Physics General Senior Syllabus 2019 v1.2

Subject report 2020

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Contents

Introduction 1

Background 2

Purpose 2

Audience and use 2

Report preparation 2

Subject data summary 3

Subject enrolments 3

Units 1 and 2 results 3

Units 3 and 4 internal assessment results 3

Total results for internal assessment 3

IA1 results 4

IA2 results 5

IA3 results 6

Units 3 and 4 external assessment results 7

Final standards allocation 7

Grade boundaries 7

Internal assessment 8

Endorsement 8

Confirmation 8

Internal assessment 1 (IA1) 9

Data test (10%) 9

Assessment design 9

Assessment decisions 11

Internal assessment 2 (IA2) 12

Student experiment (20%) 12

Assessment design 12

Assessment decisions 13

Internal assessment 3 (IA3) 18

Research investigation (20%) 18

Assessment design 18

Assessment decisions 20

External assessment 22

External assessment: Examination (50%) 22

Assessment design 22

Assessment decisions 23

Senior External Examination 31

Introduction

The first summative year for the new Queensland Certificate of Education (QCE) system was unexpectedly challenging. The demands of delivering new assessment requirements and processes were amplified by disruptions to senior schooling arising from the COVID-19 pandemic. This meant the new system was forced to adapt before it had been introduced — the number of summative internal assessments was reduced from three to two in all General subjects. Schools and the QCAA worked together to implement the new assessment processes and the 2020 Year 12 cohort received accurate and reliable subject results.

Queensland's innovative new senior assessment system combines the flexibility and authenticity of school-based assessment, developed and marked by classroom teachers, with the rigour and consistency of external assessment set and marked by QCAA-trained assessment writers and markers. The system does not privilege one form of assessment over another, and both teachers and QCAA assessors share the role of making high-stakes judgments about the achievement of students. Our commitment to rigorous external quality assurance guarantees the reliability of both internal and external assessment outcomes.

Using evidence of student learning to make judgments on student achievement is just one purpose of assessment. In a sophisticated assessment system, it is also used by teachers to inform pedagogy and by students to monitor and reflect on their progress.

This post-cycle report on the summative assessment program is not simply being produced as a matter of record. It is intended that it will play an active role in future assessment cycles by providing observations and findings in a way that is meaningful and helpful to support the teaching and learning process, provide future students with guidance to support their preparations for summative assessment, and promote transparency and accountability in the broader education community. Reflection and research are necessary for the new system to achieve stability and to continue to evolve. The annual subject report is a key medium for making it accessible to schools and others.

Background

Purpose

The annual subject report is an analysis of the previous year’s full summative assessment cycle. This includes endorsement of summative internal assessment instruments, confirmation of internal assessment marks and external assessment.

The report provides an overview of the key outcomes of one full teaching, learning and assessment cycle for each subject, including:

- information about the application of the syllabus objectives through the design and marking of internal and external assessments
- information about the patterns of student achievement in each subject for the assessment cycle.

It also provides advice to schools to promote continuous improvement, including:

- identification of effective practices in the design and marking of valid, accessible and reliable assessments
- identification of areas for improvement and recommendations to enhance the design and marking of valid, accessible and reliable assessment instruments
- provision of tangible examples of best practice where relevant, possible and appropriate.

Audience and use

This report should be read by school leaders, subject leaders and teachers to inform teaching and learning and assessment preparation. The report is to be used by schools and teachers to assist in assessment design practice, in making assessment decisions and in preparing students for external assessment.

The report is publicly available to promote transparency and accountability. Students, parents, community members and other education stakeholders can learn about the assessment practices and outcomes for General subjects (including alternative sequences and Senior External Examination subjects, where relevant) and General (Extension) subjects.

Report preparation

The report includes analyses of data and other information from the processes of endorsement, confirmation and external assessment, and advice from the chief confirmer, chief endorser and chief marker, developed in consultation with and support from QCAA subject matter experts.

Subject data summary

Subject enrolments

Number of schools offering the subject: 392.

Completion of units	Unit 1	Unit 2	Units 3 and 4*
Number of students completed	5763	5833	5817

*Units 3 and 4 figure includes students who were not rated.

Units 1 and 2 results

Number of students	Satisfactory	Unsatisfactory	Not rated
Unit 1	5613	141	9
Unit 2	5497	327	9

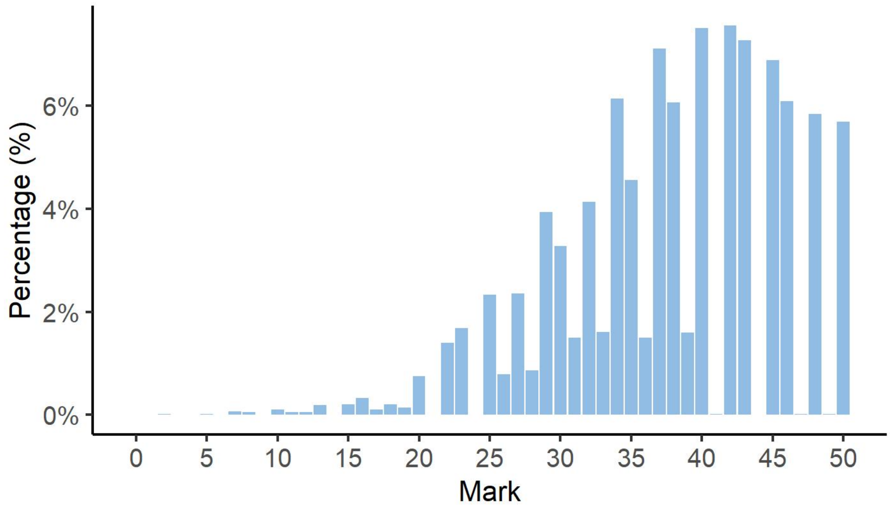
Units 3 and 4 internal assessment results

2020 COVID-19 adjustments

To support Queensland schools, teachers and students to manage learning and assessment during the evolving COVID-19 pandemic in 2020, the QCAA Board approved the removal of one internal assessment for students completing Units 3 and 4 in General and Applied subjects.

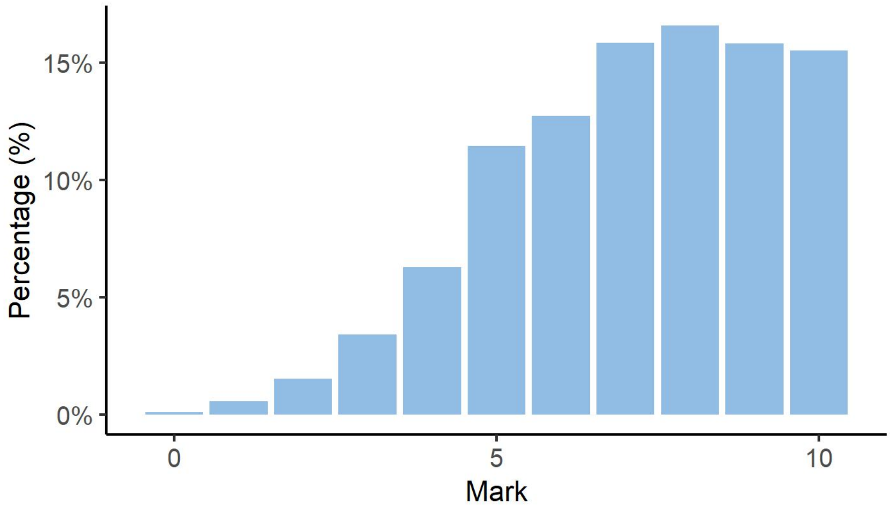
In General subjects, students completed two internal assessments and an external assessment. Schools made decisions based on QCAA advice and their school context. Therefore, across the state some instruments were completed by most schools, some completed by fewer schools and others completed by few or no schools. In the case of the latter, the data and information for these instruments has not been included.

Total results for internal assessment

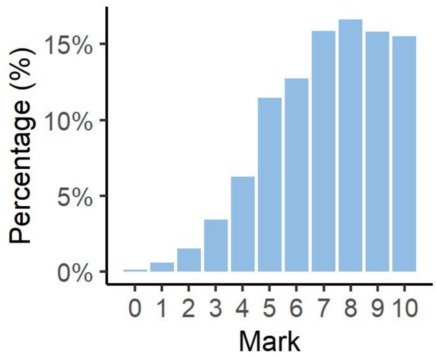


IA1 results

IA1 total

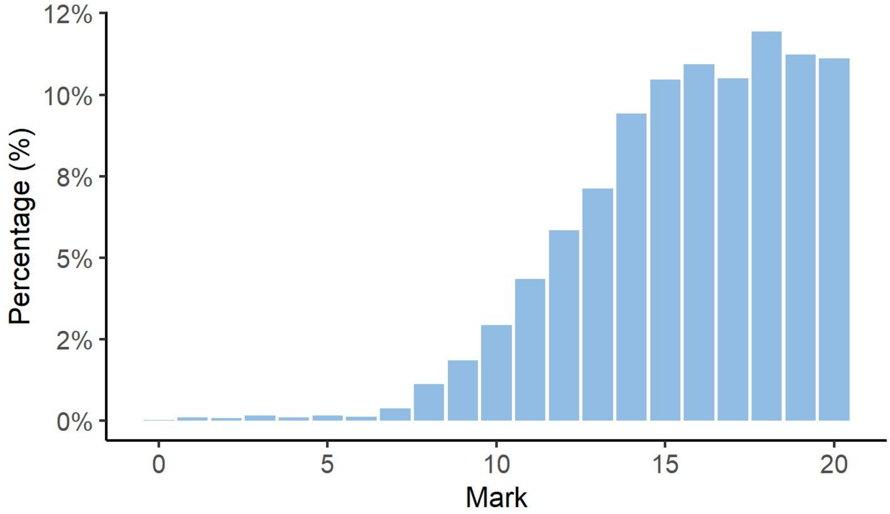


IA1 Criterion 1

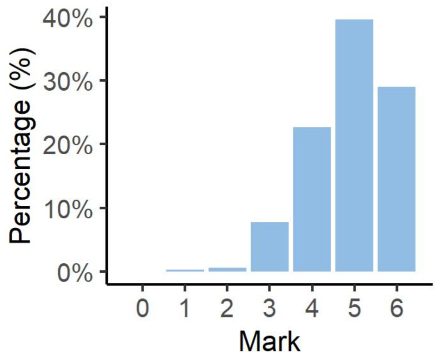


IA2 results

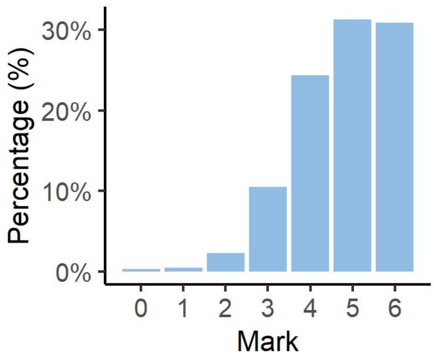
IA2 total



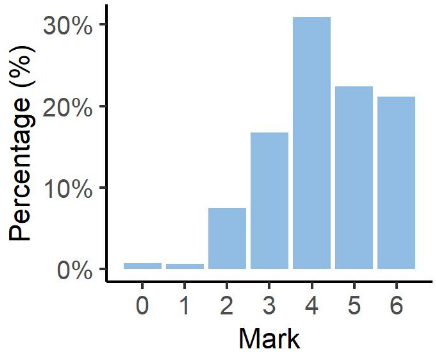
IA2 Criterion 1



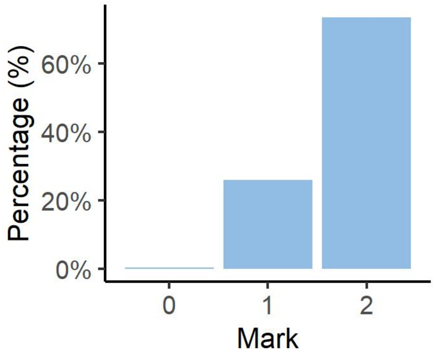
IA2 Criterion 2



IA2 Criterion 3

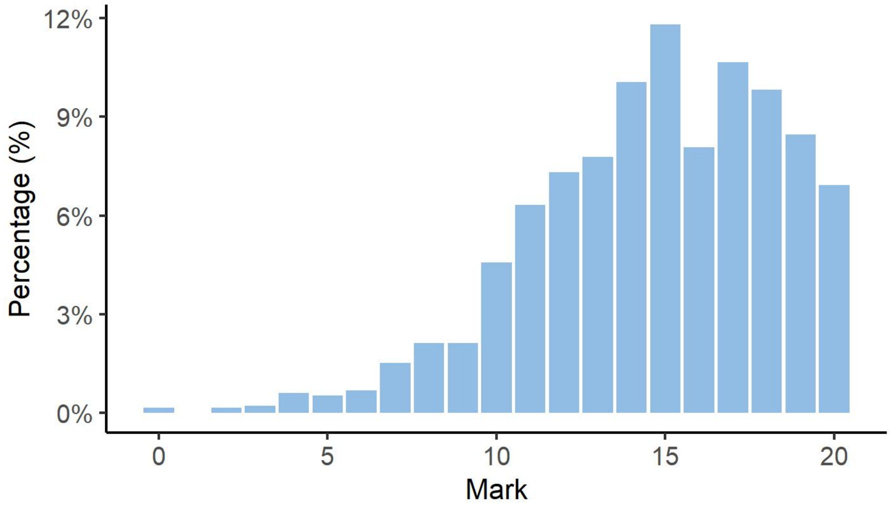


IA2 Criterion 4

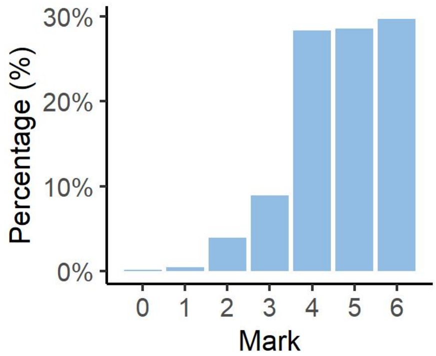


IA3 results

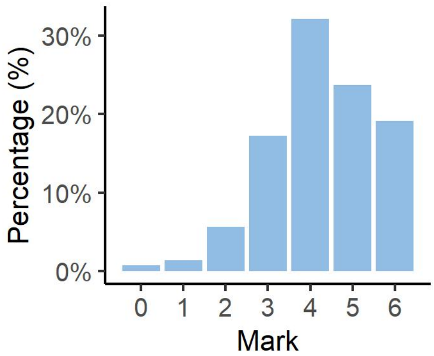
IA3 total



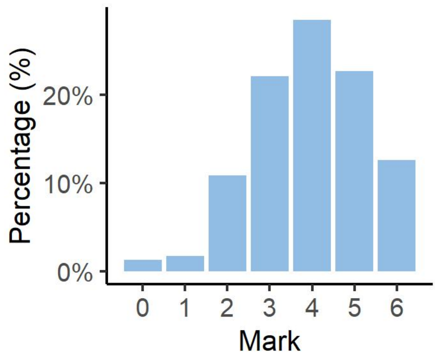
IA3 Criterion 1



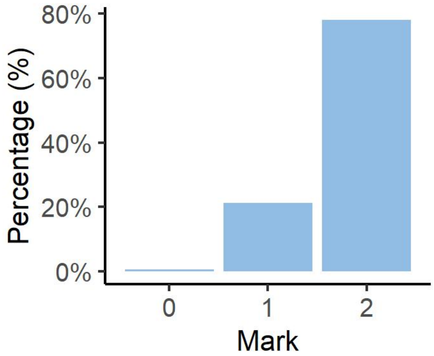
IA3 Criterion 2



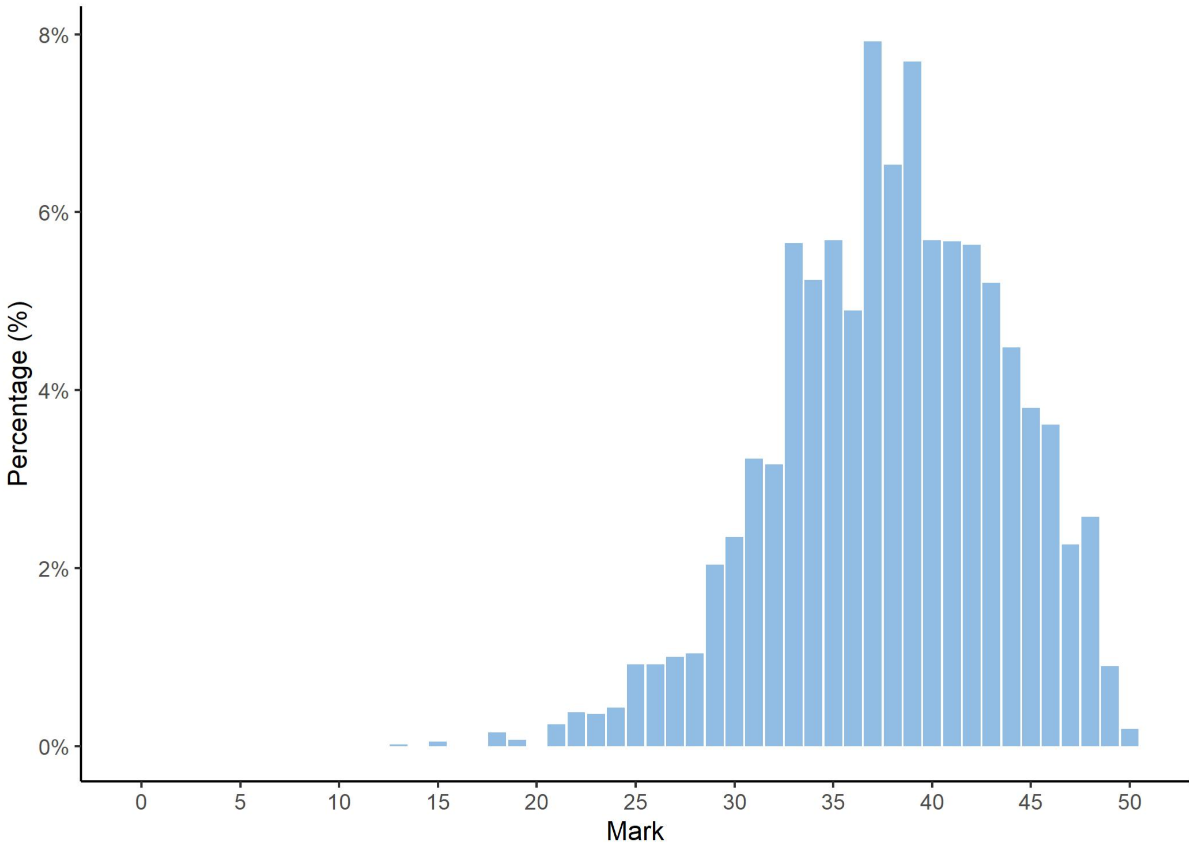
IA3 Criterion 3



IA3 Criterion 4



External assessment results



Final standards allocation

The number of students awarded each standard across the state are as follows.

Standard	A	B	C	D	E
Number of students	2059	2001	1671	48	1

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	100–82	81–70	69–44	43–21	20–0

Internal assessment

The following information and advice pertain 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 sections identifies the reasons why IA instruments were not endorsed at Application 1, by the priority for assessments. An IA may have been identified more than once for a priority for assessment, e.g. it may have demonstrated a misalignment to both subject matter and to the assessment objective. Refer to the quality assurance tools for detailed information about the assessment practices for each assessment instrument.

Total number of items endorsed in Application 1

Number of items submitted each event	IA1	IA2	IA3
Total number of instruments	393	393	393
Percentage endorsed in Application 1	41	86	74

Confirmation

Confirmation is the quality assurance process based on the attribute of reliability. Teachers make judgments about the evidence in students' responses using the instrument-specific marking guide (ISMG) to indicate the alignment of students' work with performance-level descriptors and determine a mark for each criterion. These are provisional criterion marks. The QCAA makes the final decision about student results through the confirmation processes. Data presented in the assessment decisions section identifies the level of agreement between provisional and final results.

Number of samples reviewed at initial, supplementary and extraordinary review

IA	Number of schools	Number of samples requested	Supplementary samples requested	Extraordinary review	School review	Percentage agreement with provisional
1	391	1943	0	0	1	99.91
2	270	1390	257	12	10	98.47
3	124	552	52	14	8	97.49

Internal assessment 1 (IA1)

Data test (10%)

The IA1 data test requires students to apply a range of cognitions to multiple provided items. Students respond to items using qualitative and/or quantitative data derived from practicals, activities or case studies from Unit 3. The task requires students to identify unknown scientific quantities or features; identify trends, patterns, relationships, limitations or uncertainty in datasets; and draw conclusions based on the analysis of data.

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 practices

Validity priority	Number of times priority was identified in decisions*
Alignment	153
Authentication	1
Authenticity	21
Item construction	36
Scope and scale	33

*Total number of submissions: 393. Each priority might contain up to four assessment practices.

Effective practices

Validity priorities were effectively demonstrated in assessment instruments that featured:

- a variety of datasets clearly derived from Unit 3 subject matter, e.g. mandatory or suggested practicals
- authentic datasets and questions clearly based on the teaching and learning activities students experienced in Unit 3, e.g. results from an experiment to measure the horizontal distance travelled by an object projected at various angles from the horizontal
- items with clear alignment to the objectives assessed by using the cognitive verbs listed in the mark allocation table in the syllabus, e.g. objective 2 items that use the following verbs: calculate, identify and recognise
- items using only one cognition.

Practices to strengthen

It is recommended that assessment instruments:

- include unseen datasets appropriately different from QCAA sample assessments
- include a sequence of items appropriately different from QCAA sample assessments

- include a balance of items across the apply, analyse and interpret objectives as per the syllabus instrument mark allocation table
- avoid assessing objective 1 ‘describe and explain’; valid data test items only assess objectives 2, 3 and 4
- include only items that require students to use the given datasets
- include only item types appropriate to a data test, e.g. avoid multiple-choice items
- avoid unnecessary repetition of cognitions, subject matter or calculations
- use datasets with diagrams and/or graphs rather than asking students to sketch or draw these in their responses.

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 practices

Accessibility priority	Number of times priority was identified in decisions*
Transparency	50
Language	87
Layout	36
Bias avoidance	44

*Total number of submissions: 393. Each priority might contain up to four assessment practices.

Effective practices

Accessibility priorities were effectively demonstrated in assessment instruments that featured:

- clear links between the items and the data required to answer the question, e.g. see Figure 1 in Dataset 1
- minimal distractors, i.e. brief and succinct instructions that avoided unnecessary detail or complexity
- a response length that matched the length of the expected response
- consistent layout and language with clearly legible datasets, including legends, labelled axes, correct units and figure labels.

Practices to strengthen

It is recommended that assessment instruments:

- use language consistently between datasets and questions, e.g. referring to all datasets as figures rather than alternating between terms such as figure, table, diagram, graph
- are formatted using the page break tool in the endorsement application to ensure datasets, figure labels and items are not separated across pages. Teachers should also use the print preview function to ensure the layout of the task is appropriate
- are checked before students undertake the assessment to ensure that datasets allow students to make the intended calculations.

Assessment decisions

Reliability

Reliability is a judgment about the measurements of assessment. It refers to the extent to which the results of assessments are consistent, replicable and free from error.

Agreement trends between provisional and final results

Criterion number	Criterion name	Percentage agreement with provisional	Percentage less than provisional	Percentage greater than provisional
1	Data test	99.91	0.07	0.02

Effective practices

Accuracy and consistency of the application of the ISMG for this IA was most effective when:

- school-developed marking schemes clearly matched each mark to a valued feature of the expected response
- schools updated the original marking scheme submitted at endorsement to indicate how unexpected responses were marked.

Samples of effective practices

There are no student response excerpts because either the student/s did not provide permission or there were third-party copyright issues in the response/s.

Practices to strengthen

To further ensure accuracy and consistency of the application of the ISMG in this IA, it is recommended that:

- schools implement internal quality assurance processes (e.g. cross-marking) to ensure intra-marker and inter-marker reliability.

Internal assessment 2 (IA2)

Student experiment (20%)

The IA2 student experiment requires students to modify (i.e. refine, extend or redirect) an experiment to address their own hypothesis or question related to Unit 3. Students may use a practical performed in class as the basis for their methodology. They develop a research question, collect and process primary data, analyse and interpret evidence, and evaluate the reliability and validity of their experimental process.

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 practices

Validity priority	Number of times priority was identified in decisions*
Alignment	33
Authentication	9
Authenticity	0
Item construction	11
Scope and scale	2

*Total number of submissions: 393. Each priority might contain up to four assessment practices.

Effective practices

Validity priorities were effectively demonstrated in assessment instruments that featured:

- mandatory or suggested practicals from Unit 3 as experiments for students to use as the basis for their methodology and research question
- an opportunity for students to choose from a range of mandatory and suggested practicals from the syllabus
- clear alignment of cognitions and language with the syllabus and the assessment objectives
- an indication of how students can work collaboratively and how the school will manage authentication of student work in these situations, e.g. the teacher will compare the responses of students who have worked together in groups
- clear scaffolding that modelled processes and directed students to address all components of the task without leading students to a pre-determined response
- checkpoints to support students to develop a methodology that enabled the collection of sufficient, relevant data
- checkpoints to monitor student progress through the task, e.g. select modifications, complete risk assessment, collect and analyse data, submit draft, submit final response.

Practices to strengthen

It is recommended that assessment instruments:

- include only experiments clearly related to Unit 3 subject matter (i.e. General syllabus — gravity and motion or electromagnetism; Alternative Sequence — heating processes, waves or electrical circuits) for students to modify
- include all the task specifications in the task description
- include appropriate information in the scaffolding section, e.g. timeline, checkpoints, prompts about the requirements for the response.

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 practices

Accessibility priority	Number of times priority was identified in decisions*
Transparency	3
Language	12
Layout	3
Bias avoidance	1

*Total number of submissions: 393. Each priority might contain up to four assessment practices.

Effective practices

Accessibility priorities were effectively demonstrated in assessment instruments that featured:

- clear instructions aligned to the specifications within the syllabus, the assessment objectives and the ISMG
- communication avoiding jargon, specialist and colloquial language.

Practices to strengthen

It is recommended that assessment instruments:

- communicate task elements using clear, succinct language with accurate spelling, grammar and textual features
- maintain consistent formatting, layout and visual design across the instrument to minimise distractors.

Assessment decisions

Reliability

Reliability is a judgment about the measurements of assessment. It refers to the extent to which the results of assessments are consistent, replicable and free from error.

Agreement trends between provisional and final results

Criterion number	Criterion name	Percentage agreement with provisional	Percentage less than provisional	Percentage greater than provisional
1	Research and planning	97.47	2.33	0.2
2	Analysis of evidence	97.94	1.4	0.66
3	Interpretation and evaluation	98.67	0.95	0.38
4	Communication	99.78	0.04	0.18

Effective practices

Accuracy and consistency of the application of the ISMG for this IA was most effective when:

- in the Analysis of evidence criterion
  - *thorough* identification of trends, patterns or relationships was demonstrated by data-processing techniques such as linearising data (where appropriate) to test if a relationship was consistent with theoretical models
  - the following analysis techniques were used to demonstrate *thorough and appropriate* identification of uncertainty and limitations of evidence
    - absolute and percentage uncertainty
    - error bars
    - maximum–minimum gradient lines on graphs
- in the Interpretation and evaluation criterion
  - discussion of the reliability and validity of the experimental process was *justified* by referring to the uncertainty and limitations identified in the analysis of the evidence
  - conclusions were *justified* by interpreting data, with respect to the research question, to determine whether the evidence was in line with accepted theory.

Samples of effective practices

The following are excerpts from responses that illustrate the characteristics for the criteria at the performance levels indicated. The samples may provide evidence of more than one criterion. The characteristics highlighted may not be the only time the characteristics have occurred throughout the responses.

Research and planning (5–6 marks) **A specific and relevant research question** The response explicitly states the relationship in question and connects the relationship to the original experiment.	1.0 Research Question What is the relationship between the length of a current carrying conductor and the force experienced in a constant external magnetic field, when the magnitude of current and angle of the conductor to the field is constant?

Research and planning (5–6 marks) **A considered rationale for the experiment** The response carefully communicates the purpose and reasons for the experiment.	In the original experiment, the magnitude of the current in a conductor was varied and the force experience in a constant external magnetic field was measured, assuming that the length of the wire and the angle of the conductor to the field was constant. Given Equation 1, theoretically when current was graphed against force there should have be a directly proportional relationship. Illustrated in Appendix 1, the data supported this relationship with an R^2 value of 0.9904, indicating that there was a very strong directly proportional relationship. Given the assumption that that conductor was perpendicular to the field ($\theta = 90°$), the external field strength was calculated using Equation 2. $\frac{dF}{dI} = BLsin\theta$ ---Eq. 2 $B_1 = 0.154T \pm 11.1\% \ (3SF)$ Due to the high uncertainty of 11.1%, it was concluded that the results were unreliable. Additionally, the validity of the results was unknown since an accurate measurement of the field strength was not recorded meaning that the error could not be calculated. Subsequently, it was identified that an alternative method of calculating the external field strength could be formulated by changing the independent variable. If the derived field strengths were equal, the known mathematical law (Equation 1) would be experimentally verified.
Research and planning (5–6 marks) **Justified modifications to the methodology** The response gives sound reasons for how the modifications to the methodology will refine the original experiment.	*3.2b Refinements* 1. A digital multimeter was used to measure the current $\pm 0.01A$, replacing the analog ammeter $\pm$ 0.5A to reduce the uncertainty (controlled variable). 2. The strength of the magnetic field was increased by placing two rare earth magnets on either side of channel to reduce the significance of the uncertainty (controlled variable). 3. The width of the channel size was increased to allow the copper coils to be placed within the magnetic field (controlled variable). 4. The current in the circuit was increased to $6.0 \pm 0.05A$ by increasing the voltage to 6VC DC. This reduced the significance of the associated instrumental uncertainty (controlled variable). 5. Lines were drawn down the center of the base and sides of the aluminum to guide the correct alignment of the coils with the dimeter of the external field. This established greater control of the length of wire in the field and the angle of the conductor to the field (controlled variables). 6. The number of trials was increased from 2 to 5, to reduce the significance of random error (controlled variable).

Analysis of evidence (5–6 marks) Thorough identification of relevant trends, patterns relationships

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

Figure 5 shows the trend with its max and min trend-lines. The coefficent of determination, R^2, was found to be 0.946, which is reflected by the fairly low deviation of each point and that the trend-line falls within the error bars.

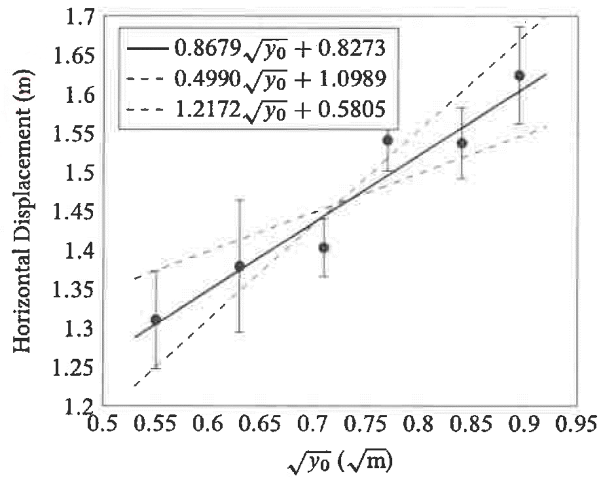


Figure 5: $\sqrt{y_0}$ aginst S_x with max-min trend-lines

Figure 5 demonstrates that a positive linear correlation between the data, and is consistent with the expected relationship between height and range.

Analysis of evidence (5–6 marks) Thorough and appropriate identification of the uncertainty and limitations of evidence

The uncertainty of the evidence has been quantified so that a decision can be made about the application of the evidence to the research question.

Using Excel, the trend-line that best fits the data is given by

$$S_x = 0.8679\sqrt{y_0} + 0.8273$$

with a minimum trend-line of

$$S_x = 0.499\sqrt{y_0} + 1.0989$$

and a maximum trend-line of

$$S_x = 1.2172\sqrt{y_0} + 0.5805$$

The uncertainty of the gradient is

$$\text{unc} = \pm\frac{1.2172 - 0.499}{2} = \pm 0.3591$$

and the percentage uncertainty of the gradient is then

$$\text{unc} = \pm\frac{0.3591}{0.8679} \times 100\% = \pm 41.38\%$$

Practices to strengthen

To further ensure accuracy and consistency of the application of the ISMG in this IA, it is recommended that:

- in the Research and planning criterion
  - a *considered* rationale should clearly establish a logical basis for the experiment, with links to Unit 3 subject matter
  - *justified* modifications to the methodology should ensure that the experiment collects sufficient data to draw valid conclusions, e.g. at least five data points to establish a trend and three trials to establish uncertainty.

Additional advice

- Experimental methodologies should be based on experiments that consider only one dependent variable (e.g. mandatory or suggested practicals from the syllabus) rather than complicated experiments that consider more than one dependent variable or involve complex systems in which external variables are difficult to control (e.g. motion of an aerofoil).
- In the best-fit process for using ISMGs, the higher of the two possible marks for a performance level should only be awarded when all the characteristics in a performance level have been demonstrated.

Internal assessment 3 (IA3)

Research investigation (20%)

The IA3 research investigation requires students to gather secondary evidence related to a research question in order to evaluate a claim about Unit 4. Students develop a research question, collect and analyse secondary data, interpret evidence to form a justified conclusion, discuss the quality of the evidence and extrapolate the findings of the research to the claim.

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 practices

Validity priority	Number of times priority was identified in decisions*
Alignment	41
Authentication	7
Authenticity	0
Item construction	27
Scope and scale	13

*Total number of submissions: 393. Each priority might contain up to four assessment practices.

Effective practices

Validity priorities were effectively demonstrated in assessment instruments that featured:

- simple and direct claims clearly aligned to Unit 4 subject matter, e.g. ‘Using electrons for microscopy means there is no limit to the resolution that can be achieved’
- sufficient claims for the size of the cohort, allowing students to develop unique responses to the task
- claims where multiple research questions could be generated, e.g. ‘Experimental work has been more important than theoretical work in establishing modern physics’
- checkpoints to monitor student progress through the task
- scaffolding that directed students to address all components of the task.

Practices to strengthen

It is recommended that assessment instruments:

- include all the task specifications in the task description
- contain claims clearly derived from Unit 4 subject matter, i.e. General syllabus — special relativity, quantum theory or the Standard Model; Alternative Sequence — electromagnetism or quantum theory
- include appropriate information in the scaffolding section, i.e. does not lead students towards a predetermined response by specifying the scientific concepts to investigate.

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 practices

Accessibility priority	Number of times priority was identified in decisions*
Transparency	17
Language	22
Layout	4
Bias avoidance	1

*Total number of submissions: 393. Each priority might contain up to four assessment practices.

Effective practices

Accessibility priorities were effectively demonstrated in assessment instruments that featured:

- claims written using clear, succinct language and featuring accurate spelling, grammar and textual features
- clear instructions aligning to the specifications within the syllabus, the assessment objectives and the ISMG
- communication that avoids jargon, specialist and/or colloquial language.

Practices to strengthen

It is recommended that assessment instruments:

- maintain consistent formatting, layout and visual design across the instrument.

Additional advice

- Before including a claim in the task, teachers should ensure that there is sufficient, relevant evidence available from sources.

Assessment decisions

Reliability

Reliability is a judgment about the measurements of assessment. It refers to the extent to which the results of assessments are consistent, replicable and free from error.

Agreement trends between provisional and final results

Criterion number	Criterion name	Percentage agreement with provisional	Percentage less than provisional	Percentage greater than provisional
1	Research and planning	96.71	2.83	0.46
2	Analysis and interpretation	98.55	1.23	0.23
3	Conclusion and evaluation	97.4	2.37	0.23
4	Communication	97.32	0	2.68

Effective practices

Accuracy and consistency of the application of the ISMG for this IA was most effective when:

- in the Analysis and interpretation criterion
  - identification of *sufficient and relevant* evidence drew on qualitative and quantitative data from scientifically credible sources, e.g. peer-reviewed research papers
  - *thorough and appropriate* identification of trends, patterns, relationships and limitations was based on evidence that was sufficient to answer the research question and was relevant to the claim.

Samples of effective practices

The following are excerpts from responses that illustrate the characteristics for the criteria at the performance levels indicated. The samples may provide evidence of more than one criterion. The characteristics highlighted may not be the only time the characteristics have occurred throughout the responses.

Research and planning (5–6 marks) **A considered rationale identifying clear development of the research question from the claim** The rationale shows evidence of careful, deliberate thought. The sequence of ideas involved in the development of the research question from the claim is easily seen.	Experiments have found that electrons have wave-like duality and, as a result, can be used in microscopes (Urone & Hinrichs, The Wave Nature of Matter, 2012). The wavelength of a particle depends on the momentum and energy; the higher the momentum and energy, the smaller the wavelength. The highest resolution that has been achieved using electron microscopes in 0.5 nm (Walding, 12.3 Wave–particle duality, 2019; Asmatulu & S.Khan, 2019). There will always be a limit to the resolution in optical systems, because diffraction, refraction and interference occurs in waves and particles with wave-like properties (Russell, 2002). Diffraction is the process of a wave encountering a slit or barrier and bending around the corners of the obstacle. A famous experiment that uses this principle is the double slit experiment to test light and particles for wave-like behaviour. Refraction is the bending of a wave as it passes from one median to another based on the velocity of the wave in that medium.

Research and planning (5–6 marks) **A relevant research question** The research question is clearly defined and developed from the claim. The response clearly states the variables to be investigated.	Research Question What wavelength of an excited electron would allow a resolution smaller than 0.5 nm in electron microscopy?

Analysis and interpretation (5–6 marks) **Justified scientific argument/s** The scientific argument uses a process of sound reasoning and draws upon valid and reliable evidence.	The concept of one photon ejecting one electron that is observed in the photoelectric effect is also demonstrated in plants (Walding, 2019). Chlorophyll molecules cannot absorb continuous amounts of light; they can only absorb a discrete package of light (a photon) at a time (Molnar, 2012). Under optimal conditions, for every photon that is absorbed and transferred by light-harvesting antennae, an electron is transported within the reaction centre of each photosystem (Marais, 2018). This occurs due to the energy from the photons that allows an electron to detach from the pigment. However, in comparison to Figure 2, where the electrons are bound by electrostatics, the electrons in photosynthesis are based on the chemical interactions that occur within the chloroplast (Marais, 2018).

Practices to strengthen

To further ensure accuracy and consistency of the application of the ISMG in this IA, it is recommended that:

- in the Research and planning criterion, a *considered* rationale should clearly
  - connect the research question to Unit 4 subject matter
  - demonstrate how the research question was developed from the claim
- in the Conclusion and evaluation criterion, conclusions should be
  - clearly *linked* to the research question
  - *justified* using the scientific arguments developed in the analysis.

Additional advice

- In the best-fit process for using ISMGs, the higher of the two possible marks for a performance level should only be awarded when all the characteristics in a performance level have been demonstrated.

External assessment

Summative external assessment: Examination (50%)

Assessment design

Assessment specifications and conditions

Description

This examination will include two papers. Each paper consists of a number of different types of possible items:

- multiple choice
- short response items requiring single-word, sentence or paragraph responses
- calculating using algorithms
- interpreting graphs, tables or diagrams
- responding to unseen data and/or stimulus.

Conditions

Paper 1

- Time: 90 minutes plus 10 minutes perusal.
- Other:
  - QCAA-approved graphics calculator permitted
  - seen Physics formula and data booklet provided.

Paper 2

- Time: 90 minutes plus 10 minutes perusal.
- Other:
  - QCAA-approved graphics calculator permitted
  - seen Physics formula and data booklet provided.

General syllabus

The assessment instrument consisted of two papers. Questions were derived from the context of Unit 3: Gravity and electromagnetism and Unit 4: Revolutions in modern physics. This assessment was used to determine student achievement in the following assessment objectives:

1. describe and explain gravity and motion, electromagnetism, special relativity, quantum theory and the Standard Model
2. apply understanding of gravity and motion, electromagnetism, special relativity, quantum theory and the Standard Model
3. analyse evidence about gravity and motion, electromagnetism, special relativity, quantum theory and the Standard Model to identify trends, patterns, relationships, limitations or uncertainty

4. interpret evidence about gravity and motion, electromagnetism, special relativity, quantum theory and the Standard Model to draw conclusions based on analysis.

Paper 1: Section 1 consisted of 20 multiple choice items (20 marks).

Paper 1: Section 2 consisted of 8 short response items (24 marks).

Paper 2 consisted of 9 short response items (37 marks).

Alternative sequence

The assessment instrument consisted of two papers. Questions were derived from the context of Unit 3: The transfer and use of energy and Unit 4: Electromagnetism and quantum theory. This assessment was used to determine student achievement in the following assessment objectives:

1. describe and explain heating processes, waves, electrical circuits, electromagnetism and quantum theory
2. apply understanding of heating processes, waves, electrical circuits, electromagnetism and quantum theory
3. analyse evidence about heating processes, waves, electrical circuits, electromagnetism and quantum theory to identify trends, patterns, relationships, limitations or uncertainty
4. interpret evidence about heating processes, waves, electrical circuits, electromagnetism and quantum theory to draw conclusions based on analysis.

Paper 1: Section 1 consisted of 20 multiple choice items (20 marks).

Paper 1: Section 2 consisted of 8 short response items (29 marks).

Paper 2 consisted of 9 short response items (40 marks).

Assessment decisions

Overall, students responded well to the following assessment aspects:

- understanding and application of Unit 3 subject matter
- application of understanding for items where ‘calculate’ was the cognitive verb.

Effective practices

The following samples were selected to illustrate highly effective student responses in some of the assessment objectives of the syllabus.

Multiple choice item response

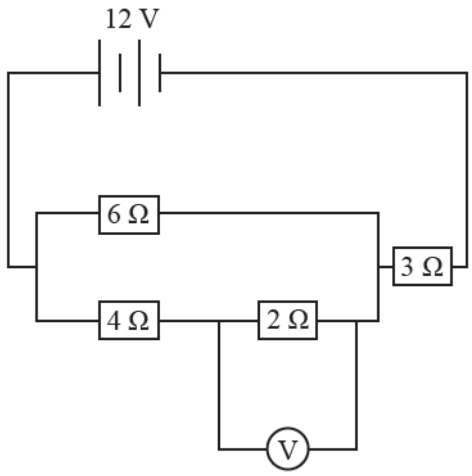
Assessment objective: Objective 2 — Apply understanding

Item: Alternative Sequence Paper 1, Question 6

This question required students to determine the voltage across a resistor in a circuit diagram.

QUESTION 6

What is the voltage measured by the voltmeter in the circuit diagram shown?



(A) 2 V

(B) 3 V

(C) 4 V

(D) 6 V

Option	Validity statements
A	Key
B	This option assumes that the voltage is shared between the resistors and ignores the 6 Ω resistor.
C	This option uses correct reasoning but misses the 3 Ω resistor.
D	This option is the voltage across each parallel branch.

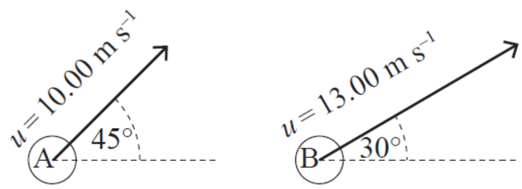
Assessment objective: Objective 2 — Apply understanding

Item: General syllabus Paper 1, Question 11

This question required students to apply their understanding of projectile motion.

QUESTION 11

The diagram shows object A and object B being projected at different velocities.



Which of the following statements is true?

(A) Object A has a shorter flight time than object B.

(B) Object A has a smaller maximum height than object B.

(C) Object A has a larger horizontal velocity than object B.

(D) Object A has a smaller horizontal displacement than object B.

Option	Validity statements
A	This option is incorrect because Object A has a flight time of 1.4 s, while Object B has a flight time of 1.3 s.
B	This option is incorrect because Object A reaches a maximum height of 2.6 m, while Object B has a maximum height of 2.2 m.
C	This option is incorrect because Object A has an initial horizontal velocity of 7.1 m s^{-1}, while Object B has an initial horizontal velocity of 11.3 m s^{-1}.
D	Key

Short response

Assessment objective: Objective 1 — Describe and explain

Item: General syllabus and Alternative Sequence Paper 2, Question 4

Student sample of an effective response

Effective student responses:

- described three relevant features of the photoelectric effect
- identified how two relevant features provide evidence of quantisation of photons.

Describe and explain (5 marks)	**QUESTION 4 (5 marks)** Describe how experiments on the photoelectric effect provide evidence of the quantised nature of photons. There are 3 main points or observations about the photoelectric effect that cannot be explained by classical physics were light is a wave and suggest light must be also quantised as a particle. The first observation was that the effect was instantaneous provided each photon had sufficient energy (above threshold frequency, f_0). This suggested that there was no build up of energy, but rather if one quanta had sufficient energy to release the photoelectron it collided and the electron was released. Another observation was that a threshold frequency existed, below which the effect did not happen regardless of the intensity. This meant that adding more photons would not cause more energy to be transformed, but rather each quanta had to have sufficient energy otherwise the collision would not liberate an electron. The way to increase energy per quanta is by increasing f or decreasing λ. Finally, it was observed that kinetic energy of electrons ejected was dependent only on the frequency of incident photons and not intensity. In other words, increasing intensity once the effect is happening will increase saturation current but not effect voltage through the circuit or stopping voltage. Again this was due to the energy per photon and meant photons had to be quantised.

This sample has been included to demonstrate a response that clearly identifies and describes relevant features of the photoelectric effect and how they provide evidence for the quantisation of photons.

Assessment objective: Objective 2 — Apply understanding

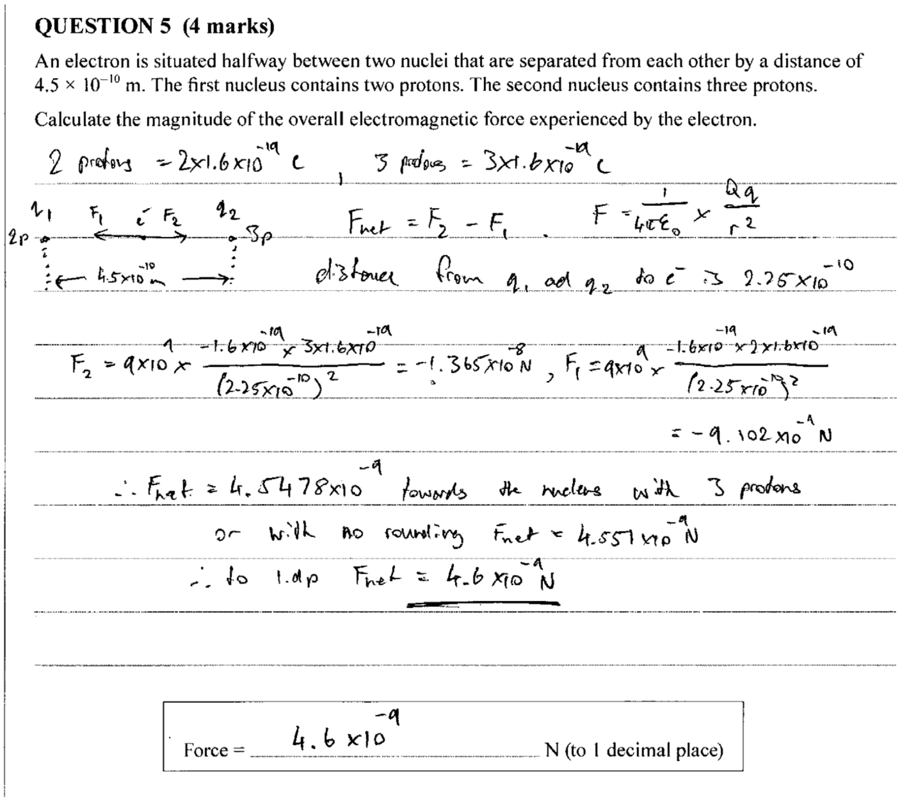
Item: General syllabus Paper 2, Question 5

Student sample of an effective response

Effective student responses:

- indicated an understanding of the physical scenario in relation to Coulomb’s law
- provided pertinent mathematical operations correctly performed
- determined the forces (or electric field strength) imposed by each nucleus on the electron
- determined the correct net force.

Apply understanding (4 marks)



QUESTION 5 (4 marks)

An electron is situated halfway between two nuclei that are separated from each other by a distance of 4.5×10^{-10} m. The first nucleus contains two protons. The second nucleus contains three protons.

Calculate the magnitude of the overall electromagnetic force experienced by the electron.

2 protons $= 2 \times 1.6 \times 10^{-19}$ C, 3 protons $= 3 \times 1.6 \times 10^{-19}$ C

q_1 F_1 e^- F_2 q_2 2p 3p 4.5×10^{-10} m

$F_{net} = F_2 - F_1$. $F = \frac{1}{4\pi\varepsilon_0} \times \frac{Qq}{r^2}$

distance from q_1 and q_2 to e^- is 2.25×10^{-10}

$F_2 = 9 \times 10^9 \times \frac{-1.6 \times 10^{-19} \times 3 \times 1.6 \times 10^{-19}}{(2.25 \times 10^{-10})^2} = -1.365 \times 10^{-8}$ N, $F_1 = 9 \times 10^9 \times \frac{-1.6 \times 10^{-19} \times 2 \times 1.6 \times 10^{-19}}{(2.25 \times 10^{-10})^2}$

$= -9.102 \times 10^{-9}$ N

$\therefore F_{net} = 4.5478 \times 10^{-9}$ towards the nucleus with 3 protons

or with no rounding $F_{net} = 4.551 \times 10^{-9}$ N

$\therefore$ to 1 dp $F_{net} = 4.6 \times 10^{-9}$ N

Force = 4.6×10^{-9} N (to 1 decimal place)

This sample has been included to

- demonstrate correct interpretation of the item
- show correct application of Coulomb's law to calculate the net forces imposed by each nucleus on the electron through vector analysis.

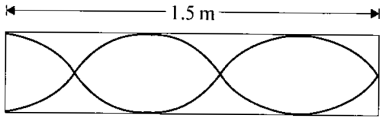
Assessment objective: Objective 2 — Apply understanding

Item: Alternative Sequence Paper 2, Question 2

Student sample of an effective response

Effective student responses:

- indicated an understanding of the physical scenario in relation to standing waves in closed pipes
- provided pertinent mathematical operations correctly performed
- arrived at a consequentially correct value.

<table>
<tr>
<td>Apply understanding (3 marks)</td>
<td>
QUESTION 2 (3 marks)
This diagram shows a pipe in which a standing wave is formed.


Calculate the wavelength of the 5th harmonic in the pipe.
$L = (2n-1)\frac{\lambda}{4}$
$\lambda = \frac{4L}{2n-1}$
$= \frac{4(1.5)}{2(3)-1}$
$= \frac{6}{5}$
$= 1.2$ m
Wavelength = 1.2 m (to 1 decimal place)
</td>
</tr>
</table>

This sample has been included to:

- demonstrate correct interpretation of the item
- show application of the formula for a closed pipe to calculate the correct wavelength.

Assessment objective: Objective 3 — Analyse evidence

Item: General syllabus Paper 2, Question 2a; Alternative Sequence Paper 2, Question 1a

Student sample of an effective response

Effective student responses:

- provided a correct value for the *y*-intercept
- provided a correct value for the gradient of the graph
- provided the equation.

Analyse evidence (3 marks)	a) Identify the mathematical relationship between E and $\frac{1}{r^2}$ *[3 marks]* Linear relationship ($y = mx + c$) $\therefore E = m \times \frac{1}{r^2} + C$ $m = \frac{rise}{run}$ (gradient) $m \approx \frac{2000 - 100}{0.0278 - 0.0013}$ $m \approx 71698.11$ $\therefore E = \frac{71698.11}{r^2} + C$ When extend line of best fit, y-int at (0,0) $\therefore C = 0$ $\therefore E = \frac{71698.11}{r^2}$

This sample has been included to:

- demonstrate calculation of the gradient
- show identification of the *y*-intercept when analysing linear data to identify a mathematical relationship between two variables.

Assessment objective: Objective 4 — Interpret evidence

Item: General syllabus Paper 1, Question 27; Alternative Sequence Paper 1, Question 28

Student sample of effective response

Effective student responses:

- provided pertinent mathematical operations correctly performed to determine the differences between the energy levels in the energy level diagram
- provided pertinent mathematical operations to convert eV to joules
- indicated wavelengths produced by Element A that are also included in the emission spectra
- provided an answer that indicates the possibility that Element A is one of the gases comprising the gas mixture.

Interpret evidence (4 marks)	Determine whether it is possible that Element A is one of the gases in the mixture. $E = hf$ $E_{1\to4} = 5.74 - 1.45$ $E = \frac{hc}{\lambda}$ $= 4.29 eV$ $\lambda = \frac{hc}{E}$ $= 6.864 \times 10^{-19}$ J $\lambda_{1\to4} = \frac{(6.626 \times 10^{-34})(3 \times 10^{8})}{6.864 \times 10^{-19}}$ $= 2.895 \times 10^{-7}$ $= 289$ nm x Does not appear on spectra. Too high energy $E_{1\to2} = 5.74 - 3.54$ $\lambda_{1\to2} = \frac{hc}{E} = \frac{(6.626 \times 10^{-34})(3 \times 10^{8})}{(3.52 \times 10^{-19})}$ $= 2.2 eV$ $= 5.65 \times 10^{-7}$ m $= 3.52 \times 10^{-19}$ J $= 565$ nm ∴ It is possible as the transition from n=1 and n=2 produces a ~~mest~~ photon with a wavelength of 565 nm, which appears on the emission spectra. $E_{1\to3} = 5.74 - 1.47$ $\lambda = \frac{hc}{E}$ $= 4.27 eV$ $= \frac{(6.626 \times 10^{-34})(3 \times 10^{8})}{(6.832 \times 10^{-19})}$ $= 6.832 \times 10^{-19}$ J $= 290$ nm x Not on spectra. Too high energy $E_{2\to3} = 3.54 - 1.47$ $\lambda = \frac{hc}{E}$ $= 2.07 eV$ $= 600$ nm $= 3.312 \times 10^{-19}$ J ∴ Further calculations show that a transition between the 2nd and 3rd energy level produces a photon with a wavelength ~~of~~ of 600 nm, which appears on the emission spectra. This is ~~further~~ further supposing evidence to show that Element A is in the mixture.

This sample has been included to demonstrate systematic calculation of emission spectrum wavelengths from an energy level diagram to come to a conclusion.

Practices to strengthen

It is recommended that when preparing students for external assessment, teachers consider:

- responses to items relating to objectives 3 and 4 that require analysis of linear-trending data or identification of distinguishing features of the graph (e.g. gradient, *x*-intercept, *y*-intercept) to support conclusions
- the cognitive verb and the number of marks for each item as a guide to determining the expected response, e.g. a 'determine' question aligning to objective 4 requires a conclusion based on consideration or calculations
- that responses should align to the stimulus provided in the item when explaining a scenario. This is done by describing the situation in more detail and/or revealing the relevant facts.

Senior External Examination

The following information relates to the Physics Senior External Examination 1 (SEE 1), a standalone examination offered to eligible Year 12 students and adult learners. For information about Senior External Examination 2 (SEE 2), this commentary should be read in conjunction with the external assessment section of the preceding comments for the General subject.

There were insufficient student enrolments in this subject to provide useful analytics.

Effective practices

Overall, candidates responded well to the following assessment aspects:

- determining unknown scientific quantities or features from data
- suggesting improvements or extensions to an experiment.

Practices to strengthen

It is recommended that when preparing candidates for the Senior External Examination 1 (SEE 1), consideration be given to:

- data test items requiring the analysis of data to draw conclusions
- the development of syllabus objectives as identified on pp. 6–7 of the syllabus. For example
  - planning and carrying out experimental and/or research activities to obtain evidence for the purpose of reaching a conclusion
  - using *mathematical processes* to identify trends, patterns, relationships, limitations and uncertainty in data
  - using data to evaluate the validity and reliability of evidence
  - using scientific language and representations to communicate ideas.