** All data is correct as at January 2026. Where percentages are provided, these are rounded to two decimal places and, therefore, may not add up to 100%.

Number of schools that offered Physics: 418.

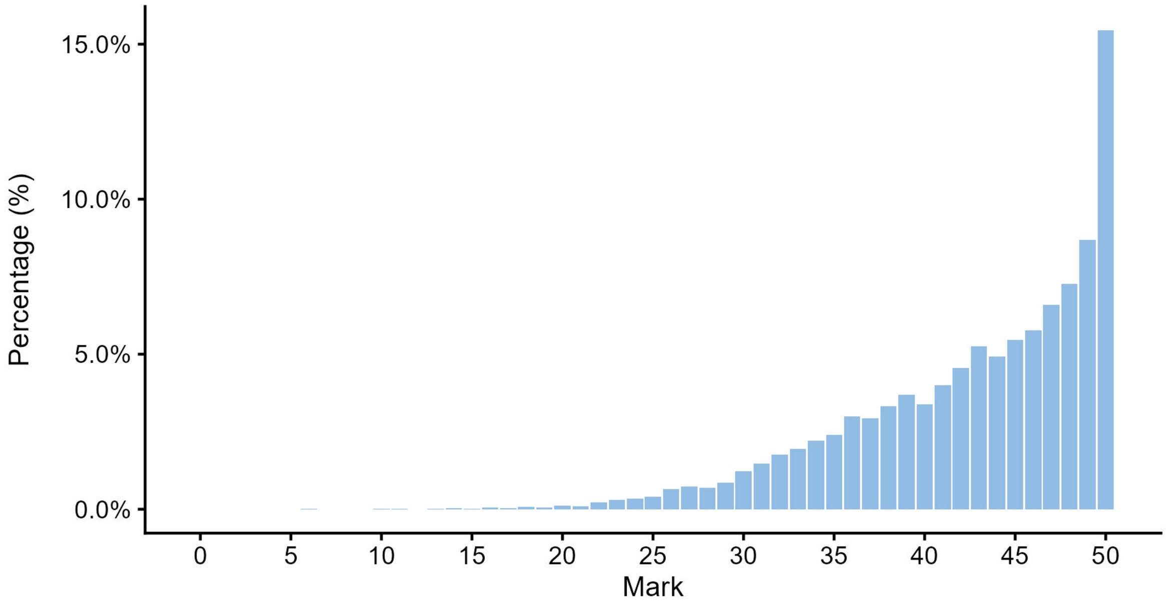
| Completion of units | Unit 1 | Unit 2 | Units 3 and 4 |
|---|---|---|---|
| Number of students completed | 9,691 | 9,163 | 8,302 |

## Units 1 and 2 results

| Number of students | Unit 1 | Unit 2 |
|---|---|---|
| Satisfactory | 9,208 | 8,536 |
| Unsatisfactory | 483 | 627 |

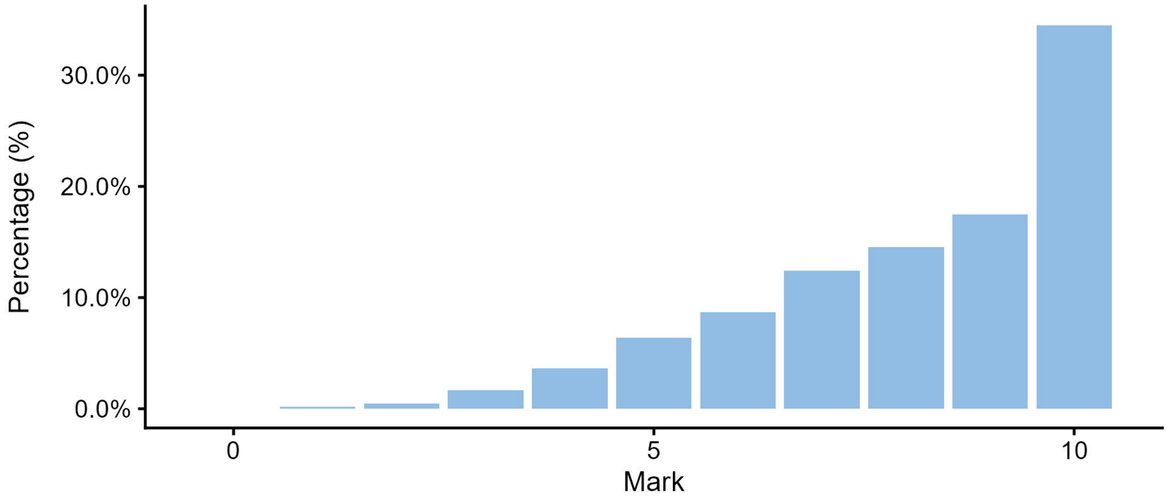
## Units 3 and 4 internal assessment (IA) results

### Total marks for IA

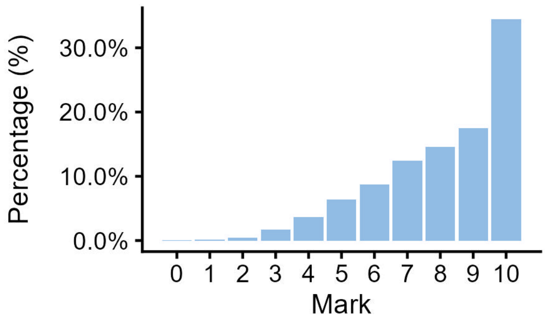


# IA1 marks

## IA1 total

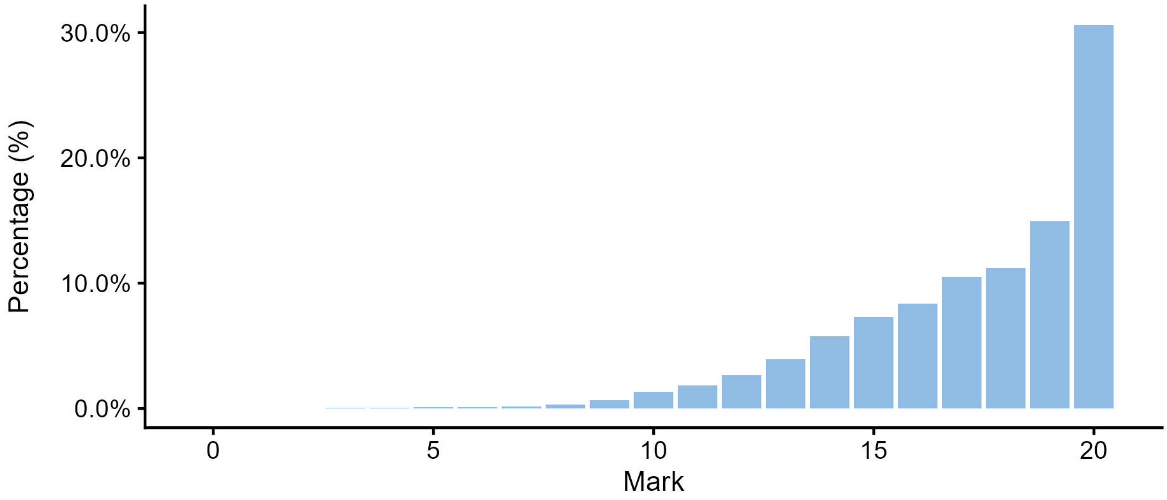



## IA1 Criterion: Data test

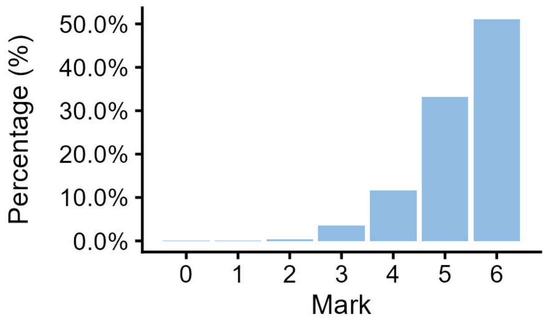


# IA2 marks

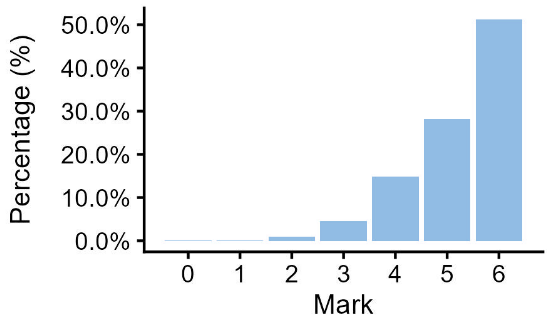
### IA2 total



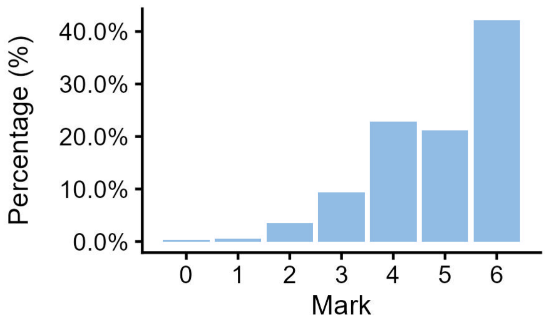

### IA2 Criterion: Research and planning



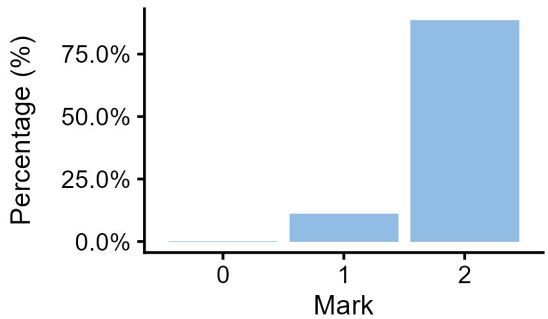

### IA2 Criterion: Analysis of evidence




### IA2 Criterion: Interpretation and evaluation

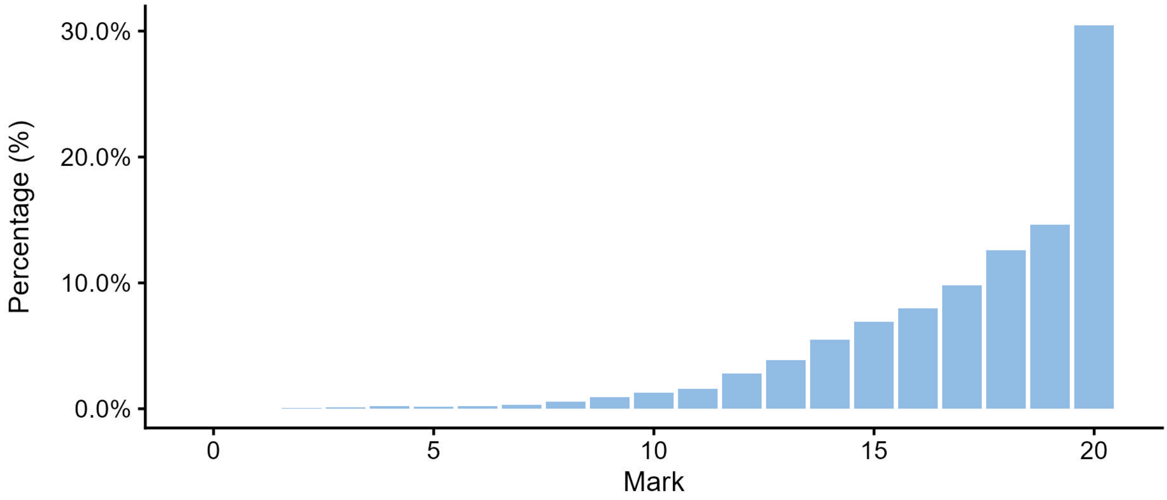



### IA2 Criterion: Communication

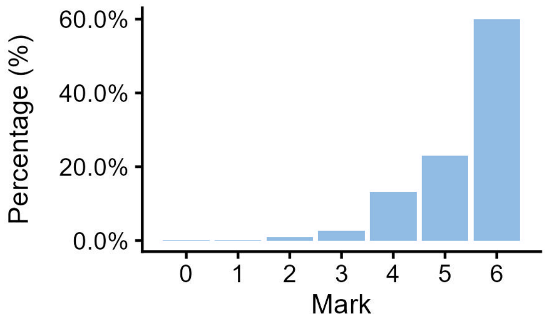


# IA3 marks

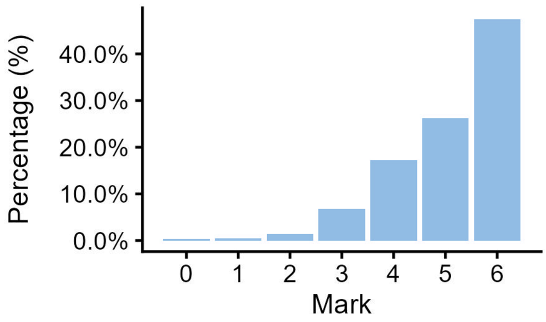
## IA3 total



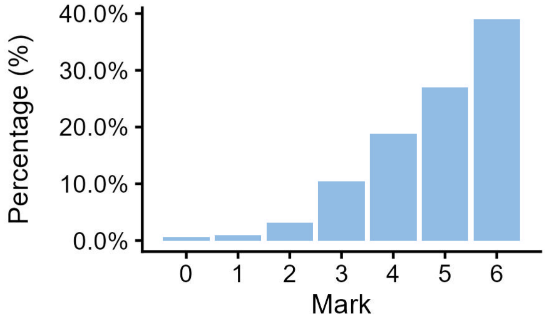

## IA3 Criterion: Research and planning



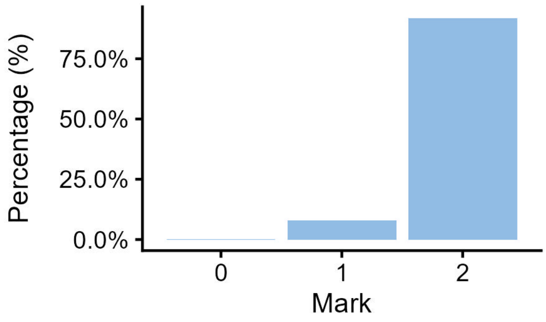

## IA3 Criterion: Analysis and interpretation



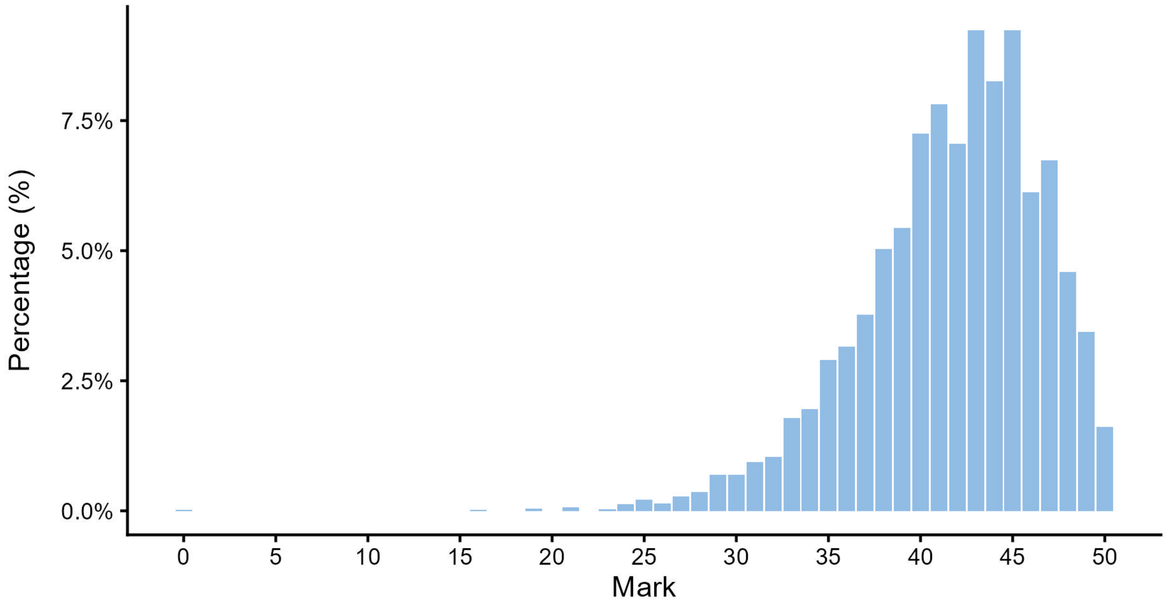

## IA3 Criterion: Conclusion and evaluation




## IA3 Criterion: Communication

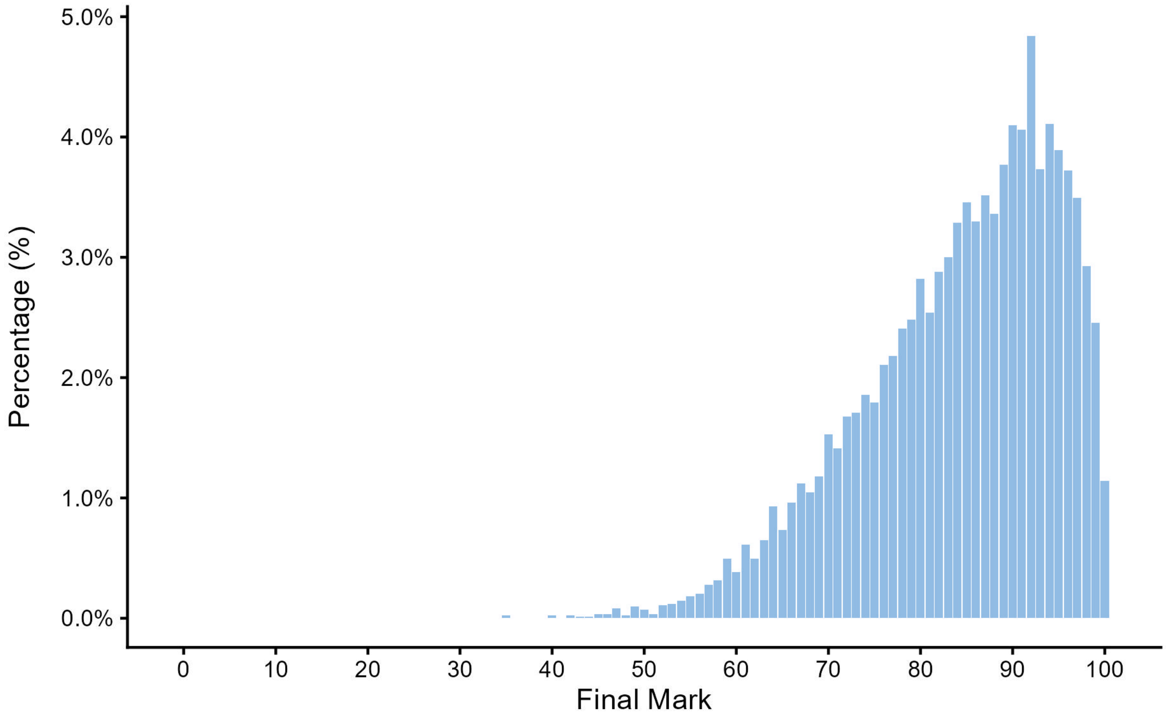


# External assessment (EA) marks




# Final subject results

## Final marks for IA and EA




## Grade boundaries

The grade boundaries are determined using a process to compare results on a numeric scale to the reporting standards.

| Standard | A | B | C | D | E |
|---|---|---|---|---|---|
| Marks achieved | 100–87 | 86–72 | 71–50 | 49–20 | 19–0 |

## Distribution of standards

Number of students who achieved each standard across the state.

| Standard | A | B | C | D | E |
|---|---|---|---|---|---|
| Number of students | 4,078 | 3,113 | 1,080 | 31 | 0 |
| Percentage of students | 49.12 | 37.50 | 13.01 | 0.37 | 0.00 |

# Internal assessment

This information and advice relate to the assessment design and assessment decisions for each IA in Units 3 and 4. These instruments have undergone quality assurance processes informed by the attributes of quality assessment (validity, accessibility and reliability).

## Endorsement

Endorsement is the quality assurance process based on the attributes of validity and accessibility. These attributes are categorised further as priorities for assessment, and each priority can be further broken down into assessment practices.

Data presented in the Assessment design section identifies the reasons why IA instruments were not endorsed at Application 1, by the priority for assessment. An IA may have been identified more than once for a priority for assessment, e.g. it may have demonstrated a misalignment to both the subject matter and the assessment objective/s.

Refer to *QCE and QCIA policy and procedures handbook v7.0*, Section 9.5.

### Percentage of instruments endorsed in Application 1

| Internal assessment | IA1 | IA2 | IA3 |
|---|---|---|---|
| **Number of instruments** | 417 | 417 | 415 |
| **Percentage endorsed in Application 1** | 48 | 88 | 59 |

## Confirmation

Confirmation is the quality assurance process based on the attribute of reliability. The QCAA uses provisional criterion marks determined by teachers to identify the samples of student responses that schools are required to submit for confirmation.

Confirmation samples are representative of the school's decisions about the quality of student work in relation to the instrument-specific marking guide (ISMG) and are used to make decisions about the cohort's results.

Refer to *QCE and QCIA policy and procedures handbook v7.0*, Section 9.6.

The following table includes the percentage agreement between the provisional marks and confirmed marks by assessment instrument. The Assessment decisions section for each assessment instrument identifies the agreement trends between provisional and confirmed marks by criterion.

### Number of samples reviewed and percentage agreement

| IA | Number of schools | Number of samples requested | Number of additional samples requested | Percentage agreement with provisional marks |
|---|---|---|---|---|
| **1** | 414 | 2,844 | 0 | 100.00 |
| **2** | 414 | 2,842 | 3 | 88.65 |
| **3** | 414 | 2,833 | 0 | 92.75 |

# Internal assessment 1 (IA1)

## Data test (10%)

This assessment focuses on the application of a range of cognitions to multiple provided items.

Student responses must be completed individually, under supervised conditions, and in a set timeframe.

### Assessment design

#### Validity

Validity in assessment design considers the extent to which an assessment item accurately measures what it is intended to measure and that the evidence of student learning collected from an assessment can be legitimately used for the purpose specified in the syllabus.

**Reasons for non-endorsement by priority of assessment**

| Validity priority | Number of times priority was identified in decisions |
|---|---|
| **Alignment** | 123 |
| **Authentication** | 0 |
| **Authenticity** | 34 |
| **Item construction** | 59 |
| **Scope and scale** | 51 |

**Effective practices**

Validity priorities were effectively demonstrated in assessment instruments that:

- integrated authentic datasets that reflected realistic, relevant scientific scenarios accompanied by clear contextual details, e.g. explaining an experiment and providing the graphed results rather than a diagram of the set-up containing no qualitative or quantitative data
- covered the scope of skills within a 60-minute test, e.g. limiting repetitive tasks, such as calculating an average, to once per test
- included a marking scheme that indicated how the mark allocations aligned to the required cognitions, e.g. 2 marks for simple calculations requiring a single step.

**Practices to strengthen**

It is recommended that assessment instruments:

- align the cognitive verb in the question to the objective and nature of the expected response, e.g. 'Determine the frequency' (obtained by reading the value from a graph) aligns more appropriately to Apply understanding (Assessment objective 2) than to Interpret evidence (Assessment objective 4)
- include questions that require analysis of data contained in the dataset to generate a response, i.e. cannot be answered using additional information in the question
- minimise excessive scaffolding by removing cues that lead to a predetermined outcome, e.g. avoid

- multiple cognitions by using ‘Determine the time taken. Show your working’ rather than ‘Calculate the time taken and justify your decision by using the graph’
- repetition of information from the dataset and/or formula and data book by using ‘Calculate the percentage error’ rather than ‘Calculate the percentage error using $\text{Percentage error }(\%) = \left|\frac{\text{measured value} - \text{true value}}{\text{true value}}\right| \times 100$.’

## Accessibility

Accessibility in assessment design ensures that no student or group of students is disadvantaged in their capacity to access an assessment.

### Reasons for non-endorsement by priority of assessment

| Accessibility priority | Number of times priority was identified in decisions |
|---|---|
| Bias avoidance | 16 |
| Language | 50 |
| Layout | 8 |
| Transparency | 17 |

### Effective practices

Accessibility priorities were effectively demonstrated in assessment instruments that:

- introduced datasets with a single statement at the start (e.g. ‘Dataset 1 refers to Questions 1–5’) rather than repeating directions in each question (e.g. ‘Refer to Graph 1 in Dataset 1’)
- applied clear and consistent formatting, including logical layout, page breaks and adequate response space.

### Practices to strengthen

It is recommended that assessment instruments:

- provide datasets that are easy to interpret and clearly labelled, e.g. with force arrows differentiated from arrows depicting movement
- use consistent units in tables and graphs
- follow mathematical and scientific conventions, e.g. use ‘$7.0 \times 10^{-15}$ kg’ rather than ‘7.0 x 10^–15 kg’ or ‘7.0e–15 kg’
- only include data relevant for analysis to maintain clarity and avoid ambiguity, e.g. include trendlines on a graph only if they will be analysed.

## Additional advice

When developing an assessment instrument for this IA, it is essential to consider the following key differences between the 2019 and 2025 syllabuses:

- Perusal time has been changed to 5 minutes.
- The question specifications table has been revised (syllabus, p. 40). Instruments should be written in line with the revised specifications so the focus of each question aligns to the relevant objective, e.g. the cognitive verb *compare* now aligns more closely to Assessment objective 3 as it relates to the similarities and differences.

# Assessment decisions

## Reliability

Reliability refers to the extent to which the results of assessments are consistent, replicable and free from error.

### Agreement trends between provisional and confirmed marks

| Criterion number | Criterion name | Percentage agreement with provisional | Percentage less than provisional | Percentage greater than provisional | Percentage both less and greater than provisional |
|---|---|---|---|---|---|
| 1 | Data test | 100.00 | 0.00 | 0.00 | 0.00 |

### Effective practices

Reliable judgments were made using the ISMG for this IA when:

- marks were correctly totalled, percentages were accurately determined, and cut-offs from the ISMG were correctly applied to determine provisional marks, e.g. 16/20 is 80%, not greater than 80%; therefore, a mark of 8 should be awarded
- annotations (e.g. ticks and crosses) on student responses clearly indicate where the evidence in the student response aligns with the school's marking scheme (*QCE and QCIA policy and procedures handbook v7.0*, Section 9.6.1).

### Practices to strengthen

To further ensure reliable judgments are made using the ISMG for this IA, it is recommended that:

- the marking scheme is accurate and aligns to the current endorsed data test
- the marking scheme is reviewed as part of the confirmation submission to ensure correct alternative student responses are indicated clearly, e.g. to indicate a range of acceptable values derived from a graph, use ‘for gradient, accept values between 3.5 to 4.1 inclusive’
- the marking scheme details the full breakdown of mark allocations for each question by clearly indicating the evidence for which marks are awarded, including follow-through (FT) marks, where applicable.

## Samples

The following excerpt demonstrates the effective use of annotations on a student response to indicate where evidence matches the marking scheme. The Assessment objective 3 question asks students to identify a relationship between two variables. The marking scheme allocates 1 mark for identifying the relationship and 1 mark for the use of appropriate data. The student response has been clearly annotated to show where it aligns with each of these characteristics.

**Note:** The characteristic/s identified may not be the only time the characteristic/s occurred throughout a response.

**Excerpt 1**

The relationship between seperation distance and force is inverse squared. As ~~force~~ seperation distance doubles from 2m to 4m, Force approximately quarters from 4.17 μN to 1.04 μN. This can be seen again as seperation distance doubles from 3m to 6m, Force approximately quarters from 1.85 μN to 0.46 μN.

The following excerpt demonstrates the effective use of annotations on a student response to indicate where evidence matches the marking scheme. The marking scheme indicated that students would need to appropriately identify values on the trendline found within the dataset, and substitute correctly into the appropriate formula.

**Note:** The characteristic/s identified may not be the only time the characteristic/s occurred throughout a response.

**Excerpt 2**

Trend Line passes through (0.40, 1.40)

∴ when $r = 0.40\,m$, $v = 1.40\,m/s$

$$v = \frac{2\pi r}{T}$$

$$1.40 = \frac{2\pi \times (0.40)}{T}$$

$$T = \frac{2\pi(0.40)}{1.40}$$

$$= 1.79\ldots$$

$$= 1.8\,s$$

Period of rotation = 1.8 s (1 d.p.)

# Internal assessment 2 (IA2)

## Student experiment (20%)

This assessment requires students to research a question or hypothesis through collection, analysis and synthesis of primary data. A student experiment uses investigative practices to assess a range of cognitions in a particular context. Investigative practices include locating and using information beyond students' own knowledge and the data they have been given.

Research conventions must be adhered to. This assessment occurs over an extended and defined period of time. Students may use class time and their own time to develop a response.

## Assessment design

### Validity

Validity in assessment design considers the extent to which an assessment item accurately measures what it is intended to measure and that the evidence of student learning collected from an assessment can be legitimately used for the purpose specified in the syllabus.

#### Reasons for non-endorsement by priority of assessment

| Validity priority | Number of times priority was identified in decisions |
|---|---|
| **Alignment** | 18 |
| **Authentication** | 18 |
| **Authenticity** | 5 |
| **Item construction** | 14 |
| **Scope and scale** | 0 |

#### Effective practices

Validity priorities were effectively demonstrated in assessment instruments that:

- included a task description that exactly matched the task specifications of the syllabus
- indicated which sections of the assignment would be completed as a group and which sections would be completed individually
- detailed all the conditions for the assessment task listed in the syllabus including the time, length and available modes.

#### Practices to strengthen

It is recommended that assessment instruments:

- clearly state that any sample research questions provided in the task must not be used to generate a response
- include a variety of practical activities aligned with the teaching and learning of Unit 3 (or AS Unit 1) to support the development of the methodology and research question
- eliminate repetition of information already provided elsewhere in the task, e.g. restating specifications in the scaffolding section.

### Accessibility

Accessibility in assessment design ensures that no student or group of students is disadvantaged in their capacity to access an assessment.

#### Reasons for non-endorsement by priority of assessment

| Accessibility priority | Number of times priority was identified in decisions |
|---|---|
| Bias avoidance | 0 |
| Language | 5 |
| Layout | 0 |
| Transparency | 2 |

#### Effective practices

Accessibility priorities were effectively demonstrated in assessment instruments that:

- included checkpoints with
  - flexibility to allow week numbers to be added once school timetabling was finalised
  - at least two checkpoints specifying draft submission and final submission.

#### Practices to strengthen

There were no significant issues identified for improvement.

### Additional advice

When developing an assessment instrument for this IA, it is essential to consider the following key differences between the 2019 and 2025 syllabuses:

- The task specifications language has been revised to align with the mid performance-level descriptor in the ISMG.

## Assessment decisions

### Reliability

Reliability refers to the extent to which the results of assessments are consistent, replicable and free from error.

#### Agreement trends between provisional and confirmed marks

| Criterion number | Criterion name | Percentage agreement with provisional | Percentage less than provisional | Percentage greater than provisional | Percentage both less and greater than provisional |
|---|---|---|---|---|---|
| 1 | Research and planning | 94.69 | 4.59 | 0.72 | 0.00 |
| 2 | Analysis of evidence | 95.89 | 3.86 | 0.24 | 0.00 |
| 3 | Interpretation and evaluation | 97.34 | 2.17 | 0.48 | 0.00 |
| 4 | Communication | 98.76 | 0.00 | 1.21 | 0.00 |

### Effective practices

Reliable judgments were made using the ISMG for this IA when:

- for the Interpretation and Evaluation criterion
  - *justified* conclusions referred to the trends, patterns or relationships identified in the analysis of evidence to indicate how the evidence matched with the theoretical concepts identified in the rationale
  - *logically derived* improvements were linked to the reliability for the experimental process and considered the calculated uncertainties in the raw data
  - *justified* discussions of validity were made with reference to the accepted and constant values derived from the *relevant* equation in the rationale.
- for the Communication criterion
  - evidence of the characteristics was considered throughout the entirety of the student response, incorporating the language and structure of the submission as a whole
  - the student *fluently and concisely* conveyed precise and accurate information through the correct use of
    - symbols, units and prefixes appropriate for the context, e.g. SI units, such as 'kg' for mass
    - indicators of measurement uncertainty, e.g. significant figures
    - graphs and lines of best fit to demonstrate trends within data.

### Practices to strengthen

When making judgments for this IA for the 2025 syllabus, it is essential to consider the following key differences between the ISMGs in the 2019 and 2025 syllabuses:

- for the Forming criterion
  - a *specific* research question explicitly states the relationship between an independent and dependent variable and is directly related to the data that will be collected
  - a *relevant* research question links appropriate subject matter to the experiment conducted
  - a *considered* rationale demonstrates how the research question was developed, giving consideration to how the dependent, independent and control variables relate to the topic of investigation
- for the Analysing criterion
  - *relevant* trends, patterns and relationships are *thoroughly* identified when they accurately describe the processed data and lead to a valid conclusion to the research question
  - uncertainties and limitations of evidence are *thoroughly* identified when they are correctly calculated and *appropriately* represented, e.g. calculation of percentage uncertainty in processed data, inclusion of appropriate error bars and/or maximum and minimum trendlines.

## Additional advice

It is essential to consider the following key differences between the 2019 and 2025 syllabuses:

- The alignment between criteria and characteristics of evidence within the student response has changed; however, teachers' judgments when determining the appropriate performance level for each characteristic remain the same.

## Samples

The following excerpts demonstrate a specific and relevant research question that clearly identifies a relationship between an independent and dependent variable. The response also illustrates justified modifications clearly indicating how the original investigation was refined and redirected. The student response explicitly addresses how the modifications address the reliability and validity of the experiment.

**Note:** The characteristic/s identified may not be the only time the characteristic/s occurred throughout a response.

**Excerpt 1**

**Research Question:** What is the relationship between angle of incline and acceleration produced by a car when it is released from the top of a ramp, with a constant mass and starting from rest, assuming friction and air resistance is negligible, and gravity is constant at 9.8 $m/s^2$?

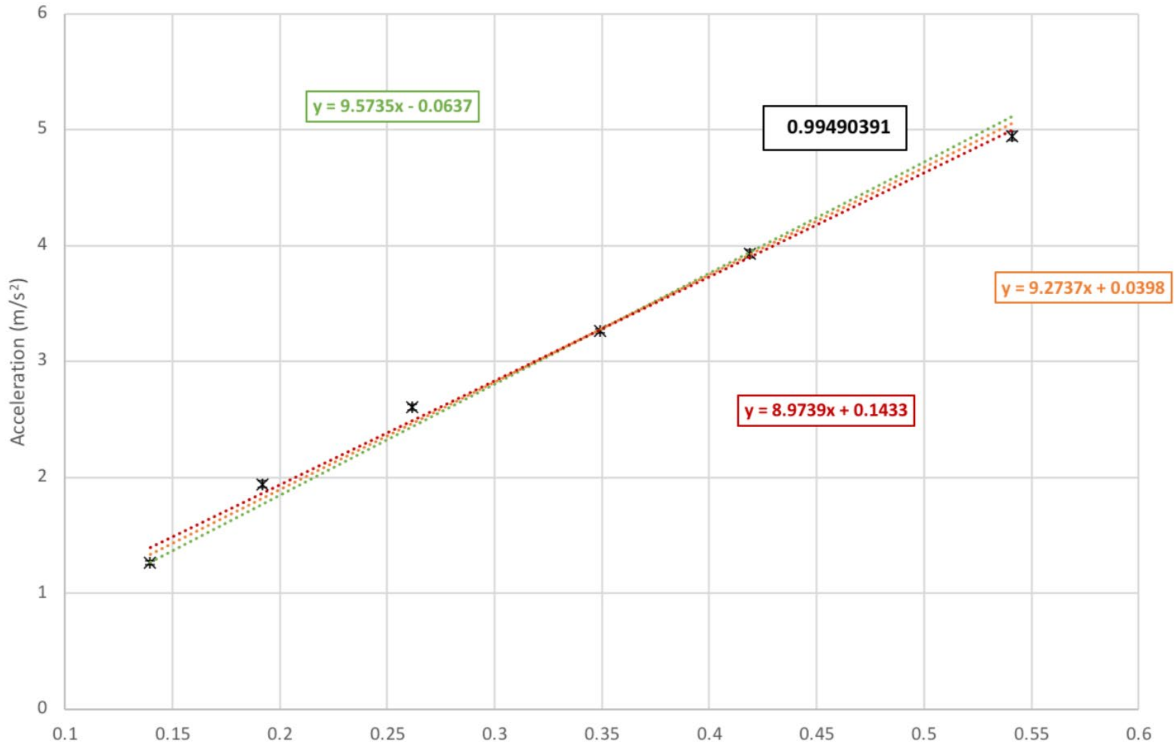
**Excerpt 2**

| Modifications | Justification |
|---|---|
| The number of trials was increased from 2 to 3. | This improves the reliability of the results as it reduces the impact of outliers. |
| The range was increased from 4 angles, (12°, 16°, 20°, 24°) to 6, (8°, 11°, 15°, 20°, 24°, 31°) | This improves the validity of the results as it confirms if the relationship between angle of incline and force is true over a larger range. |
| Instead of pulling the car up the ramp, the car will be released from the top of the ramp. | This improves the validity as it reduces the random error from fluctuating velocities when the car is pulled up the ramp by a person. |
| A smart car will be used instead of a spring balance and normal cart. | This improves the validity as the smart car can measure acceleration automatically.<br>This reduces the parallax error from reading the spring balance, increasing reliability.<br>Furthermore, using the smart car improves reliability as it can measure to 3 decimals, more than the spring balance, reducing measurement uncertainty. |
| Rails will be used for the smart car instead of the wooden ramp. | This improves the validity of the experiment as it ensures the smart car moves on only the x and y axis. Therefore there is no unintended movement to one side of the ramp which would decrease validity. |

The following excerpts demonstrate the thorough and appropriate identification of uncertainties within the evidence using correct and relevant processing of the experimental data.

**Note:** The characteristic/s identified may not be the only time the characteristic/s occurred throughout a response.

**Excerpt 1**




**Excerpt 2**

| | |
|---|---|
| Uncertainty of Gradient | $\delta_m = \pm \frac{m_{max} - m_{min}}{2}$<br>$\delta_m = \pm \frac{9.5735 - 8.9739}{2} = \pm 0.2998$<br>$\delta_{m\%} = \pm \frac{0.2998}{9.2737} \times 100 = \pm 3.233\ \%$ |

**Excerpt 3**

$$a = (9.2737 \pm 0.2998)\sin(\theta) + (0.0398 \pm 0.1035)$$

# Internal assessment 3 (IA3)

## Research investigation (20%)

This assessment requires students to evaluate a claim. They will do this by researching, analysing and interpreting secondary evidence from scientific texts to form the basis for a justified conclusion about the claim. A research investigation uses research practices to assess a range of cognitions in a particular context. Research practices include locating and using information beyond students' own knowledge and the data they have been given.

Research conventions must be adhered to. This assessment occurs over an extended and defined period of time. Students may use class time and their own time to develop a response.

## Assessment design

### Validity

Validity in assessment design considers the extent to which an assessment item accurately measures what it is intended to measure and that the evidence of student learning collected from an assessment can be legitimately used for the purpose specified in the syllabus.

#### Reasons for non-endorsement by priority of assessment

| Validity priority | Number of times priority was identified in decisions |
|---|---|
| **Alignment** | 156 |
| **Authentication** | 22 |
| **Authenticity** | 4 |
| **Item construction** | 19 |
| **Scope and scale** | 25 |

#### Effective practices

Validity priorities were effectively demonstrated in assessment instruments that:

- included a task description that exactly matched the task specifications of the syllabus
- aligned claims to the Unit 4 (or AS Unit 2) topics identified in the conditions, e.g. when only Topic 2 was listed in the conditions, claims aligned to Topic 1 subject matter were not included.

#### Practices to strengthen

It is recommended that assessment instruments:

- provide claims that
  - enable students to develop a research question that can be analysed and interpreted using data clearly linked to Unit 4 (or AS Unit 2) subject matter, e.g. 'Black-body radiation paved the way for understanding energy quantisation'
  - can be explored within the word limit, enabling students to produce a unique, well-developed response, e.g. 'Light is better described as a wave than a particle'.

### Accessibility

Accessibility in assessment design ensures that no student or group of students is disadvantaged in their capacity to access an assessment.

#### Reasons for non-endorsement by priority of assessment

| Accessibility priority | Number of times priority was identified in decisions |
|---|---|
| **Bias avoidance** | 0 |
| **Language** | 14 |
| **Layout** | 2 |
| **Transparency** | 2 |

#### Effective practices

Accessibility priorities were effectively demonstrated in assessment instruments that:

- modelled accurate spelling, grammar and punctuation
- contained clear, non-repetitive claims that avoided ambiguity and supported focused, coherent responses.

#### Practices to strengthen

There were no significant issues identified for improvement.

### Additional advice

When developing an assessment instrument for this IA, it is essential to consider the following key differences between the 2019 and 2025 syllabuses:

- The qualifiers used to describe each cognitive process in the task specifications have been revised.
- The nature of student-accessible scientifically credible sources has been clarified.
- Group elements have been added to several Forming and Finding criterion activities of the task.

## Assessment decisions

### Reliability

Reliability refers to the extent to which the results of assessments are consistent, replicable and free from error.

#### Agreement trends between provisional and confirmed marks

| Criterion number | Criterion name | Percentage agreement with provisional | Percentage less than provisional | Percentage greater than provisional | Percentage both less and greater than provisional |
|---|---|---|---|---|---|
| 1 | Research and planning | 96.62 | 3.14 | 0.24 | 0.00 |

| Criterion number | Criterion name | Percentage agreement with provisional | Percentage less than provisional | Percentage greater than provisional | Percentage both less and greater than provisional |
|---|---|---|---|---|---|
| 2 | Analysis and interpretation | 98.31 | 1.45 | 0.24 | 0.00 |
| 3 | Conclusion and evaluation | 97.58 | 2.42 | 0.00 | 0.00 |
| 4 | Communication | 99.03 | 0.00 | 0.97 | 0.00 |

### Effective practices

Reliable judgments were made using the ISMG for this IA when:

- for the Analysis and interpretation criterion
  - *relevant* evidence was drawn from *sufficient* sources to enable thorough identification of the trends, patterns and relationships between them
  - scientific arguments were *justified* by linking the relevant trends, patterns and relationships found within the evidence to support discussions
- for the Communication criterion, sources were acknowledged using referencing conventions appropriately and consistently throughout the response.

### Practices to strengthen

To further ensure reliable judgments are made using the ISMG for this IA, it is recommended that:

- for the Forming and Finding criterion
  - the rationale clearly breaks the claim into its constituent parts and outlines the logical development from the claim to the research question
  - specific and relevant research questions include measurable independent and dependent variables that allow for a response related to the appropriate subject matter
- for the Evaluating criterion
  - a *justified* discussion of the quality of evidence includes verifying the credibility, bias, relevance, accuracy and recency of multiple sources
  - findings are *extrapolated* to address not only the research question but also the claim, using *credible* evidence discussed throughout the investigation.

## Additional advice

It is essential to consider the following key differences between the 2019 and 2025 syllabuses:

- The alignment between criteria and characteristics of evidence within the student response has changed; however, teachers' judgments when determining the appropriate performance level for each characteristic remain the same.

## Samples

The following excerpts demonstrate specific and relevant research questions that address Unit 4 (or AS Unit 2) subject matter and include measurable independent and dependent variables.

**Note:** The characteristic/s identified may not be the only time the characteristic/s occurred throughout a response.

**Excerpt 1**

How does special relativity affect the clock drift (microseconds) and vertical positioning accuracy (metres) of the global positioning system (GPS) over the course of 24 hours?

**Excerpt 2**

## Research question

Does GPS technology compensate for the impact of time dilation due to special relativity on its accuracy, and achieve aircraft positioning accuracy within 10 metres?

The following excerpt demonstrates a rationale that clearly breaks the claim into its constituent parts and outlines the logical development from the claim through to the research question.

**Note:** The characteristic/s identified may not be the only time the characteristic/s occurred throughout a response.

## Claim

The theory of special relativity has little, if any, effect in the ordinary, everyday world.

## Rationale

Einstein's theory of special relativity (SR) describes the relationship between space, time, mass and energy (U.S. Department of Energy, n.d.). It has two postulates: the laws of physics are the same in all inertial (non-accelerating) frames of reference, and the speed of light in a vacuum ($c=3\times10^8$ m/s) is constant for all observers (Martin, Neary, Rinaldo, & Woodman, 2024). This led to predictions of physics phenomena including time dilation and length contraction (Science Ready, n.d.).

Time dilation in SR is often described as "moving clocks run slow", where a moving observer measures shorter time intervals than an observer at rest relative to the event (Walding, 2019). While SR accounts for motion-based time dilation, time is also affected by gravitational field strength, as described by general relativity (GR), where clocks run slower in stronger gravitational fields (Einstein's General Relativity and Your Age, 2022).

Length contraction means objects moving at relativistic speeds (>0.1c) appear shorter in the direction of motion to a stationary observer compared to an observer moving with the object (Urone, Hinrichs, Dirks, & Sharma, 2024).

Although these effects seem irrelevant to daily life, they significantly impact high-speed objects (>0.1c). For example, muon's lifetime, gold's colour, and global positioning system (GPS) with satellites moving at a speed of 14,000 km/hour are all influenced by time dilation or length contraction (Walding, 2019) (Andrei, 2023) (Kruszelnicki, 2023).

Hence GPS plays significant roles in daily lives - providing positioning, navigation, and timing services for many devices - it will be studied in this report (National Coordination Office for Space-Based Positioning, Navigation, and Timing, 2021) (Pogge, 2017). Many aircraft rely heavily on GPS, especially in poor visibility conditions. This means GPS error could compromise flight safety. By investigating how SR impacts GPS's accuracy, the claim can be discussed regarding whether aircraft - something commonly used in the everyday world – are greatly affected by the theory of special relativity.

GPS is highly accurate today because the engineers have already considered relativistic effects and effectively corrected the system to minimize the error (Pogge, 2017), leading to the following research question:

## Research question

Does GPS technology compensate for the impact of time dilation due to special relativity on its accuracy, and achieve aircraft positioning accuracy within 10 metres?

The following excerpt demonstrates *thorough* identification of relevant trends, patterns and relationships in the evidence to later develop justified scientific arguments.

**Note:** The characteristic/s identified may not be the only time the characteristic/s occurred throughout a response.

**Source 2: Relativistic Transformations for Time Synchronization and Dissemination in the Solar System (Nelson & Ely 2006).**
**Table 1: Elliptical orbit data for various global navigation satellite systems, including GPS.**

**Satellite orbital properties**

| Satellite | | ISS | GLONASS | GPS | Galileo | Molniya | GEO |
|---|---|---|---|---|---|---|---|
| Semimajor axis | km | 6766 | 25510 | 26561.8 | 29994 | 26562 | 42164 |
| Eccentricity | | 0.01 | 0.02 | 0.02 | 0.02 | 0.722 | 0.01 |
| Inclination | deg | 51.6 | 64.8 | 55.0 | 56.0 | 63.4 | 0.1 |
| Argument of perigee | deg | 0 | 0 | 0 | 0 | 250 | 0 |
| Apogee altitude | km | 456 | 19642 | 20715 | 24216 | 39362 | 36208 |
| Perigee altitude | km | 320 | 18622 | 19652 | 23016 | 1006 | 35364 |
| Ascending node altitude | km | 320 | 18622 | 19652 | 23016 | 10507 | 35364 |
| Period of revolution | s | 5539 | 40549 | 43082 | 51697 | 43083 | 86164 |
| Mean motion | rev/d | 15.6 | 2.1 | 2.0 | 1.7 | 2.0 | 1.0 |
| Mean velocity | km/s | 7.675 | 3.953 | 3.874 | 3.645 | 3.874 | 3.075 |

This table shows GPS's mean velocity is 3.874km/s which can be used in eq2, when multiplied by 1000 giving 3874m/s. By using this velocity in eq2 it will give the receivers time dilation over a certain interval, $t_o$, aboard the satellite. To show time dilations effect on signal transmit calculations over a day period, 86400 can be used for the proper time interval, $t_o = 86400s$.

Subbing $t_o = 86400s$ into eq2 would give the receivers dilated time per day, so to evaluate the error between transit time calculations the difference between proper and dilated time is found.

$$Eq3: Error = t_o - t$$

$$For\ a\ day\ period, Dilated\ time:\ t = \frac{t_o}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}\ t = \frac{86400}{\sqrt{(1 - \frac{3874^2}{299792458^2})}}$$

$$Error = 86400 - \frac{86400}{\sqrt{\left(1 - \frac{3874^2}{299792458^2}\right)}} = -7.2138 \times 10^{-6}s = -7.2138\mu s$$

This calculation shows that in a day without relativistic corrections, the time measured from the perspective of the GPS satellite, would be slower than Earth's measured time by 7.1 $\mu s/day$.

Table 1 excerpted from Nelson, Robert & Ely, Todd. (2006). Relativistic transformations for time synchronization and dissemination in the solar system. https://www.researchgate.net/publication/228346683_Relativistic_transformations_for_time_synchronization_and_dissemination_in_the_solar_system

The following excerpts demonstrate *insightful discussion* of the quality of evidence by verifying the credibility, relevance, accuracy and recency of sources.

**Note:** The characteristic/s identified may not be the only time the characteristic/s occurred throughout a response.

**Excerpt 1**

### Evaluation of Evidence

A direct limitation of this experiment is that as GPS satellites are affected by both special and general relativity, time dilation is often a result of combined effects of both of these principles, however, as this dilation is only minimal, the results are still indicative of a massive objects ability to reach lightspeeds. Another experimental limitation is that the data was only recorded over a month period, this reducing the reliability and accuracy of the data when interpreting the results over an extended period of time.

The experiment was published in January of 2013, and although is more recent in comparison to other sources, may be slightly outdate. However, the subject matter explored builds on fundamentally foundational physics concepts, making it reasonable to assume that since no major breakthroughs in GPS satellite technology have occurred since its publication, this source is still credible and relevant. The authors themselves are well cited university professors and doctors in their field, demonstrating immense credibility in their work. The publication, *the International Journal of Pure and Applied Sciences and Technology,* is established as a widely reputable and legitimate journal based on its rigorous standards and openly peer-reviewed research.

**Excerpt 2**

## QUALITY OF EVIDENCE

### STRENGTHS

- The sources were published by the American Geophysical Union, the International Journal of Thermal Sciences, and the National Oceanic and Atmospheric Administration which are reputable sources and increases credibility
- All sources corroborate each other by indicating that an increase in $CO_2$ would cause global temperatures to rise
- Source 1 uses historical data as a basis for the model, improving the reliability
- Source 2 uses known thermal laws to make predictions for temperature fluctuations due to $CO_2$
- Source 3 has data which dates back to 1860, which improves the accuracy of trends
- Data in source 3 is independently supported by Berkley Earth which further increases reliability (Berkley Earth, n.d.)

insightful

conclusion drawing from all evidence

### WEAKNESSES

- Sources 1 and 2 are simplified models which reduces their reliability and validity as they do not consider many variables such as regional variations, and other greenhouse gases effect on each other
- Source 1 uses paleo reconstructions, and the reliability is dependent on the timescale of the reconstruction
- The high margin of error in source 1 (15%-78%) which majorly limits the accuracy
- Source 2's 0.4ºC estimate on the impact of doubling $CO_2$ is low compared to other models suggesting conservative or reduced accuracy
- Source 3 does not explicitly confirm a relationship between $CO_2$ and increasing temperatures, this has to be inferred from the data which limits validity

The following excerpt demonstrates the *extrapolation of credible findings* to the claim. The response applies the conclusions drawn about time dilation calculations and accuracy of GPS positioning to the broader claim about special relativity and global navigation systems.

**Note:** The characteristic/s identified may not be the only time the characteristic/s occurred throughout a response.

**CONCLUSION AND EVALUATION OF CLAIM**

The evidence and findings of calculations supported by and derived from sources 1-5, indicate that omitting special relativistic corrections affect the receiver-satellite distance calculations by a large extent, with compounding time dilation errors in the satellite clocks, affecting the pseudo-range calculation which is fundamental for GPS positioning.

It has been found that omitting special-relativistic time-dilation calculations decreases the accuracy of GPS's receiver positioning, with pseudo-range errors of 2km from time dilation differences of 7.2microseconds/day that come from the satellites traveling at 3874m/s relative to the receiver. It has been found that acceptable pseudo-range error thresholds are exceeded afte 84seconds, and if the clocks were corrected to account for time-dilation receiver positioning accuracy would increase.

The claim, "Our global navigation satellite systems (GNSS) will not work without an understanding of special relativity." is supported by the findings of the research question, as all GNSS's travel at large velocities (Table 1), and use similar pseudo-range and trilateration calculations (source 4). So, time dilations effect on GPS can be extrapolated to all other GNSSs and the claim can be accepted.

# External assessment

External assessment (EA) is developed and marked by the QCAA. The external assessment for a subject is common to all schools and administered under the same conditions, at the same time, on the same day. The external assessment papers and the EAMG are published in the year after they are administered.

## Examination (50%)

### Assessment design

The assessment instrument was designed using the specifications, conditions and assessment objectives described in the summative external assessment section of the syllabus.
The examination consisted of two papers:

- Paper 1, Section 1 consisted of multiple choice questions (20 marks)
- Paper 1, Section 2 consisted of short response questions (31 marks)
- Paper 2, Section 1 consisted of short response questions (50 marks)

The AS assessment instrument was designed using the specifications, conditions and assessment objectives described in the summative external assessment section of the AS.
The AS examination consisted of two papers:

- Paper 1, Section 1 consisted of multiple choice questions (20 marks)
- Paper 1, Section 2 consisted of short response questions (28 marks)
- Paper 2, Section 1 consisted of short response questions (47 marks)

### Assessment decisions

Assessment decisions are made by markers by matching student responses to the external assessment marking guide (EAMG).

#### Multiple choice question responses

There were 20 multiple choice questions in Paper 1.

**Percentage of student responses to each option**

**Note:**

- The correct answer is **bold** and in a blue shaded table cell.
- Some students may not have responded to every question.

## Physics General

| Question | A | B | C | D |
|---|---|---|---|---|
| **1** | 20.89 | **71.44** | 5.73 | 1.81 |
| **2** | 18.31 | 7.58 | **72.71** | 1.22 |
| **3** | **50.53** | 17.54 | 18.55 | 13.19 |
| **4** | 5.04 | 11.85 | 11.21 | **71.53** |
| **5** | 17.81 | **43.95** | 23.62 | 14.31 |
| **6** | 8.68 | 4.24 | **77.83** | 8.96 |
| **7** | 4.57 | 6.14 | **78.31** | 10.77 |
| **8** | 43.71 | 11.29 | **29.69** | 14.89 |
| **9** | 3.48 | 11.40 | 5.00 | **79.84** |
| **10** | 4.19 | **83.72** | 6.36 | 5.03 |
| **11** | 9.31 | 6.77 | 18.99 | **64.71** |
| **12** | 2.63 | **22.98** | 65.23 | 8.90 |
| **13** | 6.82 | 2.70 | 3.23 | **86.98** |
| **14** | **65.66** | 15.04 | 12.59 | 6.10 |
| **15** | **67.21** | 6.91 | 21.69 | 3.72 |
| **16** | 1.53 | **63.58** | 15.15 | 19.35 |
| **17** | 7.74 | 22.11 | 5.77 | **64.12** |
| **18** | **70.85** | 16.49 | 3.67 | 8.72 |
| **19** | **39.63** | 16.18 | 36.24 | 7.39 |
| **20** | 14.03 | 1.97 | **47.22** | 36.32 |

### Physics AS

| Question | A | B | C | D |
|---|---|---|---|---|
| **1*** | 24.27 | **60.59** | 11.59 | 3.40 |
| **2*** | 31.22 | 8.50 | **58.27** | 1.85 |
| **3** | 1.39 | **86.40** | 4.02 | 8.19 |
| **4** | 50.39 | 4.95 | **38.64** | 5.87 |
| **5*** | 28.90 | **28.75** | 31.38 | 10.97 |
| **6*** | 11.44 | 6.03 | **66.77** | 15.46 |
| **7** | **46.06** | 2.16 | 35.24 | 16.54 |
| **8** | **63.06** | 28.59 | 1.39 | 6.96 |
| **9*** | 4.33 | 13.29 | 8.66 | **73.42** |
| **10*** | 5.72 | **73.11** | 11.59 | 8.96 |
| **11** | 6.03 | 10.82 | **81.14** | 1.85 |
| **12** | **88.25** | 4.79 | 0.93 | 5.72 |
| **13*** | 10.51 | 6.18 | 8.50 | **74.65** |
| **14*** | **48.07** | 22.10 | 20.09 | 9.43 |
| **15** | 8.04 | **52.86** | 30.91 | 7.88 |
| **16** | 15.61 | 32.46 | **47.14** | 4.79 |
| **17*** | 8.81 | 25.50 | 7.88 | **57.65** |
| **18*** | **61.67** | 22.57 | 4.64 | 10.97 |
| **19** | 61.05 | **18.86** | 11.44 | 8.50 |
| **20** | 27.20 | 12.06 | **56.57** | 3.40 |

*Questions were common to both General and AS examinations.

## Effective practices

Overall, students responded well to:

- calculation questions when they communicated their mathematical reasoning using the textual and visual cues present
- analysis questions that required the use of data to identify trends and determine unknown values.

## Practices to strengthen

When preparing students for external assessment, it is recommended that teachers:

- review questions involving the cognitive verbs *describe* and *explain* to ensure that students
  - provide more than basic descriptions of physical phenomena
  - include detailed, relevant facts that demonstrate a thorough interpretation of the concept
- support students to understand both the concepts and contexts of formulas to promote correct usage and enhance accuracy in problem-solving.

## Samples

### Short response

Question 23b) from Paper 1 of the Physics General examination

This question required students to *calculate* the time for Saturn to complete one revolution around the Sun, when given the orbital data for Earth.

Effective student responses:

- recognised the usage of Kepler's third law of planetary motion
- converted the orbital period of Earth into seconds
- provided appropriate mathematical reasoning
- calculated the correct time taken for Saturn to orbit the Sun.

These excerpts have been included:

- to demonstrate a typical student response which applies Kepler's third law of planetary motion
- to illustrate a valid alternative student response which uses Newton's Law of Universal Gravitation and the mass of the Sun before applying Kepler's third law of planetary motion.

**Excerpt 1**

$r_E = 1.49 \times 10^{11}$ m $\quad r_S = 1.43 \times 10^{12}$ m.

$T_E = 365 \times 24 \times 60 \times 60$

$= 3.1536 \times 10^7$ s

According to Kepler's 3rd law : $\frac{(T_E)^2}{(r_E)^3} = \frac{(T_S)^2}{(r_S)^3}$

$\frac{(3.1536 \times 10^7)^2}{(1.49 \times 10^{11})^3} = \frac{(T_S)^2}{(1.43 \times 10^{12})^3}$

$(T_S)^2 = 8.79 \times 10^{17}$

$T_S = 9.376 \times 10^8$ s

Time taken = $9.376 \times 10^8$ s

**Excerpt 2**

$r_E = 1.49 \times 10^{11}$ Finding $M$ using earth:

$r_S = 1.43 \times 10^{12}$ $\frac{T^2}{r^3} = \frac{4\pi^2}{GM}$ T of earth = 31536000s

$$\frac{(31536000)^2}{(1.49\times10^{11})^3} = \frac{4\pi^2}{6.67\times10^{-11}\times M}$$

$$M = \frac{4\pi^2 \times (1.49\times10^{11})^3}{31536000^2 \times 6.67\times10^{-11}}$$

$$= 1.97\times10^{30}$$

Time for Saturn

$$T = \sqrt{\frac{4\pi^2 \times r^3}{GM}} = \sqrt{\frac{4\pi^2 \times (1.43\times10^{12})^3}{6.67\times10^{-11}\times1.97\times10^{30}}} = 9.38\times10^{8}$$

Time taken = $9.38 \times 10^8$ s

Question 24a) from Paper 1 of the Physics General examination

This question required students to explain how the photoelectric effect gave evidence for the particle nature of light and contradicts the concept of light as a wave.

Effective student responses:

- recognised the need for electrons to be ejected from the metal surface
- recognised the lack of evidence present to support the wave nature of light
- recognised the relationship between the photon's energy and its frequency
- explained the relationship between the intensity of light and the number of particles ejected
- explained the nature of the threshold frequency.

This excerpt has been included to demonstrate a valid response from students who included reference to appropriate formulas to support their explanation.

When light is shone onto the metal, the incident frequency of the light must exceed the threshold frequency of the metal, (outlined in $E_K = hf_I - hf_0$) for it to eject photoelectrons in forms of kinetic energy. (~~Exx~~ Metal absorbs most of electron energy and emitts the remaining photoelectric energy as $K_E$) As seen in the experiment, intensity only increases the amount/number of electrons incident on the metal, not the energy - thus $f_I < f_0$ and no photoelectrons are emitted. This contradicts the wave nature of light as in waves, as the intensity increases so does the amplitude and thus it should eject photoelectrons. (Electrons are discrete quantized packets of energy that only exist in set energy levels)

Question 4b) and 4c) from Paper 2 of the Physics General examination

These questions required students to explain the production of photons from electron transitions between energy levels.

Effective student responses:

- explained the release of photons when electrons move down energy levels
- explained how three photons are released due to the three transitions an electron could make between n = 2 and n = 4, and how each photon was different due to the different energies of each transition
- determined the lowest energy transition.

These excerpts have been included:

- to demonstrate a typical student response for Question 4b) that indicates the three potential transitions, and the consequential unique nature of the respective photons emitted
- to demonstrate a typical student response for Question 4c) that calculates photon energy and the wavelength to determine the photon with the longest wavelength.

**Excerpt 1**

$e_{ii}$'s transitions produced two photons because it must have transitioned first from n=4 to n=3, then from n=3 to n=2, whereas $e_i$ transitioned straight from n=4 to n=2. Each of these energy transitions result in three different photons because there's a different energy difference between each of these energy levels since they're discrete; therefore, a different amount of energy must be released to transition between each. For example, to transition from n=4 to n=2, a photon containing 7.6eV must be emitted, whereas to transition from n=4 to n=3, then from n=3 to n=2, a photon of 3.4 ev, then a photon of 4.2ev must be emitted. Thus, three different photons, quantified by three different energy amounts, are produced

**Excerpt 2**

| | | |
|---|---|---|
| ① n=4 → n=2 ($e_i$) | eV → J = $3.4 \times 1.6 \times 10^{-19}$ | ∴ The wavelength of |
| Energy change (J) = $7.6 \times 1.6 \times 10^{-19}$ | $= 5.44 \times 10^{-19}$ | the photon emitted ~~from n=3 → n=2~~ |
| $= 1.216 \times 10^{-18}$ J | Wavelength: $\lambda = \frac{hc}{E}$ | will be less than that |
| wavelength: $\lambda = \frac{hc}{E}$ | $\lambda = \frac{(6.626\times10^{-34})(3\times10^{8})}{5.44\times10^{-19}}$ | of n=4 → n=3 and more than n=4 → n=3. |
| $\lambda = \frac{6.626\times10^{-34} \times 3\times10^{8}}{1.216\times10^{-18}}$ | $\lambda = 3.654044118 \times 10^{-7}$ m | ∴ Maximum wavelength |
| $\lambda = 1.634703947 \times 10^{-7}$ m | ③ n=3 → n=2 | $= 3.65 \times 10^{-7}$ m (3.s.f.) |
| ② n=4 → n=3 | Δ Energy = $\lvert E_f - E_i \rvert = \lvert 1.8 - 6 \rvert$ | (because $3.65\times10^{-7}$ m > $1.63\times10^{-7}$ m) |
| Δ Energy = $\lvert E_f - E_i \rvert$ = $\lvert 6 - 9.4 \rvert$ = 3.4 eV | = 4.2eV<br>3.4eV < 4.2eV < 7.6eV | |

Maximum wavelength = $3.65 \times 10^{-7}$ m

Question 9 from Paper 2 of the Physics General and Physics AS examinations

This question required students to describe the ladder in the barn paradox as proposed by special relativity and explain how the paradox is resolved by frames of reference.

Effective student responses:

- described the general scenario for the ladder in the barn paradox
- identified the observed contraction of the barn from the ladder's frame of reference
- identified the observed contraction of the ladder from the barn's frame of reference
- recognised the resolution of the paradox using simultaneity
- explained that what is viewed as simultaneous in a frame of reference is not necessarily simultaneous in another frame of reference.

This excerpt has been included to demonstrate an effective response to the question including the identification of key aspects of the paradox from both frames of reference and the comparative lengths for both the ladder and the barn observed within those frames.

The barn paradox is where there is a ladder (moving towards a barn at relativistic speeds) that is the exact same length of the barn. This barn has a door on either end which shut when a signal (placed in the centre of the barn) simultaneously goes off and reaches the barn doors. As the ladder is the exact same length as the barn it should not be able to fit when the doors are shut. However, in the barn's frame of reference, as the ladder is moving so fast, its length contracts, allowing it to fit. But in the ladder's frame of reference, the barn is moving towards it, causing the barn to contract and therefore the ladder can't fit. However, due to simultanaety, in the ladders frame of reference it can fit as, when the signal is sent, the barn is moving towards the ladder and therefore the back door is moving towards the signal, causing it to reach the backdoor first and shut first (then open). As this occurs before the front door shuts, it allows for the ladder to fit through while the front door is still open and leave as back door opens. In the barns frame of reference, the signal reaches both doors at the same time, meaning it doesn't make sense for the ladder to fit. However, this is resolved as both frames of reference are correct. For the barn's frame of reference, the ladder's length contracts allowing it to fit through. For the ladder's frame of reference, the doors close at different times allowing for the ladder to fit through.

Question 24 from Paper 1 of the Physics AS examination

This question required students to calculate the energy released from an isotope undergoing $\beta^-$ decay.

Effective student responses:

- calculated the mass of the products in atomic mass units
- calculated the mass defect
- converted the mass to kg
- calculated the energy released.

This excerpt has been included:

to demonstrate a typical student response that demonstrates determination of the mass defect in the required units to determine the energy released.

$\Delta E = \Delta mc^2$

$= (4.88557 \times 10^{-28}) \times (3 \times 10^8)^2$

$= 4.397 \times 10^{-11}$ J

$\Delta m = 32.26693 - (31.97207 + 5.4875804 22 \times 10^{-4})$

$= 0.29431$ amu

$= 4.88557 \times 10^{-28}$ kg

$m(e^-) = 9.1093835 \times 10^{-31}$ kg

$= 5.4875804 22 \times 10^{-4}$ amu

Energy released = $4.397 \times 10^{-11}$ J

Question 6c) from Paper 2 of the Physics AS examination

This question required students to use data provided in a graph to calculate the total work done on an object when it was pushed over two different materials.

Effective student responses:

- recognised that the work done on the coin was represented in the graph by the area under the curve
- used appropriate strategies to determine the area under the curve for each material
- calculated the total work done on the coin by calculating the sum of both areas.

These excerpts have been included to demonstrate typical student responses that use the area under the graph to determine the total work done.

**Excerpt 1**

$W = Fs = \text{Area}$

$W_1 = \frac{1}{2}(0.2)(400)$ $\quad$ $W_2 = (0.6 - 0.2)(400)$

$= 40\text{J}$ $\quad$ $= 160\text{J}$

$W_T = 40\text{J} + 160\text{J}$

$= 200\text{J}$ of work done

Work done = 200 J

**Excerpt 2**

$W = Fs$

Material 1

Area under curve.

$W = \frac{1}{2} \times 0.2 \times 400$

$= 40\,J$

Material 2

$W = Fs$

$= 400 \times 0.4$

$= 160\,J$

$s = 0.6 - 0.2$

$= 0.4\,m$

Total work $= M_1 + M_2$

$= 160 + 40$

$= 200\,J$

Work done = 200 J