Engineering subject report

2021 cohort

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For all Queensland schools

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Introduction

Despite the challenges brought about by the COVID-19 pandemic, Queensland's education community can look back on 2021 with satisfaction at having implemented the first full assessment cycle in the new Queensland Certificate of Education (QCE) system. That meant delivering three internal assessments and one external assessment in each General subject.

This report analyses that cycle — from endorsing summative internal assessment instruments to confirming internal assessment marks, and designing and marking external assessment. It also gives readers information about:

- applying syllabus objectives in the design and marking of internal and external assessments
- patterns of student achievement.

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 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
- assist in assessment design practice
- assist in making assessment decisions
- help prepare 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 (AS) and Senior External Examination (SEE) subjects, where relevant) and General (Extension) subjects.

Report preparation

The report includes analyses of data and other information from endorsement, confirmation and external assessment processes. It also includes 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 completion

The following data includes students who completed the General subject.

Note: All data is correct as at 17 December 2021. Where percentages are provided, these are rounded to two decimal places and, therefore, may not add up to 100%.

Number of schools that offered the subject: 90.

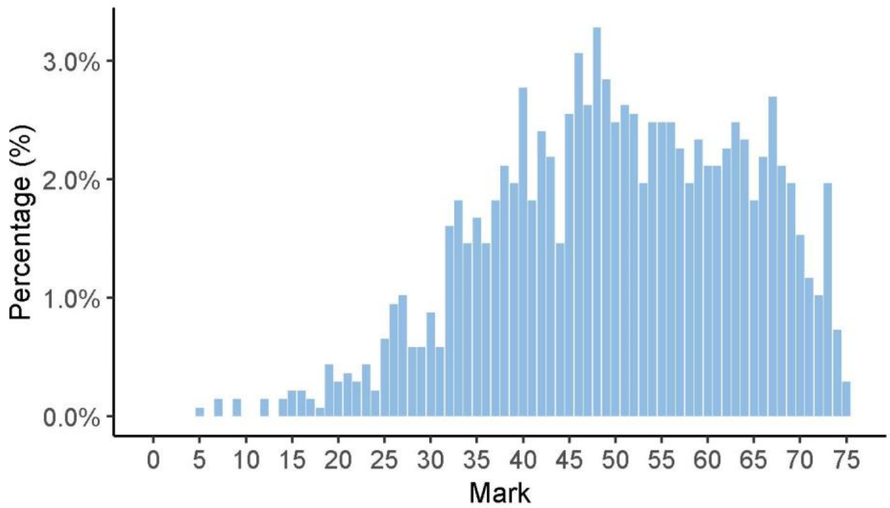
Completion of units	Unit 1	Unit 2	Units 3 and 4
Number of students completed	1671	1550	1359

Units 1 and 2 results

Number of students	Satisfactory	Unsatisfactory
Unit 1	1502	169
Unit 2	1433	117

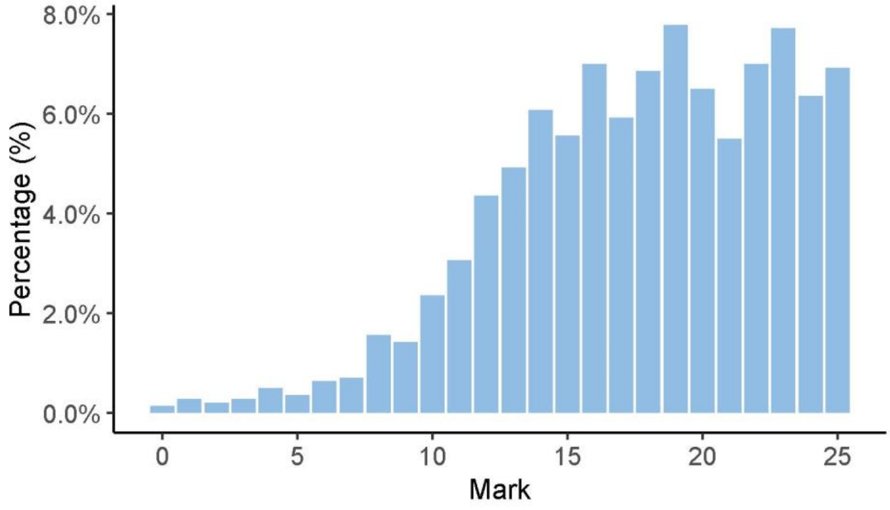
Units 3 and 4 internal assessment (IA) results

Total marks for IA

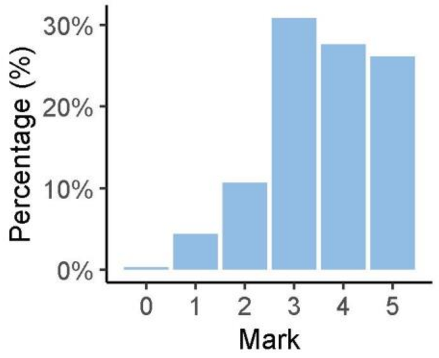


IA1 marks

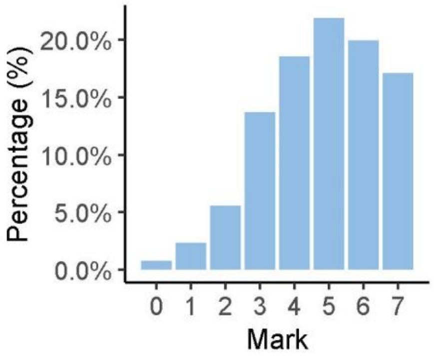
IA1 total



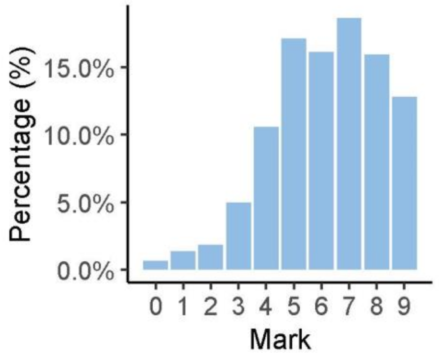
IA1 Criterion: Retrieving and comprehending



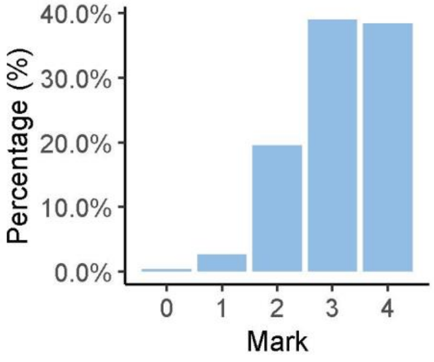
IA1 Criterion: Analysing



IA1 Criterion: Synthesising and evaluating

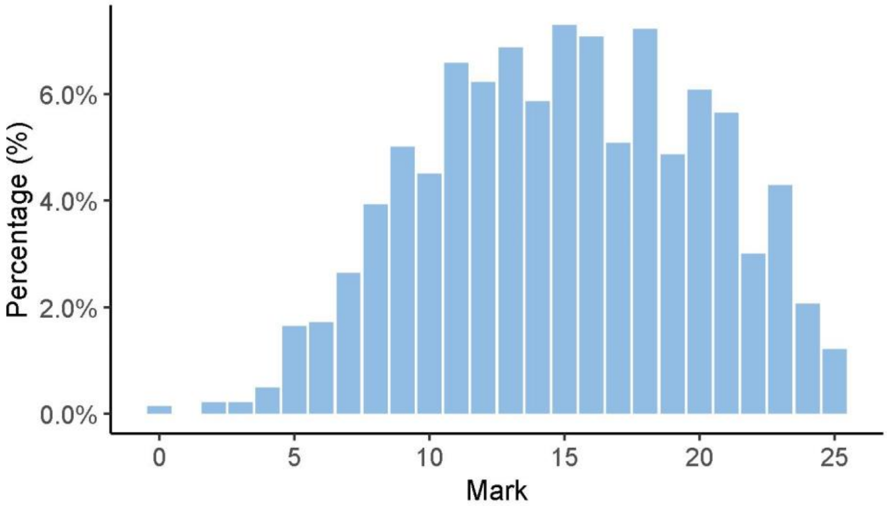


IA1 Criterion: Communicating

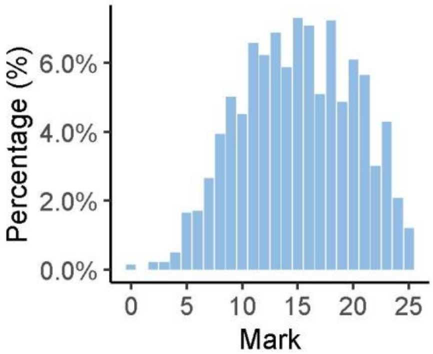


IA2 marks

IA2 total

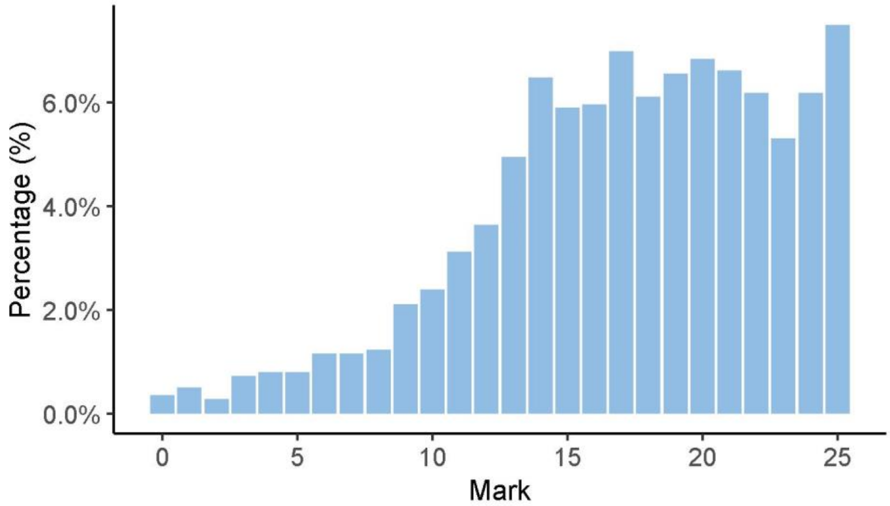


IA2 Criterion: Engineering knowledge and problem-solving

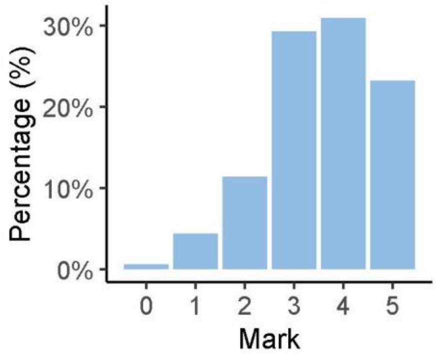


IA3 marks

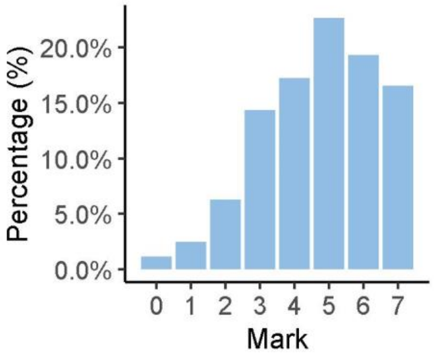
IA3 total



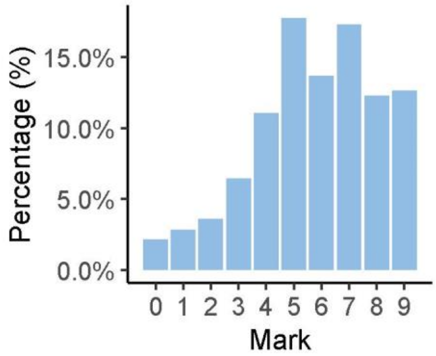
IA3 Criterion: Retrieving and comprehending



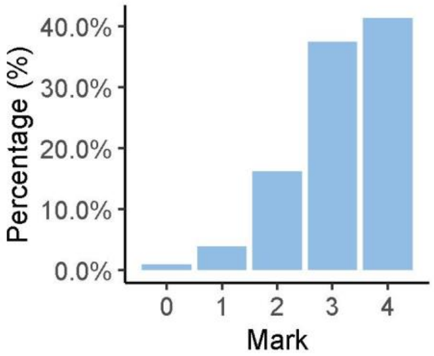
IA3 Criterion: Analysing



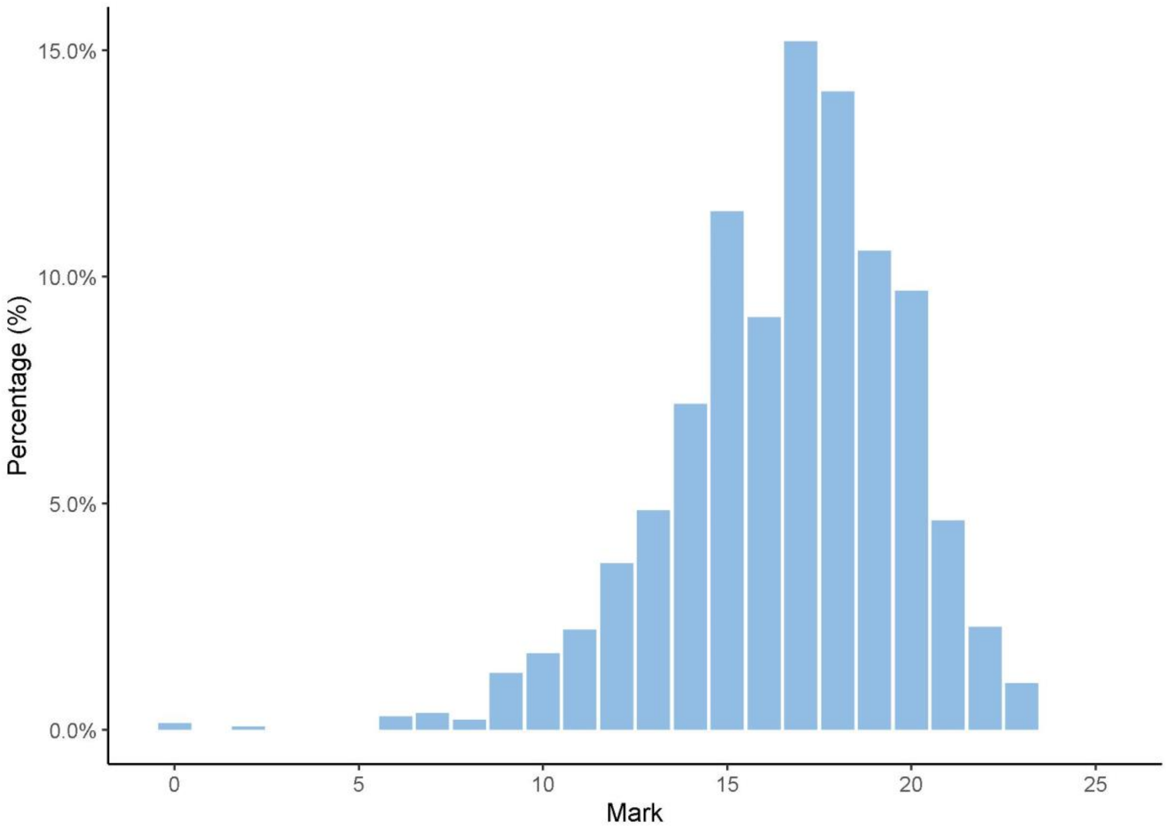
IA3 Criterion: Synthesising and evaluating



IA3 Criterion: Communicating

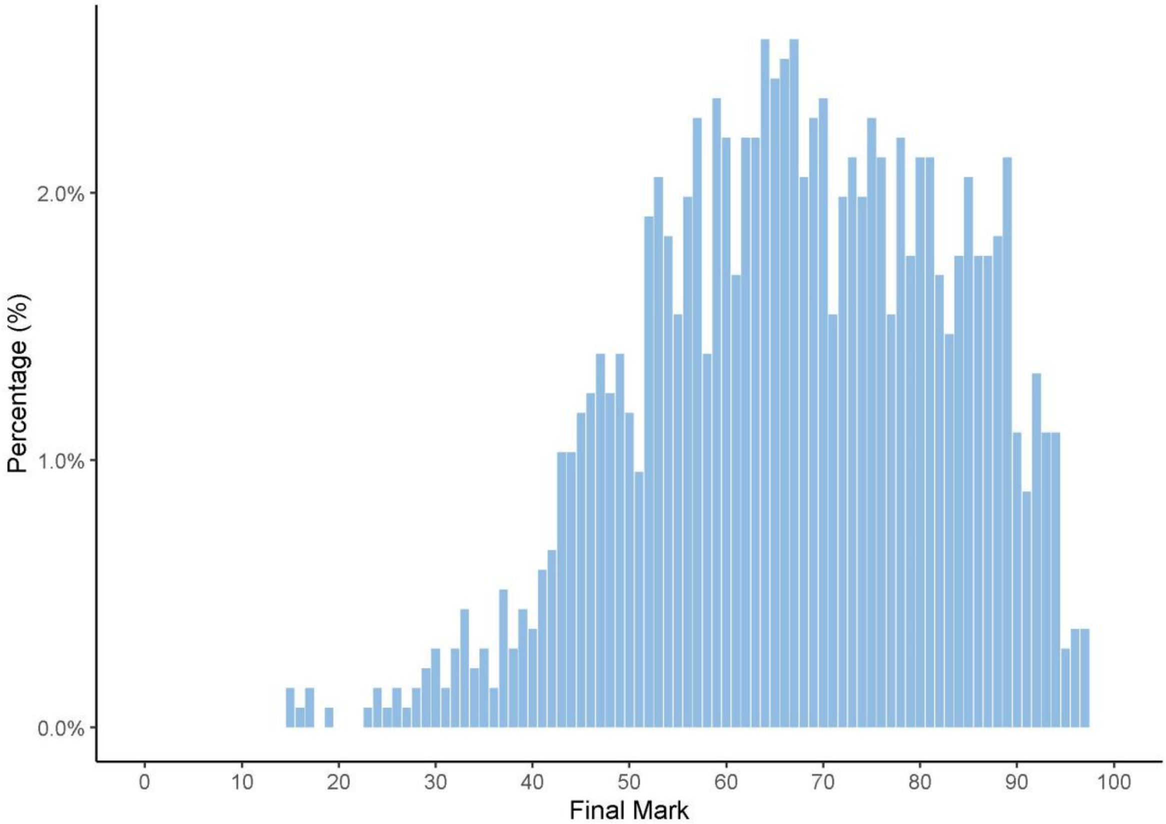


External assessment (EA) marks



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	100–83	82–67	66–45	44–20	19–0

Distribution of standards

The number of students who achieved each standard across the state is as follows.

Standard	A	B	C	D	E
Number of students	263	446	540	104	6

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 section 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 the subject matter and the assessment objective/s.

Refer to the quality assurance tools for detailed information about the assessment practices for each assessment instrument.

Percentage of instruments endorsed in Application 1

Number of instruments submitted	IA1	IA2	IA3
Total number of instruments	90	89	88
Percentage endorsed in Application 1	54%	28%	84%

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 ISMG and are used to make decisions about the cohort's results. If further information is required about the school's application of the ISMG to finalise a confirmation decision, the QCAA requests additional samples.

Schools may request a review where an individual student's confirmed result is different from the school's provisional mark in one or more criteria and the school considers this result to be an anomaly or exception.

The following table includes the percentage agreement between the provisional marks and confirmed marks by assessment instrument. The Assessment decisions section of this report 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	89	496	154	71.91%
2	89	465	0	100%
3	89	482	164	60.67%

Internal assessment 1 (IA1)

Project — folio (25%)

This assessment focuses on the problem-solving process in Engineering that requires the application of a range of cognitive, technical and creative skills and theoretical understandings in relation to Unit 3 subject matter and objectives. The response is a coherent work that documents the iterative process undertaken to develop an engineered solution to a civil structural problem using a Project — folio (Syllabus section 4.6.1).

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	14
Authentication	14
Authenticity	10
Item construction	13
Scope and scale	6

*Each priority might contain up to four assessment practices.

Total number of submissions: 90.

Effective practices

Validity priorities were effectively demonstrated in assessment instruments that:

- provided well thought out and detailed information about the real-world context. It was apparent from the way the contexts were structured that these schools had carefully considered the scope of evidence required in the student response, e.g. knowledge of the assessment specifications, objectives, ISMG and Unit 3 syllabus subject matter had been used in the development of the context statement and task requirements
- included the requirement for the use of Unit 3 syllabus subject matter, particularly in relation to engineering technology knowledge where students were provided with opportunities to develop a response that included considerations of sustainability and environmental issues, e.g. the solution's impact on the economy (whole-of-life), the natural environment (loss of habitat, erosion, etc.) and the social environment (human impacts such as safety and convenience)

- gave students the opportunity to provide evidence that aligned with the assessment specifications, e.g. the syllabus assessment specifications were included in the instrument without alteration or omission
- included a structural problem context that was sufficiently different from the QCAA sample IA1 instrument to ensure students were able to demonstrate unique responses, e.g. it was clear that schools had carefully identified relevant local community issues when developing appropriate structural problem contexts.

Practices to strengthen

It is recommended that assessment instruments:

- do not include a focus on the prototype solution within the broader real-world structural problem context. The data generated through protype testing should be used to evaluate structural aspects of the solution to the real-world problem, e.g. identification of high-force members or areas of weakness where additional strengthening, redevelopment or refinement may be required for the predicted real-world structural solution
- only include scaffolding (images) where absolutely necessary and, when included, provide students with the opportunity to develop unique responses, e.g. images of structures lead students to a predetermined solution. Additionally, it is not appropriate for assessment instruments to refer students to the QCAA samples or to provide students with Project — folio headings
- are checked to ensure that the information provided to students about the size and requirements for the development and testing of the structural protype is possible within the syllabus conditions, e.g. the dimensional and loading scale should be appropriate for the assessment conditions and allow for the generation of a prototype that, when tested, provides valid data that can be used to assess the accuracy of the predicted real-world structural problem solution
- are structured to ensure that the response is the result of individual work. Group work in any form is not a syllabus condition for Project — folio assessment, e.g. the generation and testing of a physical or virtual prototype is individual work and should not be completed as group work or as a whole of class activity.

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	13
Layout	0
Transparency	5

*Each priority might contain up to four assessment practices.

Total number of submissions: 90.

Effective practices

Accessibility priorities were effectively demonstrated in assessment instruments that:

- included a layout for the context and task that was clearly and logically ordered to provide a framework of information that gave access to the assessment objectives, specifications and ISMG (Syllabus section 4.6.1)
- contained stimulus images only when required and, when included, the images met with task requirements, e.g. an image or images were often not required as stimulus, because the context and task included sufficient contextual information to promote student exploration of the real-world problem in the development of unique responses.

Practices to strengthen

It is recommended that assessment instruments:

- use Engineering syllabus language when referring to problem-solving, solutions and solution development. It is required that schools use terms such as 'develop', 'ideas' and 'engineered solutions' in preference to 'design', 'designs' or 'design concepts' etc. Design-related concepts and principles are not included in syllabus subject matter and are not defined in the Engineering syllabus and, as such, should not be used
- use contexts that are accessible to students such as those that relate to the real world and require students to apply syllabus subject matter without placing students in professional roles, e.g. contexts should not refer to students as an engineer or as a member of an engineering firm.

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 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	Retrieving and comprehending	85.39%	12.36%	0%	2.25%
2	Analysing	77.53%	20.22%	0%	2.25%
3	Synthesising and evaluating	75.28%	20.22%	0%	4.49%
4	Communicating	85.39%	12.36%	1.12%	1.12%

Effective practices

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

- matching qualities in student responses with the Retrieving and comprehending criterion at the 1 and 2–3 performance levels; in particular, identification of evidence of competent symbolisation and appropriate explanation of some ideas and a solution using sketches, drawings, diagrams, graphs, tables and/or schemas
- matching qualities in student responses with the Analysing criterion at the 1, 2–3 and 4–5 performance levels; in particular, evidence of appropriate analysis of the structural problem and reasonable determination of some solution success criteria for the structural problem was accurately and consistently identified
- matching qualities in student responses with the Synthesising and evaluating criterion at the 1, 2–3 and 4–5 performance levels; in particular, identification of evidence in relation to feasible evaluation and adequate refinement of ideas and a solution using some success criteria to make fundamental recommendations justified by data and research evidence
- matching qualities in student responses with the Communicating criterion at the 1–2 performance level; in particular, evidence of variable decision-making about, and inconsistent use of, folio or referencing conventions was accurately and consistently identified.

Samples of effective practices

The following are excerpts from a response that illustrates the characteristics for the criteria at the performance level indicated. The excerpts may provide evidence of more than one criterion. The characteristics identified may not be the only time the characteristics have occurred throughout a response.

These student response excerpts have been included:

- to demonstrate the relationship of the prototype with the real-world problem and how students could acknowledge the purpose, or role, of the protype in predicting a real-world structural solution. The student response provides an account of the characteristics of the structural problem that displays intellectual perception concerning the role of testing of the prototype in relation to the real-world structural problem
- to show how analysis may be used to understand the characteristics of the problem. The student response includes calculations to attain relevant data that supports an understanding of the relationships that exist in complex situations to distinguish the structural problem's characteristics
- to indicate how success criteria may be prioritised and categorised to support development of the real-world solution. The student response includes an accurate assessment of the problem's characteristics to establish success criteria that are prioritised in relation to both the prototype and the real-world problem and are of critical importance for ascertaining a structural problem solution. The success criteria have been explicitly used to evaluate the predicted real-world solution.

Retrieving and comprehending (4–5 marks)

- accurate and discriminating recognition and discerning description of the structural problem, engineering technology knowledge, and mechanics and materials science concepts and principles in relation to structures
- adept symbolisation and discerning explanation of ideas and a solution in relation to structures with sketches, drawings, diagrams, graphs, tables and/or schemas.

Excerpt 1

Strength of Balsa (prototype):

Only a compressive test data was needed to be used to determine the strength of the balsa as the truss member slenderness causes members to fail by buckling in compression at significantly lower values than tensile tests conducted previously. This is relevant, because it is reasonable also to assume that the primary forces in this tower will unavoidably be compressive. The compression test results showed that the long pieces of balsa tended to buckle and to address this issue, smaller balsa pieces would be needed to reduce the distance between the bracing points in the structure. By shortening unsupported member length (by adding braces) rapidly increases buckling resistance.

The data derived from the testing supported the statement that when the length is decreased the load the material can withstand increases. Thus, by halving the length of balsa it can be said that the members of the structure will be able to withstand higher loads.

Length	Average Compression
150 mm	2513g
125 mm	4160g
112.5mm	4525g

Analysing (6–7 marks)

- insightful analysis of the structural problem, and relevant engineering mechanics, materials science, technology and research information in relation to structures, to identify the relevant elements, components and features, and their relationship to the structure of the problem

Excerpt 2

Tank mass using 3mm steel:

$$Mass\ of\ top\ \&\ bottom = \frac{\pi D^2}{4} \times t \times e \times 2$$

$$Mass\ of\ top\ \&\ bottom = \frac{\pi D^2}{4} \times 0.003m \times 7850kg/m^3 \times 2$$

$$Mass\ of\ tube = \pi D \times t \times h \times e$$

$$Total\ mass\ \approx 1776kg$$

Using 3mm thick steel, it can be said that the trussed structure would have to withstand a tank mass of 1776kg.

Finding the height of the tank using a 4m diameter and volume:

$$50m^3 = \frac{\pi \times 4^2}{4} \times H = 12.57H$$

$$\therefore H \approx 4m$$

Therefore, the dimensions of the tank are 4m (height) by 4m (diameter).

Scaled force values:

$$Total\ tower\ load = \frac{(tank\ mass + water\ mass) \times gravity}{20^3}$$

$$Total\ tower\ load = \frac{(1776 + 50000) \times 9.8}{20^3} \approx 62.7N$$

$$Wind\ force = \left(\frac{\frac{1}{2} \times e \times Cd \times A \times v^2}{20^3}\right) \div 2$$

Analyse
Insightful

$$Wind\ force = \left(\frac{\frac{1}{2} \times 1.28 \times 0.8 \times 16 \times 78^2}{20^3}\right) \div 2 = 3.1N$$

Analysing
(6–7 marks)

- astute determination of essential solution success criteria for the structural problem

Excerpt 3

Determining Success Criteria:

Success Criteria
Astute and Essential

Success Criteria	*Subtopic If Applicable*	*Description*	*Code*	*Relation to prototype or real-world structure*
Strong	-	The structure needs to strong, and able to withstand force applied from winds and environment	SC1	Mostly real - world structure
Efficient	-	The structure achieves maximum productivity with minimum wasted effort	SC2	Both
Aesthetic	-	The structure is aesthetically pleasing to its client	SC3	Mostly real - world structure
Compliance	-	The structure meets the specifications that are requested by the client	SC4	Both
Cost-effective	Material	The material used is efficient in the aspect of cost	SC5.1	Both
	Structure	The structure does not use too many components to be cost effective	SC5.2	Most - real world structure
Easy to construct	-	The structure is relatively easy to construct	SC6	Both
Sustainable	-	The structure is able to be maintained to certain level	SC7	Real - world structure
Eco-friendly	Non-harmful	The structure or water tank is not harmful to the environment	SC8.1	Both
	Recyclability	The material is able to be recycled after it is no use to the client	SC8.2	Real - world structure
Suitability of safety barriers	-	The structure has to be safe for the wellbeing of workers	SC9	Real - world structure
Maintenance	-	The structure is able to be maintained and defects can be fixed	SC10	Real – world structure

Synthesising and evaluating (8–9 marks) • critical evaluation and discerning refinement of ideas and a solution using success criteria to make astute recommendations justified by data and research evidence	**Excerpt 4** Real-world tower evaluation: The real-world design will be manufactured and constructed differently to the prototype that was made for testing. Firstly, the material used will be completely different, and the production method will be changed to allow an efficient and economic product (SC2). The best material for both the tower and tank will be steel. As researched above, '**Steel is the best option for a truss tower and the tank, as it is strong, cheap, and maintainable'** (SC1, SC5.1 & SC10). The steel used for the structure will: • Be coated to resist corrosion from environment • Be protected from UV rays • Withstand the different weather that occurs in the proposed location The structure will use a simple 'K truss' design; therefore, it will be easy to construct and aesthetic (SC3 & SC6). The joints will be supported by galvanised steel gussets to structure is strong and safe (SC1 & SC9). The structure will be manufactured in a rural town close to the site, and the tower and tank will be transported by shipping or a large transportation truck. Finally, the tower and tank will be manufactured to specifications of the client (SC4).

Practices to strengthen

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

- the Retrieving and comprehending criterion 4–5 performance-level descriptors are further examined to ensure consistency of the match with evidence in student responses including:
  - acknowledging that the explore phase of the problem-solving process requires developing an understanding through recognition, description and analysis of a problem to identify its characteristics to determine success criteria. At the 4–5 performance level, the student response should provide an account of the characteristics of the structural problem that displays intellectual perception when distinguishing between knowns, unknowns, assumptions made, the boundaries defined for problem exploration in regard to engineering technology knowledge, and mechanics and materials science concepts and principles in relation to structures. Student responses that merely provide research information, or that restate aspects of the provided problem, do not include evidence that supports school judgments of the match with the 4–5 performance-level descriptor for this criterion
  - identifying that adept symbolisation and discerning explanation of ideas and a solution requires the use of highly skilled sketches and drawings that include basic drawing standards as defined in the syllabus glossary, diagrams, graphs, tables and/or schemas. Sketches and drawings should include valuable and relevant annotations that display intellectual perception when providing additional information about ideas and a solution in relation to structures. At the 4–5 performance level, evidence should include the relative value or worth of information included with visual representations and annotations. Decisions should be made to prioritise aspects of ideas or information based on success criteria and with an understanding of the characteristics of the structural engineering problem
- the Analysing criterion 6–7 performance-level descriptors are further examined to ensure consistency of the match with evidence in student responses. It should be noted that 'astute

determination of essential solution success criteria for the structural problem' does not include a focus on success criteria that support the development of the prototype solution alone. Success criteria should primarily relate to the real-world problem. Prioritised success criteria that focus on the real-world solution will assist students to de-emphasise the importance of the prototype solution during the problem-solving process. The purpose of the prototype is to provide performance data that can be used to evaluate the significant attributes of the predicted solution, e.g. the internal forces experienced by a structure and what refinements should be incorporated to improve the predicted real-world solution

- the Synthesising and evaluating criterion 8–9 performance-level descriptors are further examined to ensure consistency of the match with evidence in student responses. Evidence at this performance level should include the use of success criteria, relevant research information and data to make justified recommendations for development and refinement of ideas throughout the problem-solving process to predict a possible structural solution. The response should be well structured, rational, and realistically combine and integrate pertinent engineering mechanics, materials science, technology, research information, data, and ideas that have a direct bearing on predicting a possible structural solution. Students will make decisions about the relative value or worth of information using success criteria as they combine and integrate ideas and resolve uncertainties towards predicting a structural solution
- the Communicating criterion 3–4 performance-level descriptors are further examined to ensure consistency of the match with evidence in student responses, including:
  - that evidence should include consistent and articulate use of a reference list and a recognised system of in-text referencing. This should acknowledge sources for information included in the Project — folio Part A and Part B. Information, including both textual and visual information (e.g. pictures, graphs and tables) should be consistently referenced
  - reviewing the use of school-templated headings. Use of these headings mean students are not making decisions about how they organise and communicate their thinking through the iterative phases of the problem-solving process in Engineering. When schools over-scaffold student responses in this way, the evidence demonstrates variable decision-making about, and inconsistent use of, folio conventions, i.e. the evidence aligns with the 1–2 performance-level descriptor.

Additional advice

- Evidence of class-wide protype performance data does not support schools' judgment of the match with syllabus assessment criteria across all performance levels, e.g. evaluation or comparison of other students' prototype performance data displayed in tables or graphs is not assessable evidence, and should not be included in student responses.
- Appendices are not assessable evidence and should not be included in responses. If an appendix is included, schools must be aware that it should contain only supplementary material that will not be directly used as evidence when marking the response (*QCE and QCIA policy and procedures handbook*, Section 8.2.6).
- The conditions for a Project — folio Part A is 7–9 A3 pages and Part B is 2–3 A4 pages. Students need to develop skills in managing the length, scope and scale of their responses appropriately and within the syllabus conditions.
- Check confirmation file uploads to ensure that the evidence provided for each sample includes a complete and properly orientated student response to the endorsed IA1 assessment instrument.

Internal assessment 2 (IA2)

Examination — short response (25%)

The short response examination assesses the application of a range of cognitions to multiple provided items drawn from across Unit 3 subject matter in each topic. The examination must assess a balance across the assessment objectives and the percentage allocation of marks must match the degree of difficulty specifications: ~20% complex unfamiliar; ~20% complex familiar, ~60% simple familiar. Student responses must be completed individually, under supervised conditions, and in the set timeframe (Syllabus section 4.6.2).

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	61
Authentication	0
Authenticity	10
Item construction	18
Scope and scale	6

*Each priority might contain up to four assessment practices.

Total number of submissions: 89.

Effective practices

Validity priorities were effectively demonstrated in assessment instruments that:

- were carefully developed to include an appropriate balance across the assessment objectives and Unit 3 subject matter using a number of item types, including multiple-choice, single-word, sentence, short-paragraph and calculation responses
- included mark allocations for items that matched with the syllabus degree of difficulty specifications for simple familiar, complex familiar and complex unfamiliar questions (Syllabus section 4.6.2). Questions should be allocated marks based on the evidence in the student response and the cognitions required to respond, e.g. complex familiar questions include a number of elements and focus on objectives 3 and 5. Such questions require analysis and synthesis of relevant information to develop responses. A complex familiar question would be allocated more marks than a simple familiar question and less marks than a complex

unfamiliar question because of the cognitions required and the nature of the evidence in the expected student response

- included items that were purposefully developed using cognitions drawn from the syllabus and aligned with the assessment objectives and item type for simple familiar, complex familiar and complex unfamiliar questions.

Practices to strengthen

It is recommended that assessment instruments:

- include items that assess Unit 3 subject matter only, e.g. defining scalar and vector quantities are Unit 1 subject matter, and stress/strain calculations are Unit 2 subject matter, and therefore should not be included. Questions that include subject matter not taken from Unit 3, particularly multiple-choice, single-word or calculation questions, should be amended or removed from the instrument during the internal school quality assurance process
- structure complex unfamiliar questions so that all the information to solve the problem is not immediately identifiable. Students should engage in sustained analysis and synthesis of relevant information to develop a response, e.g. truss analysis questions that include all the required information and a number of elements have complex familiar, and not complex unfamiliar, degree of difficulty as defined in the syllabus
- develop items that suit the local school context and are sufficiently different from the QCAA sample instrument to ensure students are able to demonstrate authentic responses, e.g. complex unfamiliar questions must be significantly different to QCAA sample questions
- include multiple choice items that are carefully constructed to align with the conventions for this item type, e.g. multiple choice questions should have options that follow the grammatical structure of the stem. Options that do not align in this regard may be considered to be obviously incorrect and therefore negatively impact on question validity.

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	4
Language	4
Layout	2
Transparency	9

*Each priority might contain up to four assessment practices.

Total number of submissions: 89.

Effective practices

Accessibility priorities were effectively demonstrated in assessment instruments that:

- included appropriately structured diagrams that presented information and data clearly, accurately, and with alignment to the information provided in the question

- structured questions using Unit 3 syllabus language, e.g. questions that include language derived from a focus on the sustainability of structures in relation to particular communities that experience different climatic conditions or environmental extremes, appropriately aligned with syllabus language
- aligned the expected response for questions indicated in the marking scheme, with the response space provided in the instrument for both short paragraph and calculation questions, e.g. allowing sufficient but not too much or too little response space provides transparency and clarity regarding the expected length of the student response.

Practices to strengthen

It is recommended that assessment instruments:

- provide clear instructions using cues that align with the cognitions in the assessment objectives, e.g. questions that require students to discriminate between different engineering concepts and principles like pre- and post-tensioned concrete beams should use instructions like 'compare' or 'contrast' to clearly inform students about the cognition involved and the type of response required
- use engineering situations to contextualise items that do not place the student in professional roles or inappropriate engineering contexts, e.g. questions should maintain a focus on civil structures as detailed in Unit 3 subject matter in each topic
- include diagrams and/or stimulus when only absolutely necessary to improve the clarity and accessibility of questions, e.g. diagrams included in complex unfamiliar questions may reduce the difficulty of the question by providing information that should not be immediately clear to the student
- include diagrams that have been carefully quality assured to be accurate and inclusive of all the required information to support the expected student response, e.g. specific points and loading on beam diagrams are well-defined and support the degree of item difficulty.

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 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	Engineering knowledge and problem-solving	100%	0%	0%	0%

Effective practices

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

- marking schemes included well-defined and set out expected student responses that clearly identified the full range of circumstances for the allocation of marks for each question

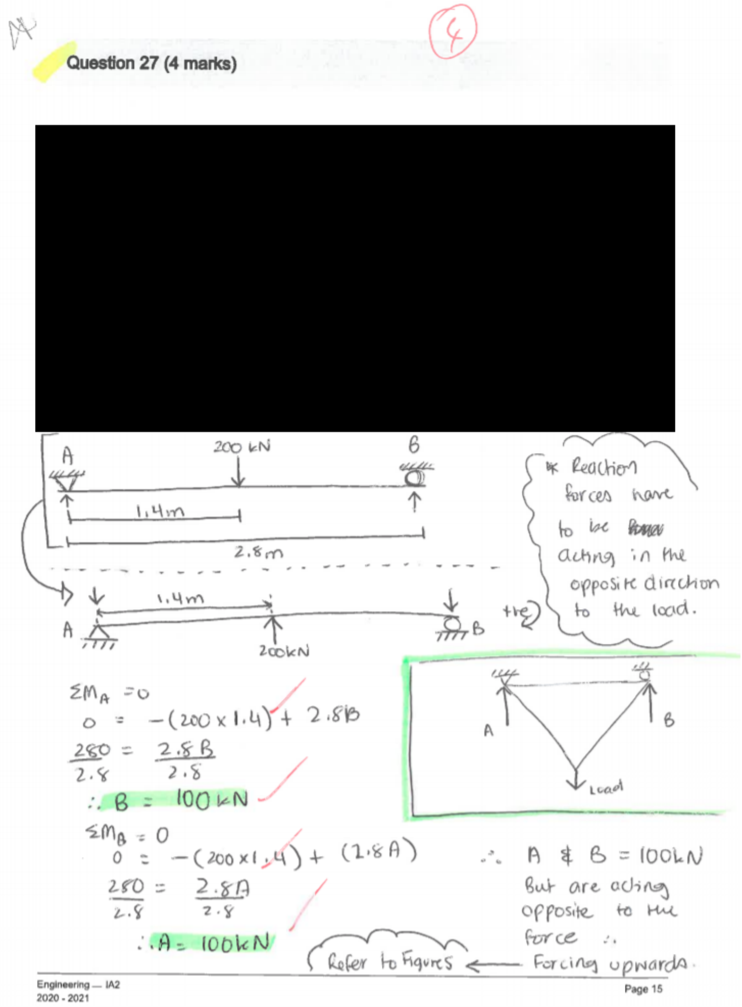
- school judgments were made consistently, with reference to the evidence provided in student responses to short-paragraph questions using key terms and ideas that were clearly identified in the marking scheme.

Samples of effective practices

The following are excerpts from a response that illustrates the characteristics for the criteria at the performance level indicated. The characteristics identified may not be the only time the characteristics have occurred throughout a response.

These student response excerpts have been included:

- to demonstrate how school judgments have been clearly indicated on the student response using marks that align with the information provided in the updated school-developed marking scheme. The school's updated marking scheme clearly indicates how and where marks are consistently awarded and includes alternative correct responses for questions where applicable
- to demonstrate a method for clearly indicating the total marks for each question. The awarded marks are identified on the student response using a circled number.

Engineering knowledge and problem-solving (4 marks)	**Excerpt 1** 

Engineering knowledge and problem-solving (2 marks)	**Excerpt 2** **Question 29 (2 marks)** 2 [redacted] Steel is ductile & strong, however it is prone to corrosion - requiring galvanising/coating for a successful design. Timber is lightweight & eco-friendly but it is not ductile/flexible and is unable to support heavy loads (compared to steel).

Practices to strengthen

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

- schools refine their marking scheme to accurately reflect the decisions to allocate marks for each question. Any errors found in the marking scheme should be amended to reflect the accurate and consistent allocation of marks for each question. The amended marking scheme must be uploaded for confirmation
- if a school decides to award half-marks, it should be clear in the marking scheme how these are allocated. The awarding of half-marks can appear to be arbitrary, with little or no explanation provided in the marking scheme. For this reason, the use of half-marks is not recommended. However, if including half-marks, careful consideration must be given to clearly indicating in the marking scheme how half-marks have been consistently awarded for each question
- the ISMG is accurately used to determine a mark out of 25, i.e. schools should provide the mark awarded out of the total marks for the paper, the percentage to at least one decimal place, and the mark out of 25 awarded using the ISMG cut offs, e.g. $\frac{53}{75} = 70.7\% = 17$.

Additional advice

- Schools should check confirmation file uploads to ensure that the evidence provided for each sample includes a complete and properly orientated student response to the endorsed IA2 assessment instrument.

Internal assessment 3 (IA3)

Project — folio (25%)

This assessment focuses on the problem-solving process in Engineering that requires the application of a range of cognitive, technical and creative skills and theoretical understandings in relation to Unit 4 subject matter and objectives. The response is a coherent work that documents the iterative process undertaken to develop an engineered solution to a mechanical and/or mechanisms problem using a Project — folio (Syllabus section 5.6.1).

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	12
Authentication	1
Authenticity	0
Item construction	0
Scope and scale	2

*Each priority might contain up to four assessment practices.

Total number of submissions: 88.

Effective practices

Validity priorities were effectively demonstrated in assessment instruments that:

- included real-world contexts that were carefully selected and developed to provide sufficient detail about the mechanical and/or mechanisms problem. These contexts facilitated student engagement with Unit 4 syllabus subject matter, e.g. the contextual statement and/or task required the use of control technologies concepts and principles in relation to machines and mechanisms in the development of a real-world solution. It was apparent that knowledge of the assessment specifications, objectives, ISMG and Unit 4 syllabus subject matter had been used in the development of the context statement and task requirements
- gave students the opportunity to provide evidence that aligned with the assessment specifications, e.g. the syllabus assessment specifications were included in the instrument without alteration or omission
- were structured to ensure that the response was the result of individual work. Group work in any form is not a syllabus condition for Project — folio assessment, e.g. the generation and

testing of a physical or virtual prototype is individual work and should not be completed as group work or as a whole of class activity.

Practices to strengthen

It is recommended that assessment instruments:

- do not include a focus on the prototype solution within the broader real-world mechanical and/or mechanisms engineering problem context. The data generated through protype testing should be used to evaluate mechanical aspects of the solution to the real-world problem, e.g. assessment of range of movement, velocity, machine control capability, etc. Testing should generate valid and applicable evaluation data that may be used in the redevelopment or refinement of the predicted real-world mechanical and/or mechanisms solution
- are checked to ensure that the information provided to students about the size and requirements for the development and testing of the mechanical and/or mechanisms protype is possible within the syllabus conditions, e.g. the dimensional scale, materials and processes should be appropriate for the assessment conditions and allow for the generation of a prototype that, when tested, provides valid data that can be used to assess the accuracy of the predicted real-world mechanical and/or mechanisms solution.

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	0

*Each priority might contain up to four assessment practices.

Total number of submissions: 88.

Effective practices

Accessibility priorities were effectively demonstrated in assessment instruments that:

- included a layout for the context and task that was clearly and logically ordered to provide a framework of information that gave access to the assessment objectives, specifications and ISMG (Syllabus section 4.6.1). It was clear from the structure of the contexts and tasks that schools had a clear understanding of the syllabus requirements for the assessment, and this was reflected in the instrument
- contained stimulus images only when required and, when included, met with task requirements, e.g. an image or images were often not required as stimulus because the context and task included sufficient contextual information to promote student exploration of the real-world problem in the development of unique responses.

Practices to strengthen

It is recommended that assessment instruments:

- use Engineering syllabus language when referring to problem-solving, solutions and solution development. It is required that schools use terms such as ‘develop’, ‘ideas; and ‘engineered solutions’ in preference to ‘design’, ‘designs’ or ‘design concepts’, etc. Design-related concepts and principles are not included in syllabus subject matter and are not defined in the Engineering syllabus and, as such, should not be used.

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 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	Retrieving and comprehending	80.9%	16.85%	0%	2.25%
2	Analysing	69.66%	28.09%	0%	2.25%
3	Synthesising and evaluating	62.92%	35.96%	0%	1.12%
4	Communicating	89.89%	10.11%	0%	0%

Effective practices

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

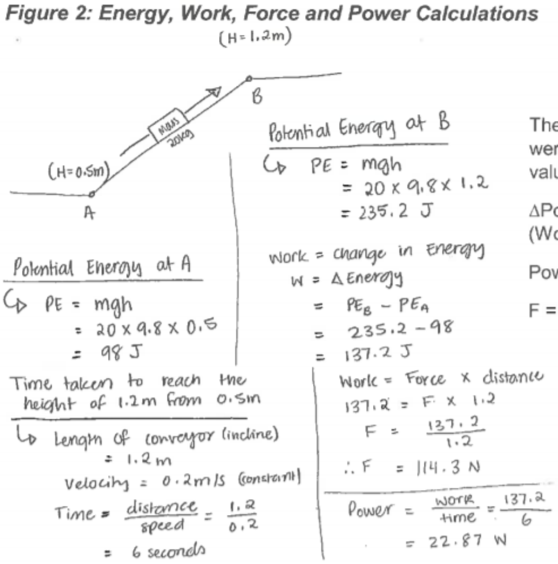
- matching qualities in student responses with the Retrieving and comprehending criterion at the 1 and 2–3 performance levels; in particular, identification of evidence in relation to accurate recognition and appropriate description of the machine and/or mechanism problem, engineering technology knowledge, and some mechanics, materials science and control technologies concepts and principles
- matching qualities in student responses with the Analysing criterion at the 1, 2–3 and 4–5 performance levels; in particular, identification of evidence in relation to reasonable determination of some solution success criteria was made accurately and consistently
- matching qualities in student responses with the Synthesising and evaluating criterion at the 1, 2–3 and 4–5 performance levels; in particular, identification of evidence of simple synthesis of relevant engineering mechanics, materials science, control technologies, technology and research information, and ideas to predict a possible machine and/or mechanism solution
- matching qualities in student responses with the Communicating criterion at the 1–2 performance level; in particular, evidence of variable decision-making about, and inconsistent use of, folio or referencing conventions was accurately and consistently identified.

Samples of effective practices

The following are excerpts from a response that illustrates the characteristics for the criteria at the performance level indicated. The excerpts may provide evidence of more than one criterion. The characteristics identified may not be the only time the characteristics have occurred throughout a response.

These student response excerpts have been included:

- to show how analysis, including calculations and sketching with annotations, may be used to identify and demonstrate understanding of the characteristics of the problem towards determining success criteria. The student response includes knowledge of Unit 4: Mechanics concepts and principles to demonstrate an understanding of the complex relationships that exist between the applicable elements, components, and features of the machine and/or mechanism problem
- to indicate how success criteria may be prioritised to support development of the real-world solution. The student response includes an accurate assessment of the problem's characteristics to establish success criteria that are prioritised according to their importance for ascertaining a machine and/or mechanism solution
- to demonstrate evaluation and refinement of the predicted solution, using performance data produced as a result of virtual testing of the prototype solution. The student response includes explicit use of prototype performance data and data produced using relevant calculations to justify refinement of the predicted solution
- to show how judgments may be explicitly made with reference to prioritised success criteria, data (including research information), test results and calculations to assess for strengths, weaknesses, implications and limitations, and to make thoughtful and accurate recommendations when evaluating the predicted solution.

<table>
<tr>
<td>Analysing
(6–7 marks)
• insightful analysis of the machine and/or mechanism problem, and relevant engineering mechanics, materials science, control technologies, technology, and research information in relation to machines and/or mechanisms, to identify the relevant elements, components and features, and their relationship to the structure of the problem</td>
<td>Excerpt 1
Basic Calculations & Mechanical Considerations
Figure 2: Energy, Work, Force and Power Calculations


The calculation for 10 kg bags were performed identically; the values are stated below:
ΔPotential Energy = 68.6 J (Work)
Power = 11.43 W
F = 57.17 N

As the bag travels up on the incline, the potential energy changes (figure 2) – however, kinetic energy remains the same as the velocity is consistant. The change in energy means there is 'work' that is taking place; this is occuring at the gears of the inclined conveyor. The force, 114.3 N, is representative of the gear's effort. Figure 2 also shows the power required for the gears to maintain the constant veocity of 0.2 m/s. However, this power only includes one scenario (only 20 kg bag); it does not include the scenario of when the 10 kg bag is also on the conveyor, which will increase the power required.</td>
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Analysing
(6–7 marks)

- astute determination of essential solution success criteria for the machine and/or mechanism problem

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Excerpt 2

Solution Success Criteria (SSC)

First Priorities: most essential qualities that must be included for the completion of the task.

- The solution must accommodate the addition of 10 kg cement bags in the original system because the task is to increase their production rate by at least 50%.
- The conveyor belt must have two separate discharging areas for 10 kg and 20 kg bags with a mechanical control system. It should also provide a 'fail area', where if in case the system fails to operate, the bags disembark in an area where they would be manual separated. This would minimise the chances of any bags being separated in a different zone (e.g., if 10 kg bags accidently are sorted in the 20 kg zone).
- There must be at least one electronic logic gate system incorporated in this report – to ensure the bags from the bagging machines do not collide with each other and are only dropped on the conveyor belt when all the hazards are assessed.
- The addition of a guiding box under both cement bagging machines (according to their dimensions) will be a priority. This will assist in correct placement of bags on conveyor and also ease the separation process.
- The task requires the exploration and possibly the change of paper bags to plastic bags – this reduces mass, enhances sealing, and provides greater benefits (especially in outdoor storage – wet conditions).

Second Priorities: these are qualities that would enhance the solution and its performance.

- Materials used in this project (such as conveyor materials, bags, etc.) must be environmentally friendly, in terms of recyclability and increased material lifespan.
- By adding a mass detecting device/scale, the quantity of the cement bags can be ensured; additionally, it could also assist in easing the operation of the mechanical control arm for separation (if the device detects the mass to be 10 kg, then the mechanical arm assigned to discharge those bags will operate – instead of relying on time).
- Doubling the velocity (from 0.2 to 0.4 m/s) by altering gear ratios (as the task offers) will increase production and assist in achieving the 50% (or more) increase in output.

</td>
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<tr>
<td>

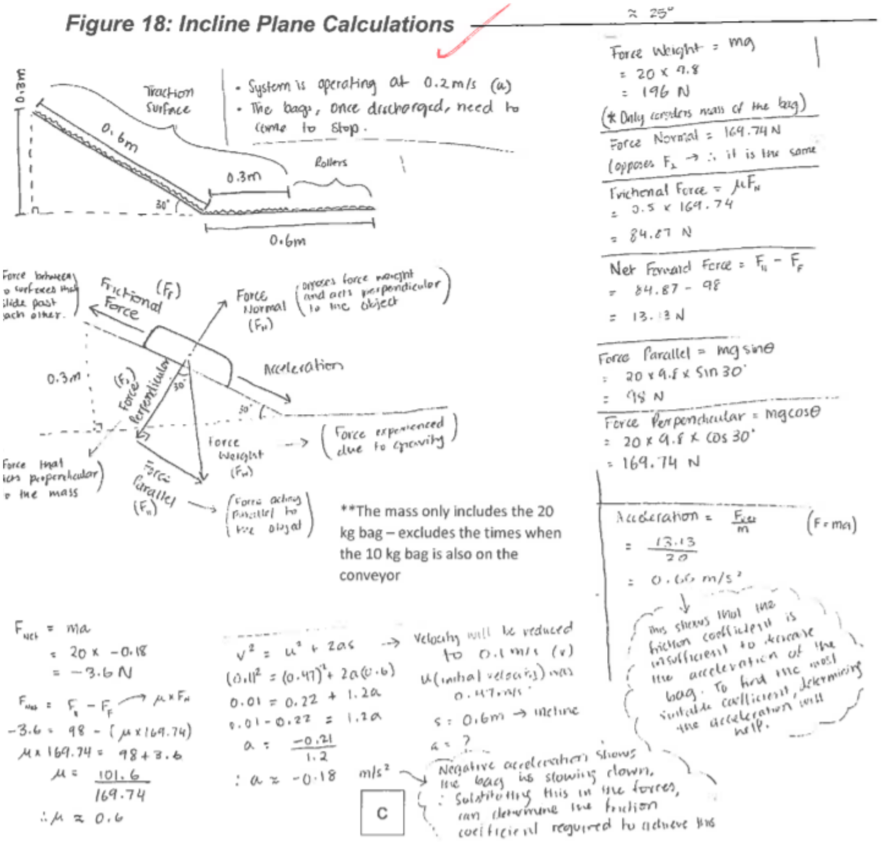
Synthesising and evaluating
(8–9 marks)

- coherent and logical synthesis of relevant engineering mechanics, materials science, control technologies, technology and research information, and ideas to predict a possible machine and/or mechanism solution

</td>
<td>

Excerpt 3

Figure 18: Incline Plane Calculations



</td>
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</table>

<table>
<tr>
<td>Synthesising and evaluating
(8–9 marks)
• critical evaluation and discerning refinement of ideas and a solution using success criteria to make astute recommendations justified by data and research evidence</td>
<td>Excerpt 4

Refining Solution & Further Calculations
During the prototype simulation stage, it was seen that it takes more energy to push the bag to the separation zone when it is parallel to the ground. To ease this process, it was decided that the separation zone would be set on an incline – however, this would impact the final height set by the project. To resolve this issue the total height by the end of the conveyor would be 1.5m. The decline at the separation zone will be from 1.5 m to 1.2 m, at an angle of 30º. This will allow gravity to assist with the separation of the bag. In terms of slowing the bag's velocity (to get it to rest), the friction of that surface will be increased. The calculations and diagrams in figure 18 show the refined and enhanced solution to the task. In order to perform the calculations using the equations of motion, the velocity of the bag after contacted by the mechanism is important to determine; this is done in figure 17.</td>
</tr>
<tr>
<td>Synthesising and evaluating
(8–9 marks)
• critical evaluation and discerning refinement of ideas and a solution using success criteria to make astute recommendations justified by data and research evidence</td>
<td>Excerpt 5

Assessing According to the Solution Success Criteria
The analysis of the obtained results is reflected in the table below; point will be given accordingly, which will help determining the success of the solution.

<table>
<tr><td rowspan="5">First priority</td><td>1</td><td>This criterion has been fully met, as more than 50% of overall increase in production is theoretically derived. Therefore, the company's requirement of wanting at least 50% increase has been achieved with 57% total outcome, through the addition of 10 kg cement bags.</td></tr>
<tr><td>1</td><td>The system is successfully able to have a separation area for 10 kg, 20 kg and also include a fail zone – meeting another criteria point.</td></tr>
<tr><td>1</td><td>In terms of logic gates, AND & NOT gate is added as an interlocking system to ensure bags do not collide – this gate works on two inputs (laser 1 and 2) and gives one output. If any of the two inputs are true, then the output will be to not push the second bag on the conveyor belt, indicating there is already another bag at that position.</td></tr>
<tr><td>0.5</td><td>The guiding box has been explored in this project; however, a simulation/prototype was not created, which cannot determine the performance of this suggestion.</td></tr>
<tr><td>1</td><td>A thorough comparison was conducted in this project, which concluded that plastic bags (specifically polypropylene) performs better and has more beneficial properties compared to paper bags.</td></tr>
<tr><td rowspan="2">Second Priority</td><td>1</td><td>This criterion outlined the environmentally friendliness of the materials in this report. Overall, these materials (stainless steel, rubber, plastic bagging, etc.) are all recyclable, which increases their lifespan.</td></tr>
<tr><td>0</td><td>The velocity of the conveyor was not increased, which gives this criterion no points – the concept of gear ratios should be explored and further assessed for increasing velocity and thereby, production of cement bags.</td></tr>
</table>
</td>
</tr>
</table>

Practices to strengthen

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

- the Retrieving and comprehending criterion 4-5 performance-level descriptors are further examined to ensure consistency of the match with evidence in student responses including:
  - acknowledging that the explore phase of the problem-solving process requires developing an understanding through recognition, description and analysis of a problem to identify its characteristics to determine success criteria. At the 4–5 performance level, the student response should provide an account of the characteristics of the machine and/or mechanisms problem that displays intellectual perception when distinguishing between knowns, unknowns, assumptions made, and the boundaries defined for problem exploration in regard to engineering technology knowledge, and mechanics and materials science concepts and principles in relation to Unit 4 subject matter. Student responses that merely provided research information, that restate aspects of the provided problem, and that do not address Unit 4 subject matter, or the assessment specifications do not include evidence that supports school judgments of the match with the 4–5 performance level descriptor for this criterion. Additionally, control technologies must be included in the development of the problem solution. Note that flow charts represent the progression

through a procedure or system and are not indicative of the inclusion of control technologies as defined in the Engineering syllabus (see syllabus glossary)

  - identifying that adept symbolisation and discerning explanation of ideas and a solution requires the use of highly skilled sketches and drawings that include basic drawing standards (as defined in the syllabus glossary), diagrams, graphs, tables and/or schemas. Sketches and drawings should include valuable and relevant annotations that display intellectual perception when providing additional information about ideas and a solution in relation to machines and/or mechanisms. At the 4–5 performance level, evidence should include the relative value or worth of information included with visual representations and annotations. Decisions should be made to prioritise aspects of ideas or information based on success criteria and with an understanding of the characteristics of the machine and/or mechanism engineering problem

- the Analysing criterion 6–7 performance-level descriptors are further examined to ensure consistency of the match with evidence in student responses. It should be noted that ‘astute determination of essential solution success criteria for the machine and/or mechanism problem’, requires that success criteria primarily relate to the real-world problem. Prioritised success criteria that focus on the real-world solution will assist students to de-emphasise the importance of the prototype solution during the problem-solving process. The purpose of the prototype is to provide performance data that can be used to evaluate the significant attributes of the predicted solution, e.g. the velocity ratio of moving components or the practical function of a mechanism incorporated in the solution
- the Synthesising and evaluating criterion 8–9 performance-level descriptors are further examined to ensure consistency of the match with evidence in student responses. Evidence at this performance level should include the use of success criteria, relevant research information, and data to make justified recommendations for development and refinement of ideas throughout the problem-solving process to predict a possible machine and/or mechanism solution. The response should be well-structured, rational, and realistically combine and integrate pertinent engineering mechanics, materials science, control technologies, technology, research information, data and ideas that have a direct bearing on predicting a possible solution. Students will make decisions about the relative value or worth of information using success criteria as they combine and integrate ideas, and resolve uncertainties towards predicting a machine and/or mechanism solution
- the Communicating criterion 3–4 performance-level descriptors are further examined to ensure consistency of the match with evidence in student responses, including:
  - that evidence should include consistent and articulate use of a reference list and a recognised system of in-text referencing. This should acknowledge sources for information included in the Project — folio Part A and Part B. Information, including both textual and visual information (e.g. pictures, graphs and tables) should be consistently referenced
  - reviewing the use of school-templated headings. Use of these headings mean students are not making decisions about how they organise and communicate their thinking through the iterative phases of the problem-solving process in Engineering. When schools over-scaffold student responses in this way, the evidence demonstrates variable decision-making about, and inconsistent use of, folio conventions, i.e. the evidence aligns with the 1–2 performance level descriptor.

Additional advice

- Evidence of class-wide protype performance data does not support the school's judgments of the match with syllabus assessment criteria across all performance levels, e.g. evaluation or comparison of other students' prototype performance data displayed in tables or graphs is not assessable evidence and should not be included in student responses.
- Appendices are not assessable evidence and should not be included in student responses. If an appendix is included, schools must be aware that it should contain only supplementary material that will not be directly used as evidence when marking the response (*QCE and QCIA policy and procedures handbook*, Section 8.2.6).
- The conditions for a Project — folio Part A is 7–9 A3 pages and Part B is 2–3 A4 pages. Students need to develop skills in managing the length, scope and scale of their responses appropriately and within the syllabus conditions.
- Check confirmation file uploads to ensure that the evidence provided for each sample includes a complete and properly orientated student response to the endorsed IA3 assessment instrument.

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.

Examination — Short response (25%)

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 one paper:

- Paper 1, Section 1 consisted of 10 multiple choice items (10 marks)
- Paper 1, Section 2 consisted of 7 short response items (36 marks)
- Paper 1, Section 3 consisted of 6 short response items (39 marks).

The examination assessed subject matter from Unit 4. Questions were derived from the context of:

- Topic 1: Machines in society
- Topic 2: Materials
- Topic 3: Machine control.

The assessment required students to respond to multiple choice and short response items.

Assessment decisions

Assessment decisions are made by markers by matching student responses to the external assessment marking guide (EAMG). The external assessment papers and the EAMG are published in the year after they are administered.

Multiple choice item responses

There were 10 multiple choice items.

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.

Question	A	B	C	D
1	9.08	4.43	23.04	**63.15**
2	9.53	**55.1**	24.52	10.04
3	**71.57**	16.54	9.75	1.85

Question	A	B	C	D
4	9.23	25.41	**45.42**	19.13
5	6.87	**66.47**	11.82	14.48
6	8.27	12.85	**71.94**	6.72
7	14.55	11.74	15.21	**57.9**
8	4.06	2.14	7.09	**86.56**
9	18.83	5.76	**73.34**	1.7
10	**42.84**	14.4	19.65	22.9

Effective practices

Overall, students responded well to:

- simple familiar calculation questions that required knowledge of Topic 1 and Topic 2 mechanics and materials science concepts and principles
- simple familiar and some complex familiar questions that required them to explain concepts, principles and situations using knowledge of mechanics, materials science and engineering technology knowledge subject matter
- simple familiar questions that required the use of Topic 3 subject matter knowledge to solve logic control problems where relationships and interactions were obvious and had few elements, and all of the information to solve the problem was provided.

The following excerpts have been selected to illustrate effective student responses in one or more of the syllabus assessment objectives. The characteristics identified may not be the only time the characteristics have occurred throughout a response.

Samples of effective practices

Short response

Assessment objective: Symbolise and explain

Paper 1

Question 14

This simple familiar question required students to:

- explain how the tensile test for low-carbon steel can be used to determine its ductility
- support their explanation using an annotated sketch of a stress-strain diagram.

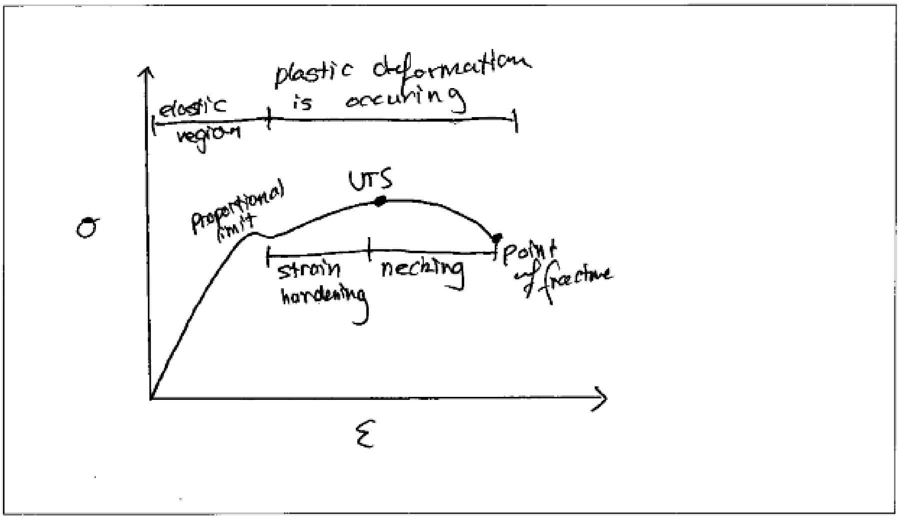
Effective student responses:

- included an appropriate explanation indicating low-carbon steel’s ability to
  - withstand strain after its yield point or UTS
  - deform plastically up to the point of fracture
- included an appropriately annotated stress–strain diagram that accurately showed
  - the plastic region

- upper yield point or UTS
- the point of fracture.

This student response except has been included:

- to demonstrate how an accurate annotated sketch of a stress–strain diagram has been used to support an appropriate explanation
- to demonstrate how the explanation references the diagram to reinforce key points, e.g. 'it can endure a large quantity of strain after reaching its proportional limit as shown on the graph'.

Engineering knowledge and problem-solving (6 marks)	**Excerpt 1**  **Note:** If you make a mistake in the sketch, cancel it by ruling a single diagonal line through your work and use the additional response space at the back of this question and response book. Low carbon steel is a very soft and ductile material containing between 0.07 and 0.15 % Carbon. As a result it can endure a large quantity of strain after reaching it's proportional limit as shown on the graph. The tensile test of low carbon steel will observe a large quantity of kneching after the UTS has been reached which is an indicative property of a ductile material. Thus, based on the amount of plastic deformation post proportional limit the tensile test can be used to determine it's ductility

Assessment objective: Symbolise and explain

Paper 1

Question 16

This simple familiar question required students to:

- demonstrate mathematical reasoning to support an explanation about the work done

- demonstrate mathematical reasoning to support an explanation about the power used by a simple machine.

Effective student responses:

- included an appropriate explanation showing logical organisation of relevant information and key steps using mathematical reasoning with the correct
  - formula for work
  - formula for power
  - value for MA
- included the correct determination of
  - work done
  - power used.

This student response excerpt has been included to:

- illustrate the qualities of an appropriately structured response that uses mathematical reasoning to support a logically ordered explanation
- demonstrate an explanation that included relevant information and key steps
- demonstrate an in-depth understanding of the mechanics concepts and principles of work done and power used in a simple machine context.

Engineering knowledge and problem-solving (5 marks)	**Excerpt 1** Work is calculated by effort force exerted, multiplied by the distance the effort wheel must be moved. In this situation, the handle operated lifting arm provided a mechanical advantage. The velocity ratio supplied by the machine is $\frac{d_e}{d_L}$, which is $\frac{1\,M}{\pi \times 0.25m} = \frac{4}{\pi} = 1.27$. Assuming 100% efficiency, $MA = VR = \frac{F_L}{F_E}$, so $F_E = \frac{F_L}{1.27}$. To lift the 98 N bucket, the effort force is $\frac{98}{1.27} = 76.97\,N$. Additionally, one revolution of handle A raises the bucket 0.785 m, so 12.73 revolutions are required to lift the bucket 10 m. So, work $= 76.97 \times 12.73 = 979.83\,Nm$. Power is the rate at which work is done, so it is $\frac{work}{time} = 979.83/30 = 32.66\,W$. So, the power required is 32.66 W.

Assessment objectives: Analyse and Synthesise

Paper 1

Question 19

This complex unfamiliar question required students to:

- analyse graphical and written information concerning the interrelationship between a moving package and carton on a conveyor system
- determine the force exerted by the package to just cause the carton to move (Part A)
- determine the distance the carton moves given a coefficient of kinetic friction
- use a free body diagram for Part A and Part B.

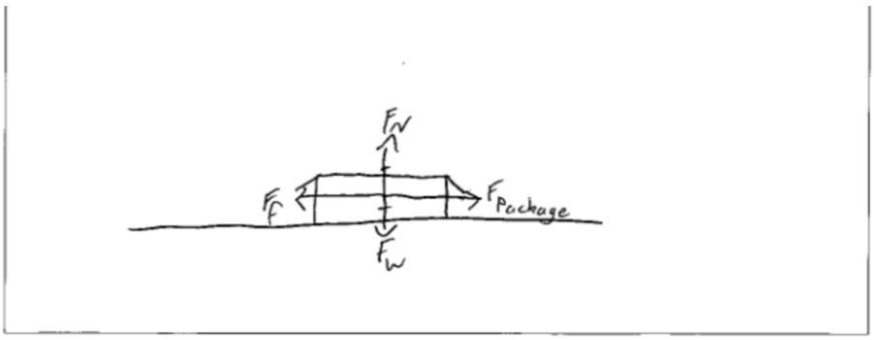
Effective student responses:

- included appropriate free body diagrams, the correct formula and working across the range of steps required to determine the correct answer to the nearest whole unit for Part A and Part B.

These student response excerpts have been included:

- to illustrate the qualities of high-level responses that were clearly and logically structured, including calculation of the:
  - force required to overcome the static friction between the carton and the conveyor surface
  - normal force acting on the box and carton
  - force of kinetic friction to determine deceleration of the box and carton
  - distance moved by the carton to the nearest whole millimetre (mm).

Note that students approached this complex unfamiliar question in different ways with additional correct responses acknowledged in the marking operation.

Part A Engineering knowledge and problem-solving (3 marks)	**Excerpt 1**  **Note:** If you make a mistake in the diagram, cancel it by ruling a single diagonal line through your work and use the additional response space at the back of this question and response book. $F_N = F_W$ $= \sout{2.25 \times 9.8}\ 0.25 \times 9.8$ $= \sout{22.05N}\ 2.45N$ $F_f\ \sout{8.82} = 0.98N$ ∴ 1N must have been applied to overcome F_f & make it move

Part B Engineering knowledge and problem-solving (5 marks)	Excerpt 2

Part B
Engineering knowledge and problem-solving
(5 marks)

Excerpt 2

Applied force : 9N

Kinetic friction : $F_f = \mu_k N$

$= 0.3 \times 9.8 \times (2 + 0.25)$

$= 6.615$

Net force forward once sliding : $9 - 6.615$

$= 2.385N$ ✗ (two) } opinion

$= 2.39\,N$ (2dp)

Excerpt 3

Package moving $3ms^{-1}$

Conveyor moving $2ms^{-1}$

Difference of $3ms^{-1}$

Assume box accelerated to $3ms^{-1}$ by pulley

Kinetic friction force of $6.613N$

$\approx 6.62N$

$F = ma$

$a = \frac{F}{m} = \frac{6.62}{2.25} = 2.9422$

≈ 2.94

Suvat $v^2 = u^2 + 2as$

$s = \frac{v^2 - u^2}{2a}$

$s = \frac{0^2 - 3^2}{2 \times -2.94}$

$s = 1.5306\,m$

$= 1531\,mm$ (mm)

∴ The carton slides 1531 mm on the conveyor surface after the package lands on it

Assessment objective: Analyse and Synthesise

Paper 1

Question 20

This simple familiar question required students to:

- analyse graphical and written information to determine the velocity of a piledriver just after impact with a pile (Part A). The answer here was required to two decimal places
- analyse graphical and written information to determine the distance the pile is driven into the ground given that the pile and piledriver decelerate at a constant rate (Part B). The answer here was required to be to the nearest whole millimetre (mm).

Effective student responses:

- included the correct formula and working across the range of steps required to determine the correct answer to Part A and Part B.

This student response excerpt has been included:

- to illustrate the qualities of a high level response that is clearly and logically structured, including calculation of the:
  - remaining kinetic energy after impact
  - velocity of the pile driver and pile just after impact to two decimal places
  - distance the pile is driven into the ground to the nearest whole millimetre (mm).

Part A **Engineering knowledge and problem-solving** **(3 marks)**	**Excerpt 1** $KE_I + PE_I - PE_F \pm W = KE_F$ $19600 - 5400 = KE_F$ $KE_F = 14200 J$ $KE = \frac{1}{2}mv^2$ $14200 = \frac{1}{2}(500+200)v^2$ $v^2 \approx 40.57$ $v \approx 6.37 m/s$
Part B **Engineering knowledge and problem-solving** **(2 marks)**	b) If the pile and piledriver decelerate at a constant rate of 30 m/s^2 after impact due to the resistance of the soil, determine the distance the pile is driven into the ground. Answer to the nearest whole unit (mm). $u = 6.37 m/s$ $v = 0 m/s$ $s = ? m$ $a = -30 m/s^2$ $t = ? s$ ~~$s = ut + \frac{1}{2}at^2$~~ $v^2 = u^2 + 2as$ $0 = 6.37^2 - 2(30)(s)$ $s \approx 0.676 m \approx 676 mm$

Assessment objective: Analyse and Synthesise

Paper 1

Question 23

This complex unfamiliar question required students to:

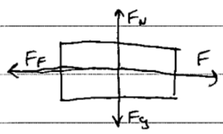
- analyse written information concerning the linear movement of a component between two points on a conveyor to determine the coefficient of static friction required if the transfer time was reduced
- produce an answer to two decimal places.

Effective student responses:

- included the correct formula and working across the range of steps required to determine the correct answer to two decimal places.

This student response excerpt has been included:

- to illustrate the qualities of a high-level response that is clearly and logically structured including calculation of:
  - velocity to determine time
  - 20% time reduction
  - acceleration to determine force of friction
  - the coefficient of static friction to two decimal places.

Engineering knowledge and problem-solving (10 marks)	**Excerpt 1** Assume that 10m is the complete distance travelled and the box stops instantly: $u = 0 m/s$ $v = ?$ → + $a = 2 m/s^2$ $t = ?$ $s = 10m$ $s = ut + \frac{1}{2}at^2$ $10 = \frac{1}{2}(2)(t^2)$ $t^2 = 10$ $t \approx 3.16 s$ Time reduced by 20%: $T_F = 0.8 T_I$ $= 0.8 \times 3.16$ $\approx 2.53 s$  $u = 0$ $v = ?$ $a = ?$ $t = 2.53 s$ $s = 10m$ $s = ut + \frac{1}{2}at^2$ $10 = \frac{1}{2}(a)(2.53^2)$ $a \approx 3.12 m/s^2$ $F = ma$ $= 2 \times 3.12$ $\approx 6.25N$ $F_F = F$ $= 6.25N$ $F_g = 2 \times 9.8 = 19.6N$ $F_N = F_g$ $= 19.6N$ $F_F = \mu_s F_N$ $6.25 = \mu_s \times 19.6$ $\mu_s \approx 0.32$

Practices to strengthen

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

- further focused practice to support students to understand what is required to respond to different types of questions fully and accurately. A number of students provided an incorrect or incomplete response or solution because they did not meet the stated requirements for some questions, e.g. calculation questions required an answer to a set number of decimal places or to a whole unit correctly stated, e.g. power in watts. In some instances, the units required were also provided in the question, e.g. mm or m. Note that the Formula and data book provides the value for acceleration due to gravity i.e. $\mathrm{g} = 9.8\ \mathrm{ms}^{-2}$
- providing students with opportunities to further develop and apply knowledge of stress–strain diagrams and their key features, and the microstructures of the steel and cast iron portions of an iron–carbon phase diagram. In particular, students should have an in-depth knowledge of:
  - Young's Modulus (stiffness, the ability to withstand elastic deformation within the material's proportional limit)
  - toughness (ability to absorb and store energy)
  - ductility (ability to sustain plastic deformation before fracture)
  - the cast iron section of the iron–carbon phase diagram (specifically, the microstructure and how it changes for different percentages of carbon and temperatures)
- providing opportunities that contribute to students' in-depth understanding of Unit 4 Topic 1: Mechanics concepts and principles to support the appropriate application of knowledge in a range of complex familiar and complex unfamiliar engineering situations in relation to machines and mechanisms, e.g. gear ratio, kinetic and potential energy, uniformly accelerated motion in one dimension, friction, work and power.