Engineering subject report

2022 cohort

February 2023

Queensland Government

QCAA
Queensland Curriculum & Assessment Authority

230042

For all Queensland schools

ISBN

Electronic version: 978-1-74378-244-6

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Introduction

Throughout 2022, schools and the QCAA worked together to further consolidate the new Queensland Certificate of Education (QCE) system. The familiar challenges of flood disruption and pandemic restrictions were managed, and the system continued to mature regardless.

We have now accumulated three years of assessment information, and our growing experience of the new system is helping us to deliver more authentic learning experiences for students. An independent evaluation will commence in 2023 so that we can better understand how well the system is achieving its goals and, as required, make strategic improvements. The subject reports are a good example of what is available for the evaluators to use in their research.

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

- how schools have applied syllabus objectives in the design and marking of internal assessments
- how syllabus objectives have been applied in the marking of external assessments
- patterns of student achievement.

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, including those that demonstrate best practice.

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

Audience and use

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

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

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

Note: All data is correct as at 31 January 2023. 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: 91.

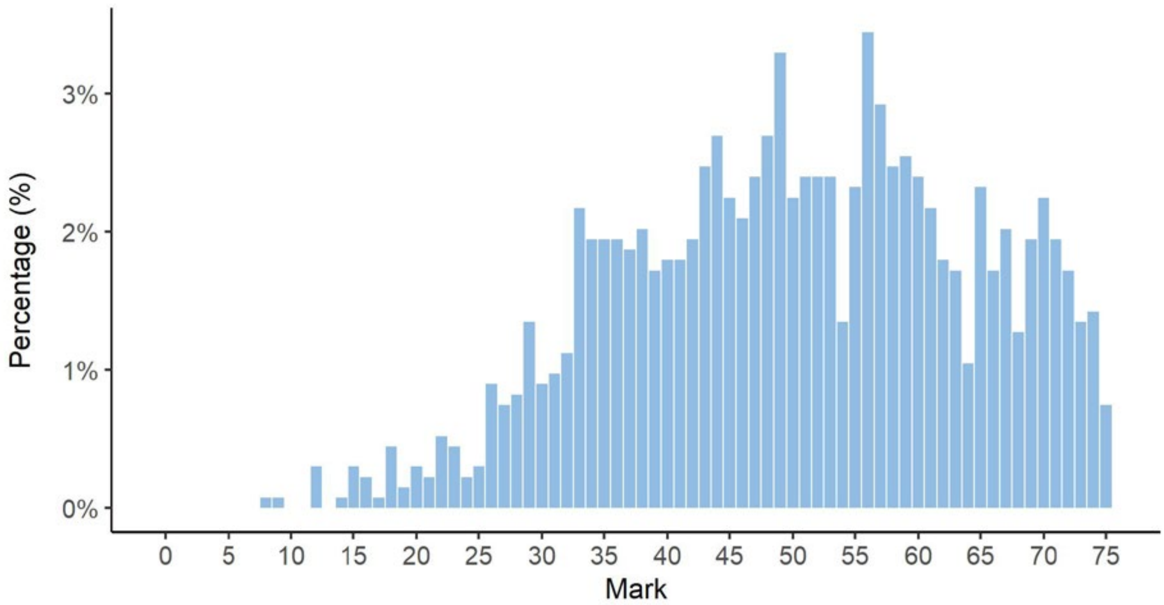
Completion of units	Unit 1	Unit 2	Units 3 and 4
Number of students completed	1616	1484	1326

Units 1 and 2 results

Number of students	Satisfactory	Unsatisfactory
Unit 1	1439	177
Unit 2	1397	97

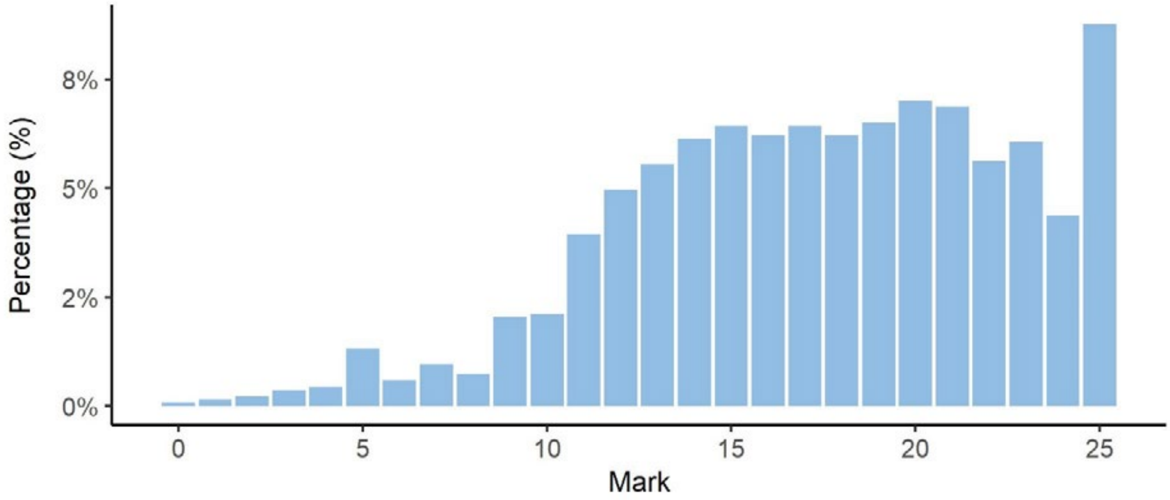
Units 3 and 4 internal assessment (IA) results

Total marks for IA

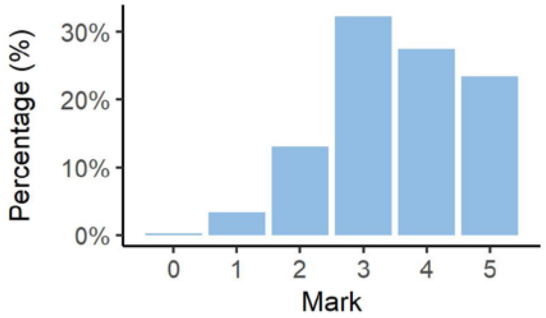


IA1 marks

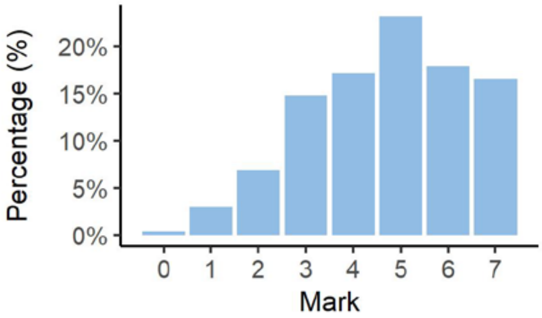
IA1 total



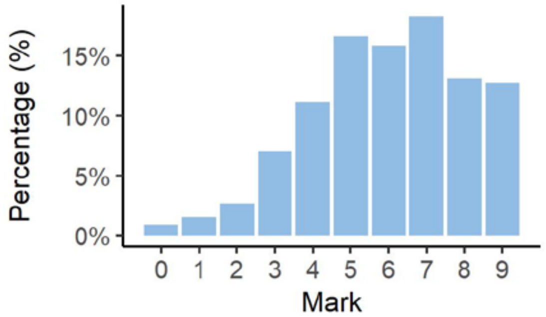
IA1 Criterion: Retrieving and comprehending



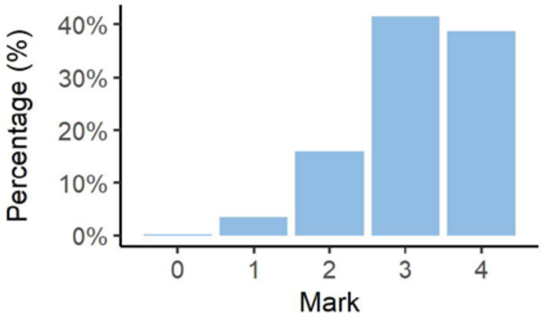
IA1 Criterion: Analysing



IA1 Criterion: Synthesising and evaluating

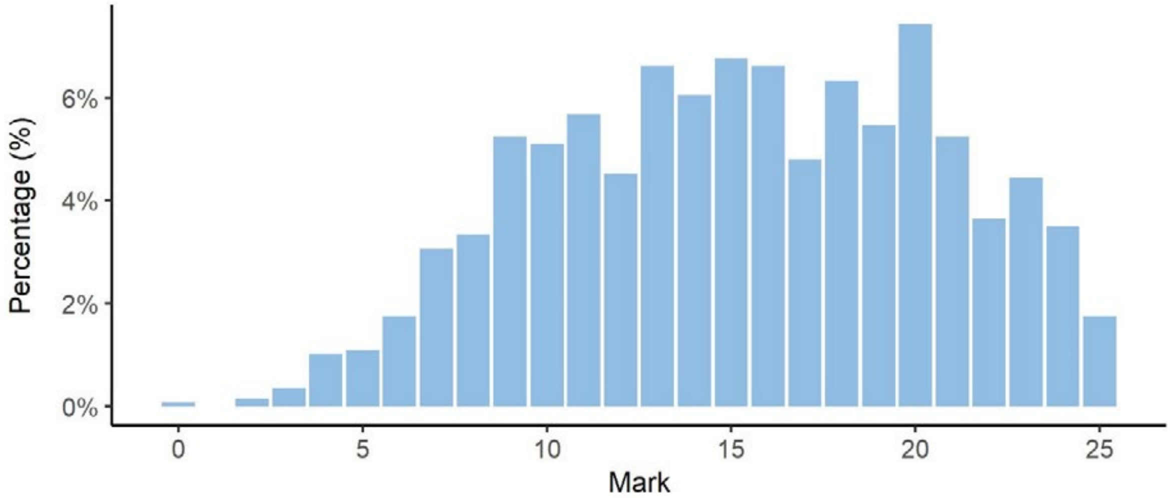


IA1 Criterion: Communicating

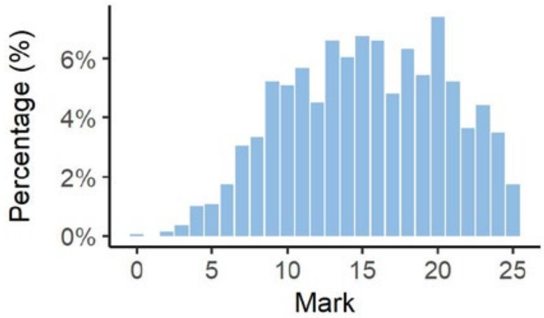


IA2 marks

IA2 total

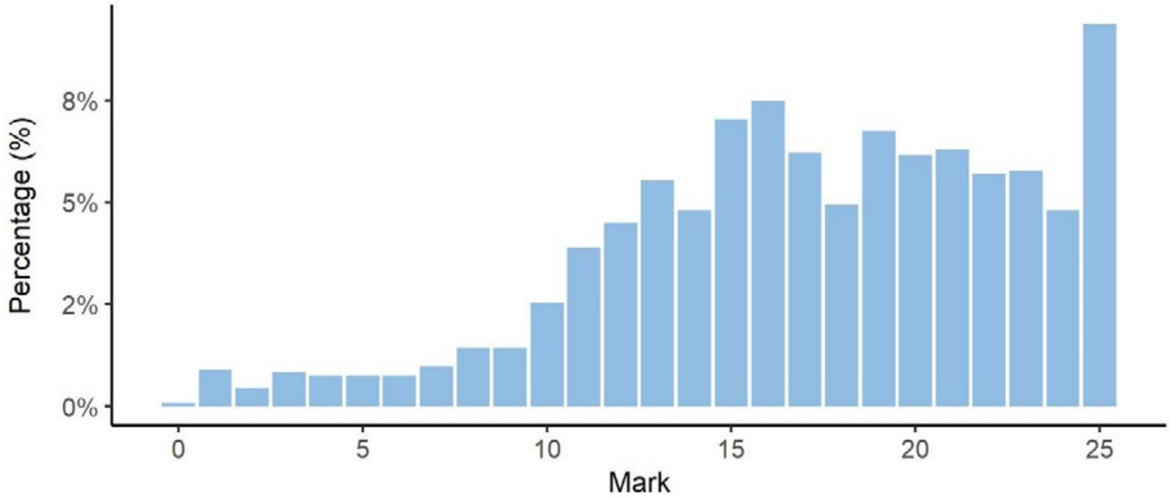


IA2 Criterion: Engineering knowledge and problem-solving

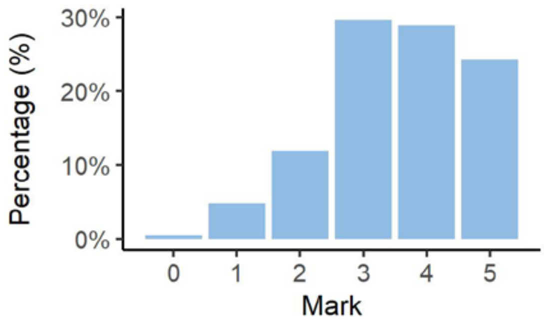


IA3 marks

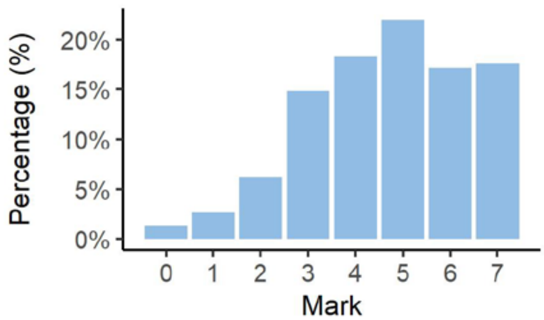
IA3 total



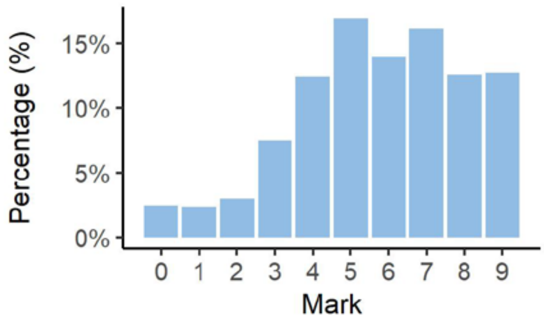
IA3 Criterion: Retrieving and comprehending



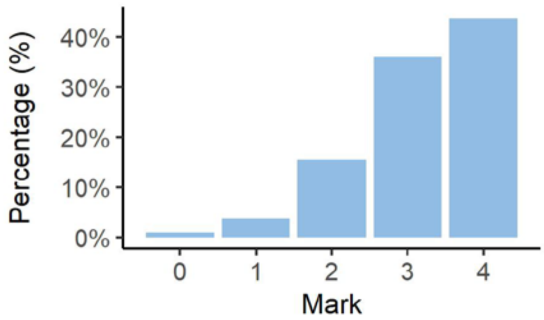
IA3 Criterion: Analysing



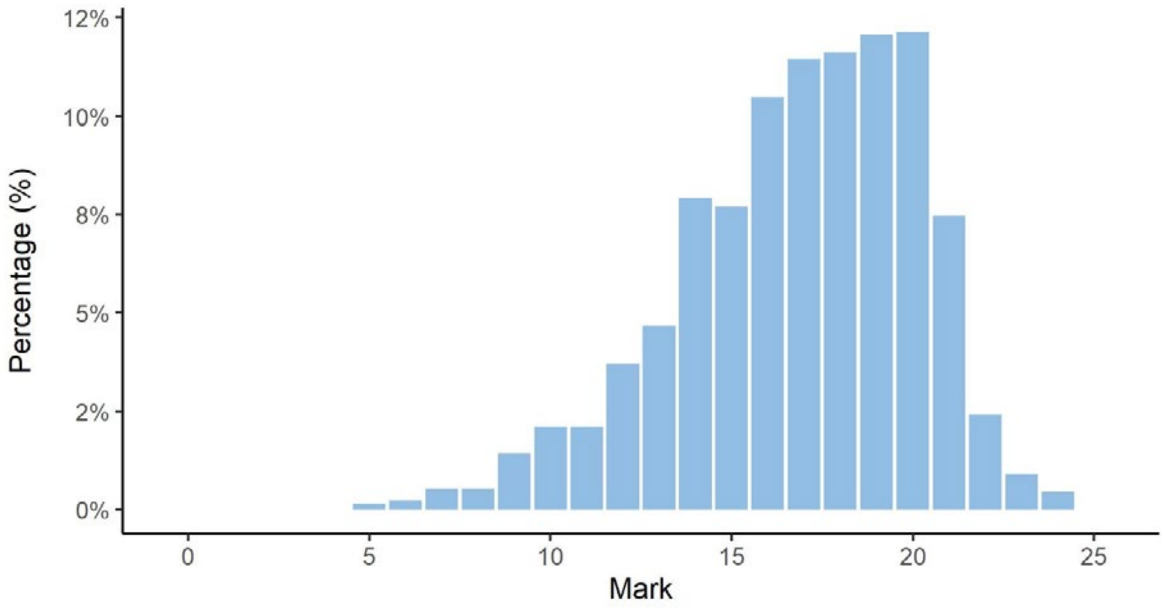
IA3 Criterion: Synthesising and evaluating



IA3 Criterion: Communicating

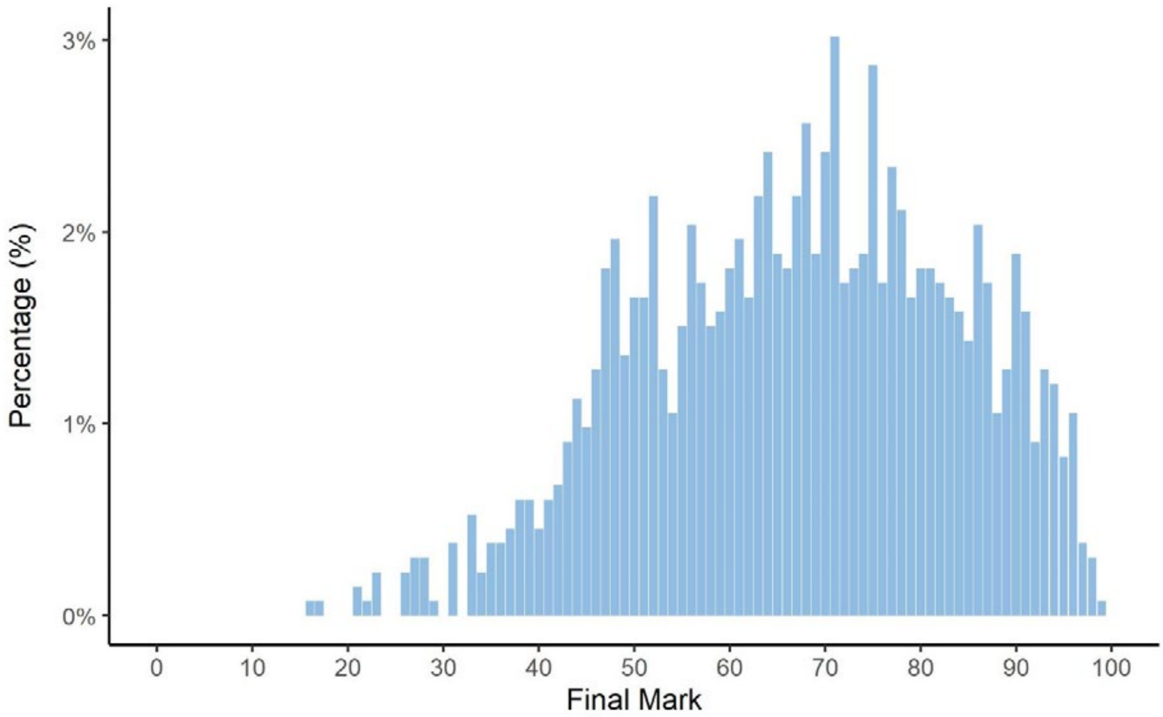


External assessment (EA) marks



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	44–19	18–0

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	269	445	495	115	2

Internal assessment

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

Endorsement

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

Data presented in the Assessment design section identifies the reasons why IA instruments were not endorsed at Application 1, by the priority for 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	91	91	91
Percentage endorsed in Application 1	68%	42%	58%

Confirmation

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

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

Refer to *QCE and QCIA policy and procedures handbook v4.0*, Section 9.6.

The following table includes the percentage agreement between the provisional marks and confirmed marks by assessment instrument. The Assessment decisions section 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	91	556	121	63.74%
2	91	490	0	100%
3	91	549	85	73.63%

Internal assessment 1 (IA1)

Project — folio (25%)

This assessment focuses on a problem-solving process that requires the application of a range of cognitive, technical and creative skills and theoretical understandings. The response is a coherent work that documents the iterative process undertaken to develop a solution to a problem. It may include written paragraphs and annotations, diagrams, sketches, drawings, photographs, tables, spreadsheets and prototypes.

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

Assessment design

Validity

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

Reasons for non-endorsement by priority of assessment

Validity priority	Number of times priority was identified in decisions*
Alignment	7
Authentication	3
Authenticity	6
Item construction	2
Scope and scale	12

*Each priority might contain up to four assessment practices.

Total number of submissions: 91.

Effective practices

Validity priorities were effectively demonstrated in assessment instruments that:

- aligned with the assessment specifications, objectives, ISMG and Unit 3 syllabus subject matter in the development of the context statement and task requirements by
  - providing considered and detailed information about the real-world context relevant to the development of a truss structure
  - effectively specifying the scope of evidence required in the student response
- included a structural problem context that allowed students to demonstrate their knowledge of structures, in particular truss style structures, while enabling the development of unique responses, e.g. it was clear that schools had carefully identified relevant community issues, either local or global, when developing appropriate structural problem contexts

- included the requirement for the use of Unit 3 syllabus subject matter, particularly in relation to engineering technology knowledge, by providing sufficient and relevant detail in the problem context and task requirements for students to develop a response that included considerations of sustainability and environmental issues, e.g. how the solution could be developed to mitigate its impact on the natural, economic and social environments.

Practices to strengthen

It is recommended that assessment instruments:

- include all Part A and Part B assessable evidence as provided (Syllabus section 4.6.1)
- are checked to ensure the information provided to students about the size and requirements for the development and testing of the structural prototype is possible within the syllabus conditions, e.g. the scale, in both dimension and load, 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 solution
- are structured such that students develop unique individual responses, including prototype development. Syllabus conditions state that the Project — folio assessment, e.g. the generation and testing of a physical or virtual prototype, is individual work, and it should be completed as such. Scaffolding (images) should only be included where absolutely necessary and relevant to the task. When included, images should provide students with information that aligns with the task context, e.g. images of relevant and correct road or river crossings, wharf areas. Referring students to the QCAA samples in the assessment instruments or providing students with Project — folio headings is over-scaffolding.

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	9
Layout	0
Transparency	5

*Each priority might contain up to four assessment practices.

Total number of submissions: 91.

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).

Practices to strengthen

It is recommended that assessment instruments:

- use only 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’. Design-related concepts and principles are not included in syllabus subject matter and are not defined in the Engineering syllabus and therefore 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	82.42%	16.48%	1.1%	0%
1	Analysing	73.63%	25.27%	1.1%	0%
1	Synthesising and evaluating	67.03%	30.77%	0%	2.2%
1	Communicating	91.21%	7.69%	1.1%	0%

Effective practices

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

- in the Retrieving and comprehending criterion upper performance levels
  - an account of the structural problem included the knowns and unknowns for problem exploration
  - sketches and drawings with annotations provided information about ideas and a solution
  - testing was used to understand aspects of the problem that were unknown or problematic. For example, testing of materials, truss member joints, length and angle demonstrated recognition of the characteristics of the structural problem
- in the Communicating criterion upper performance levels
  - written and visual features presented information to a technical audience
  - a reference list and a recognised system of in-text referencing was applied.

Samples of effective practices

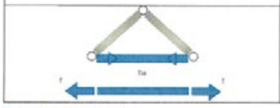
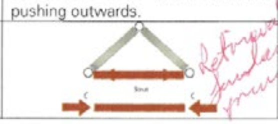
The following excerpts have been included to provide examples of the Retrieving and comprehending criterion 4–5 performance level. Excerpt 1 demonstrates that testing is used to clarify unknowns during exploration of the problem. Annotations on drawings and pictures provides evidence of intellectual perception when providing additional information about ideas and a solution. Excerpt 2 demonstrates evidence of adept symbolisation through engineering drawings that include use of basic drawing standards as defined in the syllabus glossary.

Note: The characteristics identified may not be the only time the characteristics have occurred throughout a response.

Excerpt 1

2.3 Truss Features

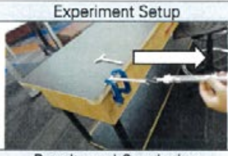
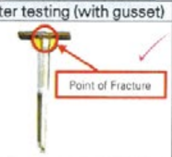
Under the Newton's third law: for every action there is an equal and opposite reaction, each individual part of a truss frame (members) can be treated as a two-force body. An individual member falls into two types being:

Tension members (Ties)	Compression members (Struts)
Members that stretch. It is an industry convention that the arrows are shown pulling on themselves.	Members that are being shortened. They are frequently thickened to prevent buckling. The industry convention shows arrows that are pushing outwards.
	

2.4 Experimentation

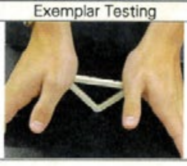
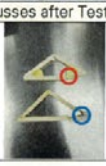
Experiment #1 – T-model Testing

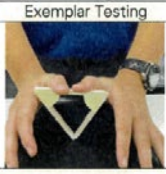
The purpose of this experiment is to determine whether the usage of card gussets influences the joint performance under tension force. Two 150mm length T-models: one with and another without card gusset, have been made up with balsa wood for experiment.

T-models (without & with gusset)	Experiment Setup
	
T-model after testing (with gusset)	**Results and Conclusion**
	T-model *without* card gusset withstood 13N of tension force. T-model *with* card gusset withstood 47N of tension force. Through the experiment, it was found that the use of card gussets is required to prevent tensile failure at joints.

Experiment #2 – Angle of Joints Testing

The purpose of this experiment is to (1) determine the influence of angle on truss performance, and (2) whether usage of card gussets strengths the joint performance under compression force. To do this, four single truss models have been made (2 with, and 2 without card gussets). Then, the compression force has been acted on four single truss models made up of 6.5mm × 6.5mm balsa wood. All trusses used in the experiment have a base length of 10mm, but different angles formed at the joint (45° and 60°).

Single Truss Model with 45° Joint Angle	
Exemplar Testing	**Trusses after Testing**
	
Results	
The truss *without* card gussets withstood 15kg of compression force, and it fractured at the joint (blue circle). However, the truss *with* card gussets withstood 32kg of compression force, and it fractured at its member (strut, red circle).	

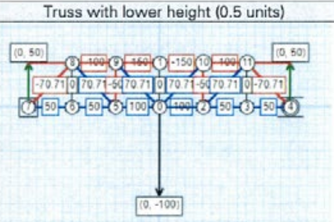
Single Truss Model with 60° Joint Angle	
Exemplar Testing	**Trusses after Testing**
	
Results	
The truss *without* card gussets withstood 22kg of compression force, and it fractured at the joint (blue circle). However, the truss *with* card gussets withstood 38kg of compression force, and it fractured at its member (strut, red circle).	

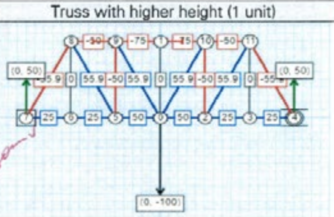
Note: For both experiments, 1kg = 10N

Overall, the experiment proved that (1) larger joint angle increases maximum compressive strength of the truss, and (2) the use of card gussets reinforces the joint performance, by preventing compression failure on joints, while increasing maximum compressive strength of the truss. Thus, the truss bridge to be presented as a solution of the project must be constructed in large joint angle, as well as high height, while ensuring the efficient use of material for cost-efficiency.

2.5 Virtual Testing on the Influence of Height on the Truss Performance

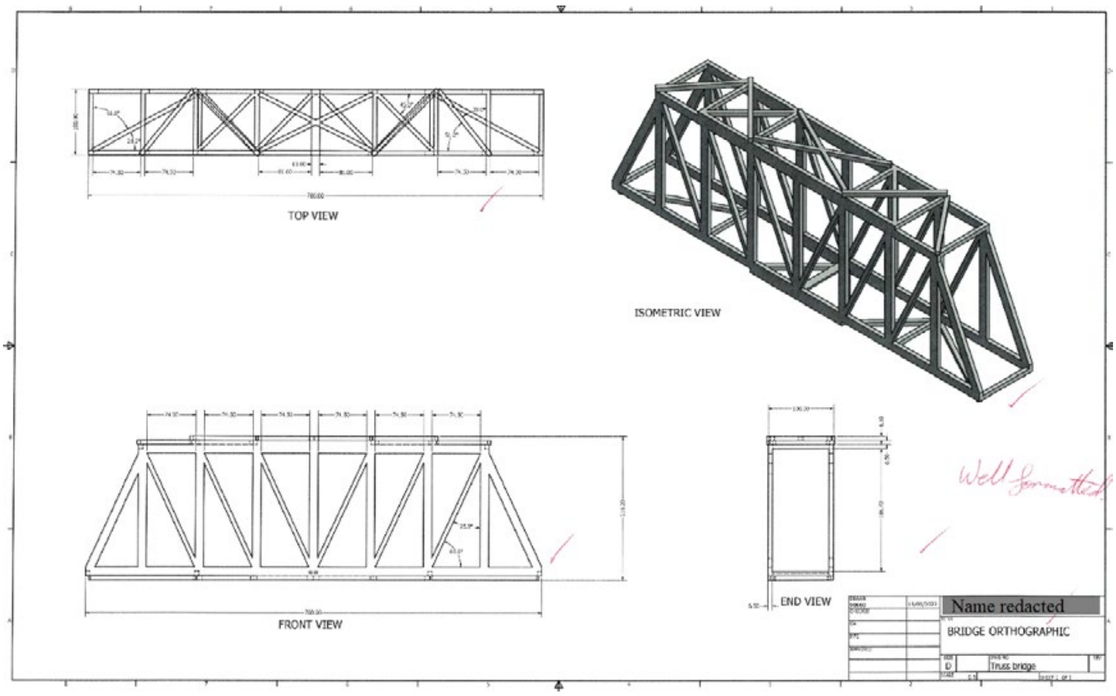
Performance of two Pratt trusses with different height have been compared to determine the effect of the height of the structure on truss performance. Both trusses are made up of 7 nodes, and a vertical force is applied in the centre of the truss. Online truss simulator, JHU simulator, has been utilised to analyse truss performance.

Truss with lower height (0.5 units)	Truss Performance
	Highest Tension Force on the member: 100N Highest Compression Force on the member: 150N Total Tension + Compression forces applied on the structure: 1,424.26N

Truss with higher height (1 unit)	Truss Performance
	Highest Tension Force on the member: 55.9N Highest Compression Force on the member: 75N Total Tension + Compression forces applied on the structure: 885.4N

In summary, it was observed that the higher the height of the truss, the smaller the total amount of force the structure receives. In addition, the maximum tension and compression force applied to the member also received fewer trusses with higher height. Therefore, the truss bridge to be presented as the solution of the project must be constructed high in the line of efficient use of the material.

Excerpt 2



The following excerpts have been included to provide examples of the Analysing criterion 6–7 performance level. Excerpt 1 provides evidence of solution success criteria that are determined to clearly differentiate between the real-world solution and the prototype. Excerpt 2 demonstrates evidence of ideas being developed with an understanding of the problem's characteristics, established using relevant engineering mechanics, materials science, technology and research information.

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

Excerpt 1

3.2 Real-world & Prototype Success Criteria (SSC)

Real-world Bridge Solution Success Criteria

#	Criteria: Reasoning
1	**Design Specification:** The design of the bridge should meet the constraints Setout by the Queensland Road & Highway Department. In order for the bridge to be successful, it must satisfy the given design specification of the client.
2	**Bridge Performance:** The bridge must be able to sustain full legal loads (expected to be 2,000kg, approximately) repeatedly and withstand occasional overloads without being damaged. Global deflection, local deformations, and thermal distortions must be kept to a minimum so that the wearing surface does not crack or spall, internal delamination must not occur, and fatigue problems should not occur at the connection points. This ensures structural rigidity and is directly related to the safety of the bridge: clear limitation of the load force should be made on the bridge to ensure motorists' safety while in use.
3	**Reasonable Cost:** Given that the client is expecting to receive cost-efficient solution, the budget for planning and construction process of the project must be minimised. This includes operational costs such as storage costs, transportation costs, construction costs, etc.
4	**Durability:** Maintenance should be kept to a bare minimum. The bridge must be brittle fracture, and corrosion resistance. Service life of the bridge is expected to be more than 100 years; thus, durability of the material should be considered when determining the real-world bridge construction material.
5	**Constructability:** The bridge should be able to be installed quickly and easily, using light equipment to minimise construction and transport costs.
6	**Environmental Impact:** The structure should have a minimal environmental impact, be simple to maintain during its useful life, and be recyclable when no longer needed.
7	**Strengths on Dynamic Factors:** Corrosion-resistant materials should be chosen, as well as materials that can resist extreme weather conditions such as storms and wind. Furthermore, the construction material should not expand or shrink significantly in response to large temperature fluctuations.

Prototype Bridge Solution Success Criteria

#	Criteria: Reasoning
1	**Bridge Performance:** The prototype bridge should withstand maximum load (expected to be 40kg, or 392N) without any sign of fracture, buckling, or torsion (on left or right side of the structure; unbalanced structure). The high stability, and rigidity of the structure will indicate the successful construction of the prototype bridge.
2	**Lightweight:** The weight of the bridge must be kept light to increase the performance index of the bridge; minimum amount of materials (less than or equal to 15 balsa woods) should be utilised for structural efficiency of the solution.
3	**Distribution of Forces:** The load force applied on the bridge should be efficiently distributed throughout the structure; struts and ties should be applied with similar amount of forces to ensure the stability and balanced structure. Theoretical calculations through the utilisation of Method of Joints can be evidence for this certain criterion.
4	**Structural Efficiency:** The truss bridge's structural efficiency will be determined using the truss performance index: mass supported divided by mass of the structure. The higher the performance index, the more structurally efficient the structure is. Expected performance index for the prototyped bridge is approximately 300. Thus, performance index over 300 resulting from the testing process will be treated as a success.

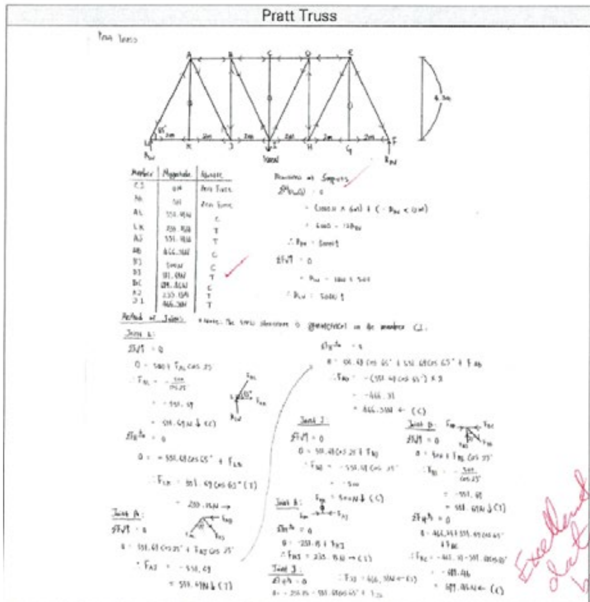
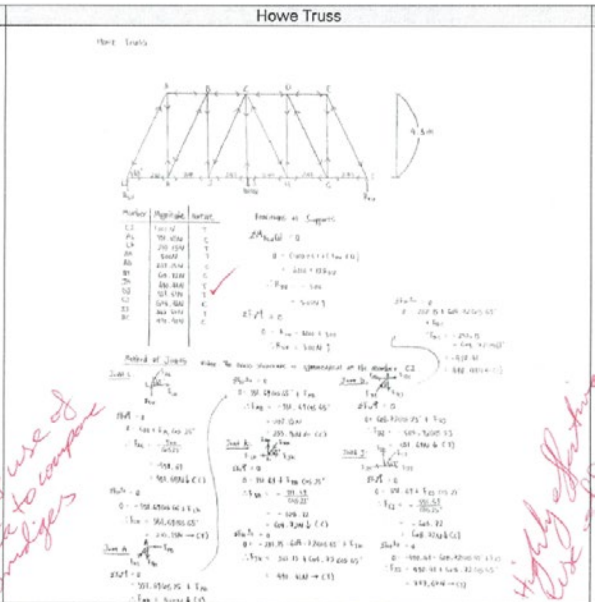
Note: Prototype bridge SSC also applicates into the real-world bridge SSC; it has been separated to specifically evaluate the successfulness of the prototype bridge.

Excerpt 2

4.0 Developing Ideas

4.1 Investigation on the Truss Designs

Three different types of trusses; Pratt, Howe, and Warren, with the same height (4.3m) and the joint angle (65°), have been calculated, analysed, evaluated, and compar
determine the best design for the project: the most cost-efficient and robust design. The performance analysis process has been conducted through the utilisation of rea

Pratt Truss	Howe Truss
	
Total number of Nodes: 12	Total number of Nodes: 12
Total number of Members: 21 (3 Zero Forces, 8 Struts, 10 Ties)	Total number of Members: 21 (10 Struts, 11 Ties)
Total Length of the Truss: 69.88m	Total Length of the Truss: 69.88m
Maximum Tension Force on the Member: 551.69N	Maximum Tension Force on the Member: 1,000N
Maximum Compression Force on the Member: 699.46N	Maximum Compression Force on the Member: 608.72N
Total Force applied on the Truss: 8,504.9N	Total Force applied on the Truss: 11,031.22N
Performance Index (Mass Supported / Mass of Structure): 14.31	Performance Index (Mass Supported / Mass of Structure): 14.31

4.2 Evaluation and Links to SSC

The Pratt Truss has been determined to be the strucutre with the most efficient force distribuion: the amount of maximum tension force and compression force applied on the strut and tie was the closest among other designs. Furthermore, considering that the total number of nodes and members contained throughout the Pratt Truss is more than the Warren Truss, the Pratt Truss has been discovered to perform better than any other trusses on the force application: the total force applied on the Pratt Truss structure was relatively smallest out of three designs. As verified from the *The Way Forward*, the Pratt Truss is the most cost-effective structure which has an advantage of ease of construction, low-self weight, and simple yet well accepted design. This will increase structural efficiency of the bridge by reducing construction costs, have relatively low selfweight, yet is capable of withstanding large amount of loads.	The Howe Truss had a largest maximum tension force as well as a lowest maximum compression force out of three different truss designs applied on the structure. This contributed into the Howe Truss design being more effective than other designs for the aspect of compressive strength, as the members forming the structure are much more susceptible to compression forces than tension forces. However, considering that the Howe Truss has a largest total force applied on the truss, it is a concern whether the Howe Truss would be able to withstand large amount of forces as other desgins trusses would do. As verified from *The Way Forward*, Howe Truss maximises its structural efficiency when the load is applied on the joints located at the bottom chord of the bridge. Considering this applicates to the real-world and prototype environment, Howe Truss is expected to show its maximum efficiency as the motorway bridge.

The following excerpts have been included to provide examples of the Synthesising and evaluating criterion 8–9 performance level. Excerpt 1 provides evidence of a well-structured, rational and valid combining and integrating of information and ideas developed as a result of knowledge gained through research, structural analysis and testing (data). Skilful judgements have been made about the suitability of ideas and the solution with reference to solution success criteria. Excerpt 2 demonstrates that data, including research information, test results and calculations, have been used to assess for strengths, weaknesses, implications and limitations, and to make thoughtful and accurate recommendations.

Note: The characteristics identified may not be the only time the characteristics have occurred throughout a response.

Excerpt 1

5.0 Predicting a Solution

The design of the final solution was sketched with the understanding of solution success criteria. It focused on (1) minimising the total tension/ compression force acting on the truss; (2) minimising the total length of the design (to minimise the amount of material to be used); (3) using the efficient amount of points of concurrency to balance and stabilise the structure; (4) reinforcing members with high risk of fracture when load is applied. Force analysis and magnification from *Developing Ideas* process have been used to classify the members and the size of the force received by each frame. This later helped to make the truss more robust by using additional material for the compression member. As mentioned from the design philosophy, the final solution is constructed to lift at least 2,000kg of loads (for prototype, 40kg).

5.1 Height and Number of Nodes of the Truss

Height

As verified in the *Clarifying Unknowns*, the bridge should be constructed in high height to reduce the total amount of force acting on the structure. However, to ensure the SSC of efficient utilisation of material as well as reasonable cost, the height of the bridge should be decided in line with the minimal use of materials. Thus, it has been decided to set the height of the bridge to be 8.685m (for prototype, 173.7mm).

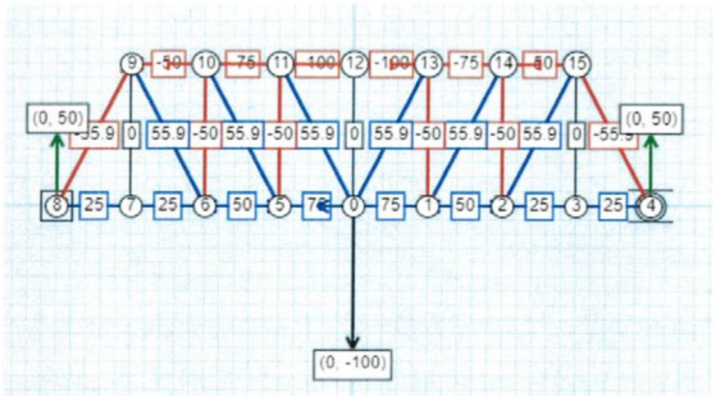
Number of Nodes

Since the structure would have advantage on maximum compressive strength in larger joint angle (refer to *Clarifying Unknowns*), the joint angle of the bridge has been determined to be 65°. With the joint angle determined, increase in the number of nodes of the bridge decreases the height, which has been proved to decrease structural efficiency of the truss from the *Clarifying Unknowns*. Thus, it has been decided to use 16 nodes in total for the solution bridge (7 on top, 9 on bottom).

5.2 Member Lamination

For better structural performance of the bridge, it is essential to reinforce the bridge members under high risk of fracture while it is in use. The method of reinforcement is adding laminations on members (double-lamination, triple-lamination), to provide more strength on them.

The diagram below displays the second-dimension design of the solution bridge, designed throughout the employment of JHU Truss Simulator: dimensions for height and horizontal length might differ from actual solution bridge, however, the focus is the truss's performance and identification of members that requires the reinforcement. The members coloured in red represents struts, while members coloured in blue represents ties.



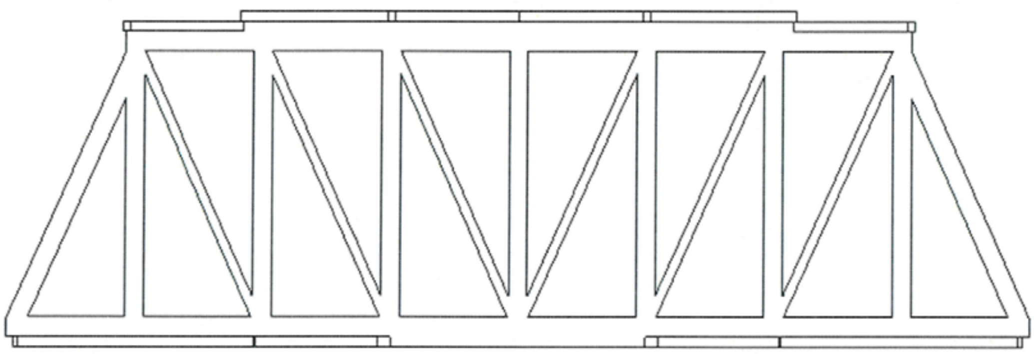
Excerpt 2

6.0 Structural Analysis

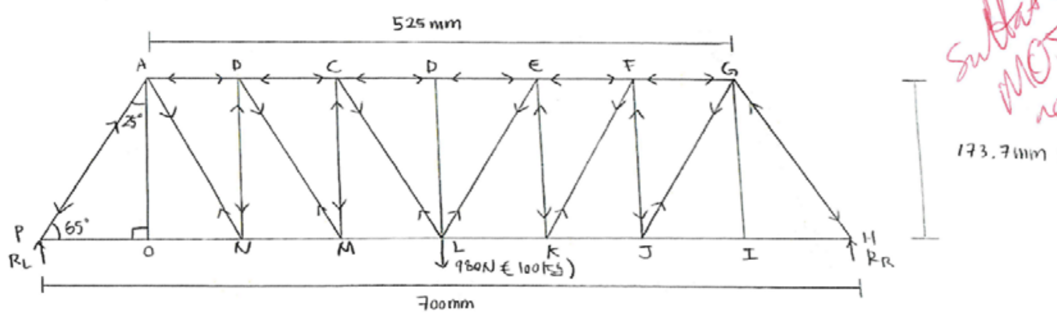
6.1 Joint

The solution truss design derived from previous procedures have been drawn to analyse and evaluate the predicted performance of the final solution bridge. The diagrams below display the second-dimension view of the prototype bridge that will be constructed for testing process. The horizontal length of the truss is 700mm, joint angle of the truss is 65°, and the height of the truss is 212.7mm. The nature of each member (struts or ties) has been identified through the force analysis process. The load acting on the predicted design has been decided to be 100kg, to enable easier calculation of joint analysis – for the bridge applied by $n$kg of load force, magnitude of force can be scaled by 100:n (1kg = 9.8N). Given that the design philosophy of the project suggest that the prototype model should withstand 40kg (=392N) of load, the prediction of prototype model's joint analysis will be measured by using ratio of 100:40 (or 980:392).

Note: The dimension of the sketch has been scaled by 1:50 to the actual size of the prototype bridge. In comparison with real-world bridge, the sketch has a ratio of 1:2500.



Space Diagram of the Final Design



Free Body Diagram of the Final Design

6.2 Performance Analysis

Throughout the RaS calculation, it has been determined that the reaction force on left support and right support equals, proving that the truss structure is symmetrical on the centre member.

The mathematical investigation of the solution bridge when 100kg (= 980N) load force applies on the structure discovered that, the maximum compression force that the truss should withstand is 913.97N, while the maximum tension force the truss should withstand is 664.06N. The minimum compression force applied on the strut has been determined to be larger than the mimimum tension force on the tie, thus, every strut (compression member) has been at least double laminated as a reinforcement (refer *Predicting a Solution* for further elaboration).

The joint analysis has enabled the project team to predict the member of failure – given that the members are weaker on compression force than tension force, the structure may fail at the member which maximum compression force will be applied – that is, member CD or DE froom the free body diagram above. However, as these members will be triple laminated (refer to *Prediction a Solution*), they are more unlikely to fail. Other potential member that may fail is member AP or GH, which they are applied by third largest compression force among the structure. These members will be double-laminated, so it may possible fail when the compression force exceeds the compressive strength of double-laminated materials.

Practices to strengthen

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

- in the Analysing criterion upper performance levels
  - the problem-solving process focuses on development of the real-world solution and not the prototype, e.g. solution success criteria primarily relate to the real-world structural problem. This emphasises the real-world connection of the data generated through prototype testing
  - an understanding of the structural problem's characteristics has been established using knowledge of engineering mechanics, materials science and technology developed through research, testing and data analysis
- in the Synthesising and evaluating criterion upper performance levels
  - prototype testing provides performance data used to evaluate aspects of the real-world structural solution, e.g. the internal forces experienced by a structure and how ideas or the real-world solution may be refined to improve performance
  - decisions are made about the relative value or worth of data, including research information, test results and calculations when evaluating ideas and the real-world structural solution
  - engineering mechanics, materials science, technology, research information, data and ideas are used to develop a structural solution. For example, data, including research information, test results and calculations are used to evaluate and make recommendations about the suitability of ideas and the real-world structural solution with reference to solution success criteria.

Additional advice

- The conditions for a Project — Folio Part A are 7–9 A3 pages, and for Part B, 2–3 A4 pages. During the drafting process, or when providing feedback, students must be supported to develop skills in managing the length, scope and scale of their responses appropriately and within the syllabus conditions.
- Appendices are not assessable evidence and as such should not be included in student responses. If an appendix is included, it should contain only supplementary material that will not be directly used as evidence when marking the response (*QCE & QCIA policy and procedures handbook v4.0* Section 8.2.6).

Internal assessment 2 (IA2)

Examination — short response (25%)

The examination assesses the application of a range of cognitions to multiple provided items — questions, scenarios and problems.

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

Assessment design

Validity

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

Reasons for non-endorsement by priority of assessment

Validity priority	Number of times priority was identified in decisions*
Alignment	41
Authentication	0
Authenticity	1
Item construction	11
Scope and scale	2

*Each priority might contain up to four assessment practices.

Total number of submissions: 91.

Effective practices

Validity priorities were effectively demonstrated in assessment instruments that:

- were developed to include an appropriate balance across the assessment objectives using a range of multiple-choice, single-word, sentence, short-paragraph and calculation items
- 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 cognitions required to respond and the evidence in the student response, e.g. complex unfamiliar questions include a number of elements and not all the information required to solve the problem is immediately identifiable. These questions focus on Assessment objectives 3 and 5. Such questions require sustained analysis and synthesis of relevant information to develop responses. A complex unfamiliar question should be allocated more marks than a complex or simple familiar question due to the cognitions required, and the nature and extent of the evidence expected in the student response.

Practices to strengthen

It is recommended that assessment instruments:

- include only items that assess Unit 3 subject matter e.g. stress/strain and ultimate tensile strength calculations are Unit 2 subject matter
- structure complex unfamiliar questions so not all the information to solve the problem is immediately identifiable. Students should engage in sustained analysis and synthesis of relevant information to develop a response, e.g. short-paragraph response questions, such as those including images of structures constructed using innovative technologies and techniques for particular communities, should provide opportunities for interpretation using Unit 3 subject matter in the development of unique responses
- include accurate and clear diagrams only where appropriate. When diagrams are included, they should not provide information that supports a response to other items in the instrument, e.g. a diagram showing where concrete is reinforced with steel should not be included if another item requires a diagram to be drawn using the same or similar subject matter knowledge of steel reinforced concrete.

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	9
Language	9
Layout	2
Transparency	3

*Each priority might contain up to four assessment practices.

Total number of submissions: 91.

Effective practices

Accessibility priorities were effectively demonstrated in assessment instruments that:

- structured questions using Unit 3 syllabus language, e.g. questions that required students to solve truss analysis problems included terms, concepts and principles taken directly from the syllabus, such as roller and pin support, actions, loads and reactions
- aligned the expected response for questions indicated in the marking scheme with the response space provided in the instrument for sentence, short paragraph and calculation questions.

Practices to strengthen

It is recommended that assessment instruments:

- ensure diagrams have been 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

- provide clear instructions within items 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 dry, wet and stress corrosion should use instructions such as ‘explain’, ‘compare’ or ‘contrast’ to clearly inform students about the cognition involved and the type of response required.

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
2	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:

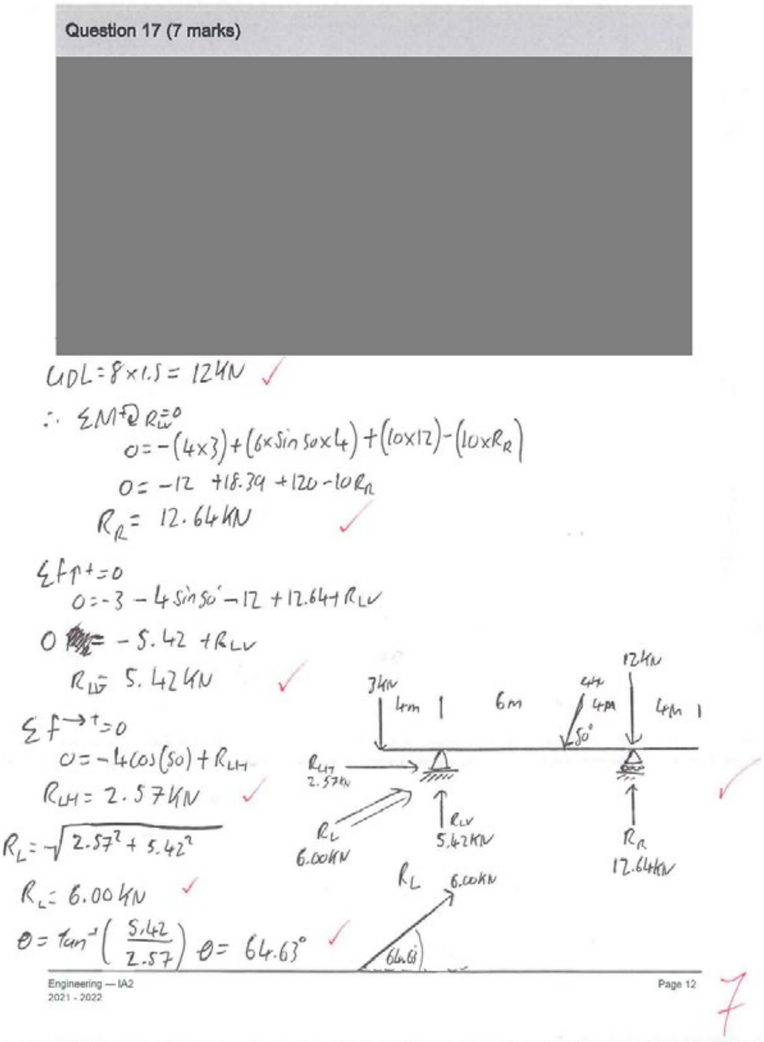
- the evidence provided in student responses to short-paragraph questions using key terms and ideas was clearly identified in the marking scheme
- marking schemes included clearly defined and well set out expected student responses that identified the full range of circumstances for the allocation of marks for each question
- the response to calculation questions identified where follow-through errors occurred and this was clearly stated in the marking scheme.

Samples of effective practices

The following excerpt has been included to provide evidence of a well-structured response to a question that required calculating reactions at beam supports. A free body diagram was required with the response. Marks are clearly annotated and the total mark for the question is included with the response.

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

Excerpt 1



Practices to strengthen

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

- the ISMG is accurately used to determine a mark out of 25. 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. $\frac{47}{80} = 58.8\% = \frac{14}{25}$
- annotations on responses clearly indicate the total marks awarded for each question and that the ticks for each question correlate with the marks awarded and with marking schemes to support student understanding
- marking schemes are refined to clearly identify where and how marks are awarded and accurately reflect the decisions made to allocate marks for each question. If an error is found in the marking scheme, it must be amended to reflect the accurate and consistent allocation of marks for each question across the cohort.

Additional advice

- Upload an amended marking scheme for confirmation if this was used to determine student marks for the examination. The amended marking scheme must support the confirmation process and clearly indicate the mark allocations for all examination questions in the one document.
- 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.
- Upload a marking scheme with the student response for comparable assessment as detailed in the Engineering confirmation submission information, Section 2.2.

Internal assessment 3 (IA3)

Project — folio (25%)

This assessment focuses on a problem-solving process that requires the application of a range of cognitive, technical and creative skills and theoretical understandings. The response is a coherent work that documents the iterative process undertaken to develop a prototype solution to a problem, situation or need. It includes written paragraphs and annotations, diagrams, sketches, drawings, photographs, tables, spreadsheets and prototypes.

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

Assessment design

Validity

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

Reasons for non-endorsement by priority of assessment

Validity priority	Number of times priority was identified in decisions*
Alignment	21
Authentication	2
Authenticity	4
Item construction	8
Scope and scale	5

*Each priority might contain up to four assessment practices.

Total number of submissions: 91.

Effective practices

Validity priorities were effectively demonstrated in assessment instruments that:

- included real-world contexts that were 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 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 opportunities to provide evidence that aligned with the assessment specifications, i.e. the syllabus assessment specifications were included in the instrument without alteration or omission

- were structured to ensure the response was the result of individual work. Group work in any form is not a syllabus condition for Project — folio assessment, i.e. the generation and testing of a physical or virtual prototype is individual work and should be completed as such.

Practices to strengthen

It is recommended that assessment instruments:

- include all Part A and Part B assessable evidence (see Syllabus Section 5.6.1)
- ensure students have the opportunity to apply their knowledge of Unit 4 content during problem-solving, e.g. students should apply knowledge of machine or mechanism control technologies as described in Unit 4 content and defined in the syllabus glossary
- include a focus on the development of a solution to the mechanical and/or mechanisms engineering problem in a real-world context, rather than on the prototype. The data generated through prototype testing is 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 data used to evaluate and refine the predicted real-world mechanical and/or mechanisms solution
- are checked to ensure the information provided to students about the size and requirements for the development and testing of the mechanical and/or mechanisms prototype is possible within the syllabus conditions, e.g. the dimensional scale, materials and processes should be appropriate for the assessment conditions.

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	1
Language	12
Layout	0
Transparency	2

*Each priority might contain up to four assessment practices.

Total number of submissions: 91.

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 5.6.1)
- contained stimulus images only when required and, when included, met with task requirements, e.g. an image was 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 therefore 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
3	Retrieving and comprehending	89.01%	8.79%	1.1%	1.1%
3	Analysing	81.32%	17.58%	0%	1.1%
3	Synthesising and evaluating	80.22%	18.68%	1.1%	0%
3	Communicating	92.31%	6.59%	1.1%	0%

Effective practices

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

- in the Retrieving and comprehending criterion upper performance levels
  - selection and use of engineering technology knowledge (sustainability impacts), and mechanics, control technologies and materials science fundamentals in relation to the machines and/or mechanism problem was clearly identified
  - an account of the problem included the knowns and unknowns for problem exploration
- in the Communicating criterion upper performance levels
  - use of written and visual features presented information to a technical audience
  - a reference list and a recognised system of in-text referencing was applied.

Samples of effective practices

The following excerpts have been included to provide examples of the Retrieving and comprehending criterion 4–5 performance level. Excerpt 1 demonstrates that testing is used to clarify unknowns during exploration of the problem. The stress–strain graph and accompanying text provides evidence of the consistently correct identification of the characteristics of the machine and/or mechanism problem, with thoughtful and astute choices made in the selection and use of Unit 4 materials science concepts and principles. Excerpt 2 demonstrates evidence of adept symbolisation through engineering drawings, including use of basic drawing standards as defined in the syllabus glossary.

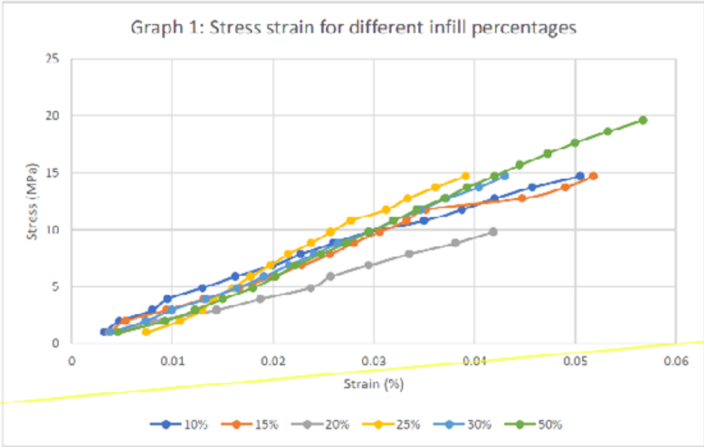
Note: The characteristics identified may not be the only time the characteristics have occurred throughout a response.

Excerpt 1

Clarifying unknowns through research and testing

Infill testing

The infill percentage and shape of 3D printed objects can be modified using the 3D printer program. The infill percentage changes the density of the plastic within the 3D printed object. The effect of infill on the produced stress-strain graph was investigated by compressing various test samples. The results of the test can be seen in graph 1. The infills all had similar trends with comparable gradients, thus all having similar values for young's modulus, as would be expected as the material remains constant. Where the samples differ is their yield strength. Yield stress is the point at which young's modulus ends and deformation becomes plastic, it is the maximum stress the material can withstand before permanently become distorted. Generally, as the infill percentage increased, so did the yield stress as anticipated as there was more material resisting the compressive force. Thus increasing the infill percentage increases the yield stress of the member, therefore any members or parts under significant stress in the prototype should have high infill percentages to ensure it can resist such a force.



Infill shape and orientation testing

The pattern of the infill can be changed when 3D printing parts. To investigate if different infill patterns effected the loading behaviour of the material 3 different infill patterns were tested. Further, a secondary test investigated the effect of the infill orientation when loaded and its effect on the Yield point of the material. In graph 2 the different infill patterns are tested with the load being applied parallel to the direction of the infill, all samples had 10% infill. All of the infill patterns produced similar results with almost identical trends, indicating that the infill pattern doesn't greatly impact loading ability as there is the same amount of material axially resisting that force. The text data did show however that the diamond infill had the highest yield load of 170kg. The samples behaved very differently when they were loaded perpendicularly to the direction of the infill. As seen in graph 3, they failed catastrophically, not tapering off like they did when loaded axially. This means there is only elastic deformation before the yield point, further the yield points had very similar values in both tests, thus the direction of the load only impacts the deformation behaviour, not the yield point of the part. As the diamond infill had the highest yield point and the greatest Youngs modulus, diamond infill will be used in all 3D printed parts.

Excerpt 2

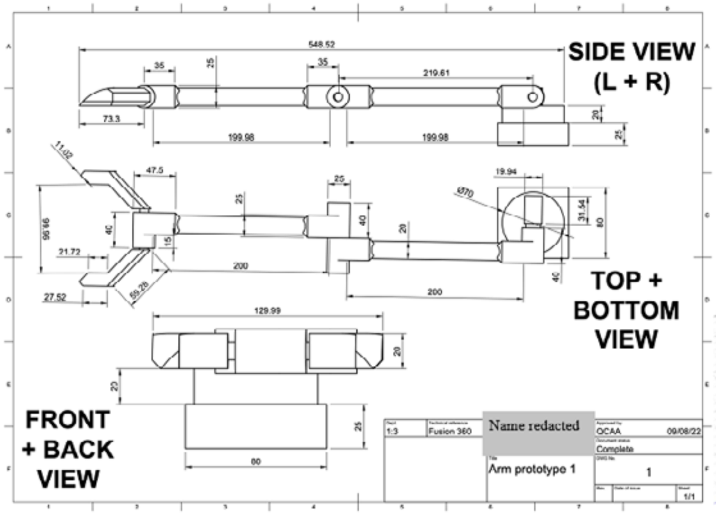


Figure 15: Mechanical Arm Sketch

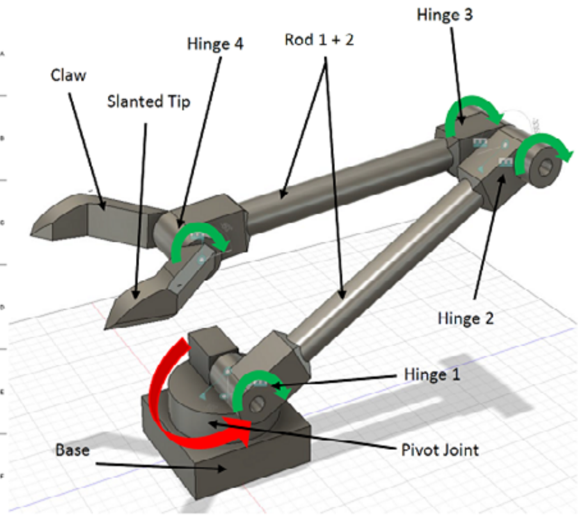


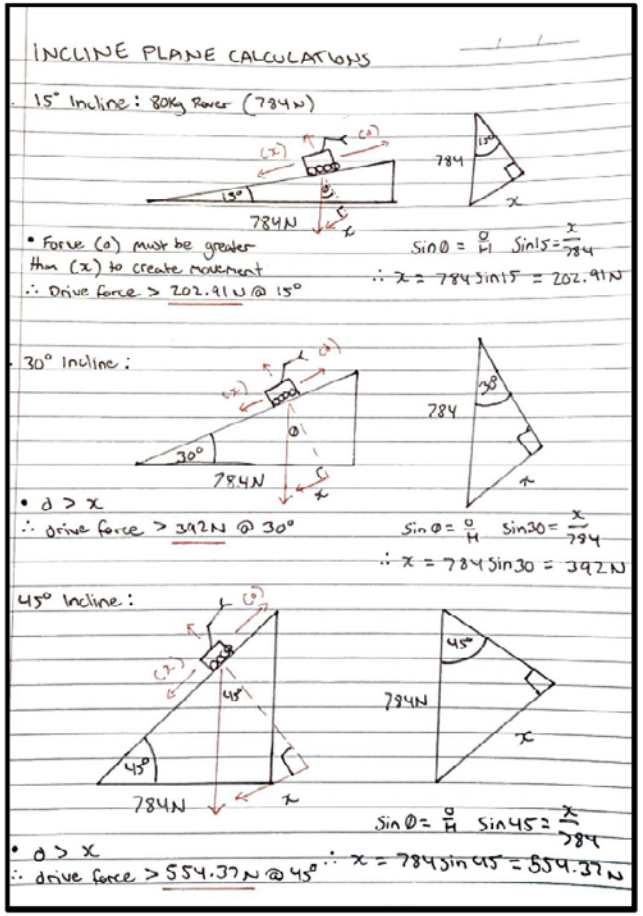
Figure 16: Mechanical Arm Prototype 1

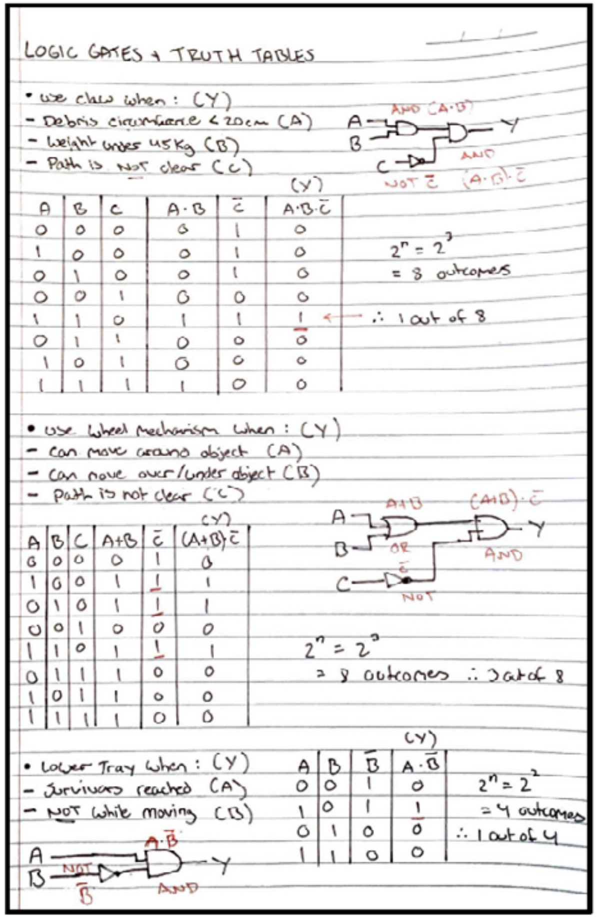
Rover Arm Analysis and Evaluation: In order to move obstacles that are in the rover's path, an arm prototype was developed (figure 16). This feature is equipped with a stainless steel 17-4p rod and claw which can lift a maximum of 45kg (441N). Because the arm is subjected to a large amount of force, stainless steel is the most suitable material to use due to high levels of UTS (600Mpa) and yield strength (550MPa). Although the carbon steel alloy has similar qualities, due to its high levels of thermal conductivity it would not be appropriate in hot/humid environments. The bottom pivot joint is a 70mm cylinder base which allows for rotational movement via the y axis only, essentially allowing the arm to spin a full 360 degrees (red arrow). Hinge joints were used as connectors as they restrict the arm's movement to be only vertical, making lifting objects more stable in a fixed position (green arrow). The two rods are 25ml thick and 200ml long each. Combing these figures with the other connectors and claw, the mechanic arm has a total length span of roughly 0.55m (548.52mm). Also, the claw is designed in a way to not only clamp onto objects but can slide underneath and move larger pieces of debris due to the slanted edges. All of the joints can be rotated to fully collapse the arm, allowing it to fit easier in confined spaces which are too dangerous for humans According to Fusion 360, the stainless steel arm weighs approximately 25kg, therefore obtaining an almost double strength to weight ratio of 1.8:1. This is important as the rover as a whole must be light yet still strong enough to undertake difficult tasks.

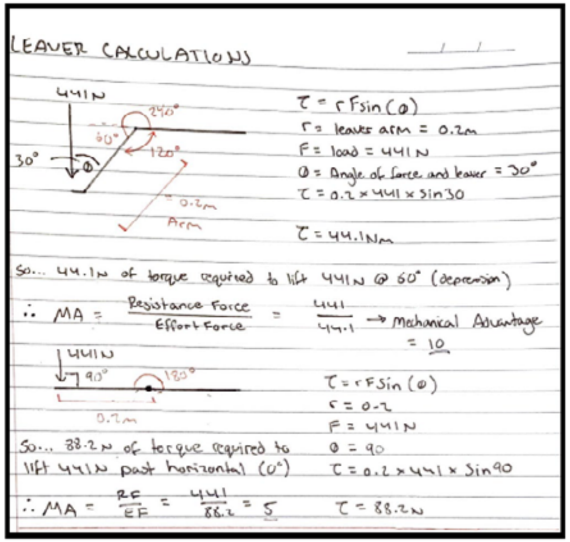
The following excerpts have been included to provide examples of the Analysing criterion 6–7 performance level. Excerpts 1 and 2 provide evidence of Unit 4 mechanics and control technologies analysis of a machine and/or mechanism problem. Ideas are developed with an understanding of the problem's characteristics, established using pertinent engineering mechanics, materials science, technology and research information. Excerpt 3 demonstrates evidence of solution success criteria that are determined to clearly differentiate between the real-world solution and the prototype.

Note: The characteristics identified may not be the only time the characteristics have occurred throughout a response.

Excerpt 1







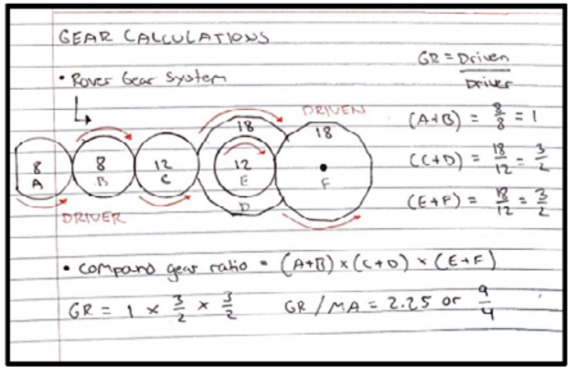


Figure 27: Gear Calculations

Incline Plane: The above calculations found the different driving forces required to create movement over various incline surfaces. Assuming the rover weighs less than 80kg, 784N was used as a control variable for the vertical force. It was found that 202.91N of force is required to move along a 15° incline. When the incline increased to 30°, the required force needed also increased to 392N. Finally, a large force of 554.37N is needed to travel up a 45° incline.

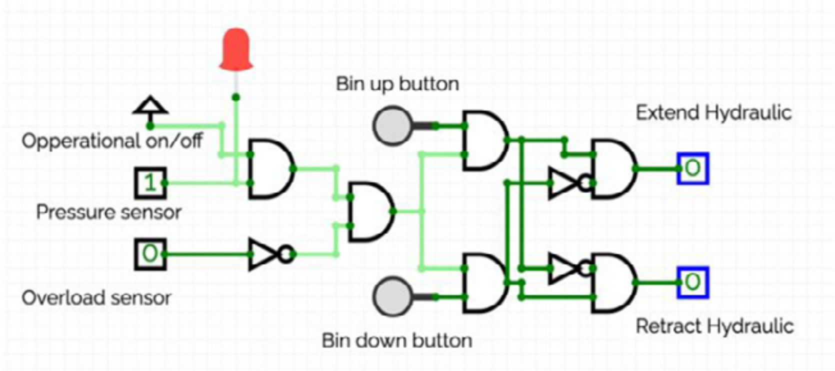
Logic Gates + Truth Tables: Automated systems were implemented to allow the rover to undertake tasks without manual input. This is useful if communications disconnect. Unless the required conditions are met (such as weight), the rover will shut down or place the object down for safety reasons. The rover will also only use various features such as the arm, suspension, or storage when a certain scenario is present.

Mechanical Advantage calculations: Leaver calculations were compassed to generate the figures of torque and mechanical advantage involved with lifting a 45kg object (441N). To lift an object from the ground to horizontal, 44.1Nm of torque is required. To then further lift the object above the horizontal, 88.2Nm is needed. The mechanical advantage of these systems was calculated at 5 and 10. Gear ratios were also calculated with reference to the rover's gear combinations within the motor, generating a mechanical advantage of 2.25MA based on the above calculations.

Excerpt 2

Control technologies

Logic gates with on/off logic will be used to control and automate the machine. Several redundancies and safety measures will be built into the logic design to ensure its safe operation. The first iteration included a pressure sensor which monitored the force applied through the gripping mechanism, when activated the light would turn on indicating it was safe to raise or lower the bin. Further, an overload sensor would trigger if the bin was overloaded putting too much strain through the mechanism. This would deactivate any other commands if activated. Finally, an exclusive loop was added to ensure the pneumatic wasn't both extended and retracted at the same time.



Inputs				Outputs		
Pressure sensor	Overload sensor	Up button	Down button	Extend pneumatic	Retract pneumatic	Pressure sensor light
1	0	1	0	1	0	1
1	0	0	1	0	1	1
1	0	1	1	0	0	1
1	1	1	0	0	0	1
0	0	1	0	0	0	0
0	0	0	1	0	0	0

Limitations of this first model include the lack of limiter sensors that stop the over extension and retraction of the linear actuator, protecting it and the machine from damage. Further, there was no automation of the action of the grabbing arms. These issues were addressed in the second iteration.

Excerpt 3

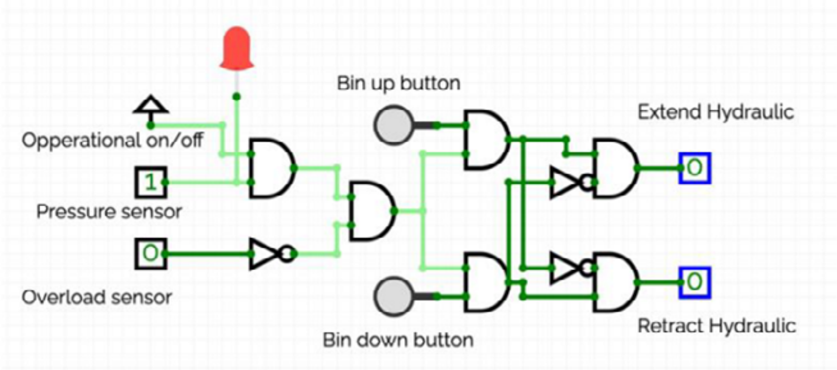
The way forward

Success criteria

- The prototype must lift and tilt a scaled fully laden, standard sized, 240L wheelie bin with a scaled load of 252g. Thus, ensuring it can lift a bin with a mass of 170.5g, the maximum mass allowed by the GCCC. This will give the machine a factor of safety of 1.24.
- The wheelie bin must be tilted to at minimum of 20° above the horizontal and be able to completely empty the contents of the bin when it is tilted. It should not spill any of its rubbish, all contents must land inside the $3m^3$ skip.
- Must include a system of parts and simple machines and mechanisms.
- The prototype must be automated, thus control systems must be considered and planned into the prototype.
- 3D printed parts of the prototype will use the diamond infill and any parts under high compressive or tensile loads should use high infill percentages. Further, any sections under a large bending moment should use 5 shells.
- The actual machine should be only need one person to operate and move it. Thus, it should be free standing and lightweight to allow for its easy transport between skips.
- The materials used for the actual bin tipper must be corrosion resistant, tough, hard and not fatigue from repeated use. The machine will be heavily used and is likely to be treated roughly, thus the material must be able to withstand the repeated use. Further, parts likely to wear or be damaged should be easily replaceable by staff on site, furthering the machines life span.
- The actual bin tipper should have as minimal impact as possible on the environment both in its manufacturing and use on site.
- The actual tipper should make use of either a hydraulic or pneumatic piston system to drive the machine. The system should be powered by a rechargeable battery.
- The control system of the actual tipper must ensure the machine can only be used in its safe, intended way. Thus, using sensors and limiters to stop the bin being raised when not properly secured or overextending a part past its intended range of movement.

Control technologies

Logic gates with on/off logic will be used to control and automate the machine. Several redundancies and safety measures will be built into the logic design to ensure its safe operation. The first iteration included a pressure sensor which monitored the force applied through the gripping mechanism, when activated the light would turn on indicating it was safe to raise or lower the bin. Further, an overload sensor would trigger if the bin was overloaded putting too much strain through the mechanism. This would deactivate any other commands if activated. Finally, an exclusive loop was added to ensure the pneumatic wasn't both extended and retracted at the same time.



Inputs				Outputs		
Pressure sensor	Overload sensor	Up button	Down button	Extend pneumatic	Retract pneumatic	Pressure sensor light
1	0	1	0	1	0	1
1	0	0	1	0	1	1
1	0	1	1	0	0	1
1	1	1	0	0	0	1
0	0	1	0	0	0	0
0	0	0	1	0	0	0

Limitations of this first model include the lack of limiter sensors that stop the over extension and retraction of the linear actuator, protecting it and the machine from damage. Further, there was no automation of the action of the grabbing arms. These issues were addressed in the second iteration.

The way forward

Success criteria

- The prototype must lift and tilt a scaled fully laden, standard sized, 240L wheelie bin with a scaled load of 252g. Thus, ensuring it can lift a bin with a mass of 170.5g, the maximum mass allowed by the GCCC. This will give the machine a factor of safety of 1.24.
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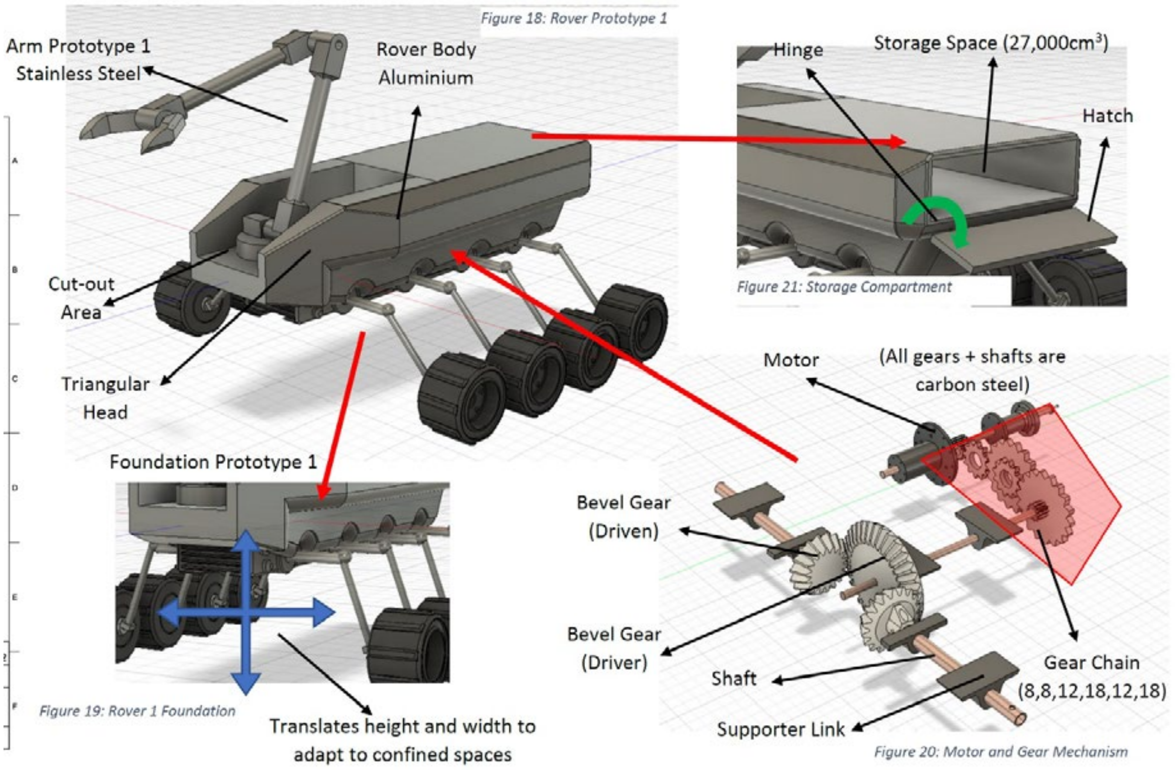
- The materials used for the actual bin tipper must be corrosion resistant, tough, hard and not fatigue from repeated use. The machine will be heavily used and is likely to be treated roughly, thus the material must be able to withstand the repeated use. Further, parts likely to wear or be damaged should be easily replaceable by staff on site, furthering the machines life span.
- The actual bin tipper should have as minimal impact as possible on the environment both in its manufacturing and use on site.
- The actual tipper should make use of either a hydraulic or pneumatic piston system to drive the machine. The system should be powered by a rechargeable battery.
- The control system of the actual tipper must ensure the machine can only be used in its safe, intended way. Thus, using sensors and limiters to stop the bin being raised when not properly secured or overextending a part past its intended range of movement.

The following excerpts have been included to provide examples of the Synthesising and evaluating criterion 8–9 performance level. Excerpt 1 provides evidence of a well-structured, rational and valid combining and integrating of information and ideas developed as a result of knowledge gained through research, analysis and testing (data). Skilful judgements have been made about the suitability of ideas and the solution with reference to solution success criteria. Excerpt 2 demonstrates that data, including research information, test results and calculations, have been used to assess for strengths, weaknesses, implications and limitations, and to make thoughtful and accurate recommendations.

Note: The characteristics identified may not be the only time the characteristics have occurred throughout a response.

Excerpt 1



Excerpt 2

Final Product and Future Recommendations: After a careful study of calculations, simulations, and several prototypes, many adjustments were made to optimise the reliability and efficiency of the design, culminating in a final rescue rover for the National Japanese Emergency Association (NJEA). Instead of originally having a simple connection via a hinge joint for the foundations, a sliding pin was incorporated to generate suspension by moving the rover up and down. This not only increased the wide range of mobility for the wheels but also increased the strength of each of the 8 supports as it absorbs the vertical forces through linear movement. In conclusion, a successful rescue rover prototype was generated and has the ability to move objects through leavers (<45kg), drive up stairs and incline planes, generate energy efficient power through gear combinations, manoeuvre over and under rubble in confined spaces, manipulate size and orientation (rotating arm and legs) to reach difficult places, commence automation tasks if connection is lost, deliver resources and equipment to survivors (<30kg), and can collapse into a small structure for easy transportation. Such tasks are demonstrated below (figure 35).

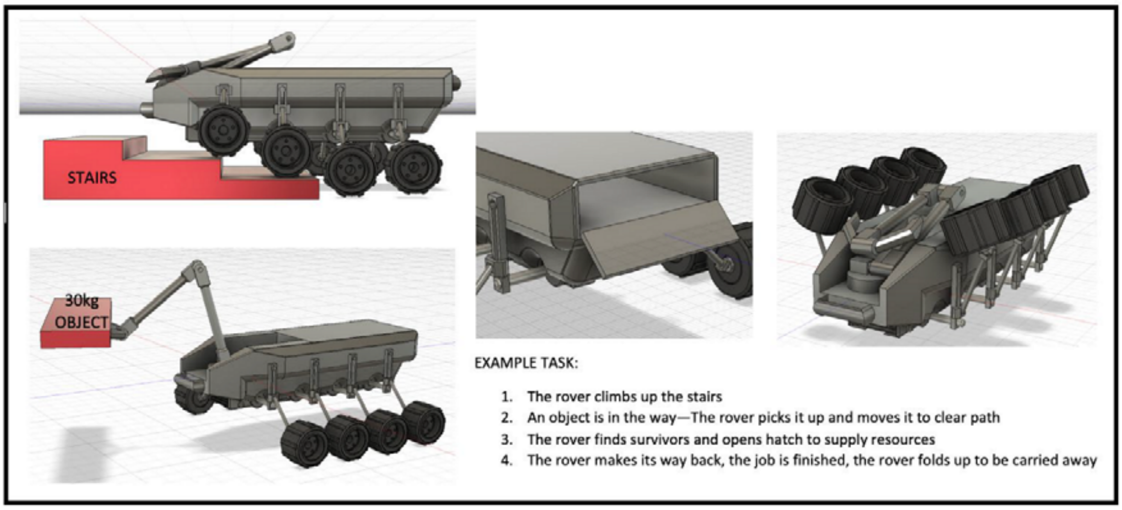


Figure 34: Final Rescue Rover Performing Task

Practices to strengthen

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

- in the Analysing criterion upper performance levels
  - the problem-solving process focuses on development of the real-world solution and not the prototype. For example, solution success criteria primarily relate to the real-world machine and/or mechanism problem. This will emphasise the real-world connection of the data generated through prototype testing
  - an understanding of the problem’s characteristics is established using engineering mechanics, control technologies, materials science and technology information developed through research, testing and data analysis
- in the Synthesising and evaluating criterion upper performance levels
  - justified recommendations for development and refinement of ideas and a real-world solution are made throughout the problem-solving process
  - data, including research information, test results and calculations, are used to evaluate the suitability of ideas and the real-world machine and/or mechanism solution with reference to solution success criteria.

Additional advice

- The conditions for a Project — Folio are: Part A, 7–9 A3 pages; and Part B, 2–3 A4 pages. During the drafting process, or when providing feedback, students must be supported to develop skills in managing the length, scope and scale of their responses appropriately and within the syllabus conditions.
- Appendices are not assessable evidence and as such should not be included in student responses. If an appendix is included, 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 v4.0* Section 8.2.6).

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 questions (10 marks)
- Paper 1, Section 2 consisted of 7 short response written questions (41 marks)
- Paper 1, Section 3 consisted of 5 short response calculation questions (34 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 questions.

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 question responses

There were 10 multiple choice questions.

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	23.56	6.53	**60.18**	9.42
2	4.48	23.18	3.57	**68.24**
3	20.52	31.08	**42.78**	4.41
4	26.37	**41.79**	25	6.08

Question	A	B	C	D
5	**33.13**	19.15	33.81	12.16
6	9.57	**69.07**	8.43	12.46
7	7.9	31.53	21.12	**38.75**
8	8.81	13.37	**65.05**	12.01
9	7.9	**63.22**	16.41	11.7
10	10.71	**63.15**	2.74	22.87

Effective practices

Overall, students responded well to:

- simple familiar, complex familiar and complex unfamiliar calculation questions that required knowledge of incline planes, friction force, and the equations of motion
- simple familiar and some complex familiar questions that required them to identify or explain concepts, principles and situations using knowledge of mechanics and materials science subject matter
- simple familiar questions that required the use of logic control subject matter knowledge.

Samples of effective practices

Short response

Paper 1: Question 11

This simple familiar question required students to:

- explain the concepts of mechanical advantage (MA) and velocity ratio (VR) using a simple pulley system
- support their explanation using an annotated sketch of a simple pulley system.

Effective student responses:

- provided a clear written explanation of mechanical advantage that included the ratio of the load force to the effort force or the number of ropes supporting the load
- provided a clear written explanation of velocity ratio that included the ratio of the effort distance to the load distance
- provided an annotated sketch that clearly labelled the effort and load force to support the student response
- provided the mechanical advantage or velocity ratio based on the annotated sketch.

This excerpt has been included:

- to provide a high-level response that demonstrates how an annotated sketch may be used to reinforce key points highlighted in an appropriate explanation concerning the concepts of MA and VR.

Excerpt 1

$VR = 2$

$100\% = \frac{MA}{2}$

$MA = 2$

$MA = \frac{F_c}{F_E} = \frac{(10 \times 9.8)}{F_E}$

$F_E = 49N$

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.

Velocity Ratio is determined by distance effort over distange load. For every metre the block is raised, the rope has to be pulled 2 meteer, giving it a Velocity Ration of (2:1). Mechanical advatage without friction (100% efficency) is equal to the velocity ratio. Mechanical advatage compares the Force load to the Force effort, in this case with the pully system, the force effrt will be half that of the force load.

Paper 1: Question 15

This complex familiar question required students to:

- contrast the suitability of mild and high carbon steel in an industrial context where the materials would experience repeated loads and high impacts
- use the microstructure of mild and high carbon steel and three relevant mechanical properties in their response.

Effective student responses:

- contrasted mild and high carbon steel microstructures
- contrasted three relevant mechanical properties of the two materials considering their microstructures
- justified the suitability of the materials used in the provided industrial context.

These excerpts have been included:

- to illustrate a high-level response that contrasts the suitability of the materials using knowledge of mild and high carbon steel microstructure and three relevant mechanical properties to justify why mild carbon steel is the preferred option in the given industrial context.

Excerpt 1

Mild carbon steel (0.15% -0.30% carbon) has a microstructure of grains of tough and strong pearlite, and soft and ductile ferrite, making it overall more tough, impact resistant and workable. As such, mild carbon steel is more suitable for automobile axles and overall framing which require properties of toughness and impact resistance to withstand repeated blows as the automobile travels. In addition, mild steel is cheaper and more workable, allowing for greater manufacturing of complex frames. In contrast, high carbon steel (0.60 - 1.25% carbon) is made up of majority ~~of~~ pure grains of tough pearlite and strong and hard boundaries of cementite. This makes the alloy more hard and stiff, thus ~~does not~~ cannot withstand the in-service conditions as well, of high repeated impact as the mild, due to ~~the~~ ~~to~~ being less tough.

Excerpt 2

Considering the automotive subframes manufactured will experience repeated loads and high impacts, it is inevitable that the material used to manufacture must have high toughness, impact-resistance, and strength. Mild carbon steel is a steel material with a carbon percentage of 0.15 − 0.3%. In this region, the steel material will have a microstructure made of majority of ferrite and few pearlite. Hence, it is to be explained that the mild carbon steel will have high toughness and impact-resistance, but will has low strength as ferrite, the most ductile, soft yet tough material forms majority of the mild carbon steel's microstructure. Contrastingly, high carbon steel with 0.6-1.25% carbon is formed by majority of pearlite in its microstructure. Given that the pearlite is most brittle, hard and strong material, it is known that the high carbon steel will have high strength yet toughness and impact-resistance will be relatively lower than the mild carbon steel. Hence, it is inevitable that the mild carbon steel is more suitable material option for the automotive subframe, however, few reinforcement on mild carbon steel's strength will be required.

Paper 1: Question 17

This simple familiar question required students to:

- interpret data provided in a stress–strain diagram
- explain, using four relevant mechanical properties, how adding epoxidised natural rubber (ENR) to nylon influences the material's effectiveness for gear manufacture.

Effective student responses:

- provided an appropriate explanation that included four relevant mechanical properties
- used the provided stress–strain diagram data to justify why the inclusion of ENR reduces nylon's effectiveness as a material for gear manufacture.

This excerpt has been included:

- to illustrate a high-level response that demonstrates how to analyse a question, including stimulus, to ensure that the response addresses the required information, i.e. four relevant mechanical properties interpreted from the provided data.

Excerpt 1

For a material to be used for gears, the material must be, hard, strong and stiff and abrasion resistant. As seen in the graph, adding ENR decreases the yield stress at the end of the straight section, and increases the softness and ductility, as indicated by the elongation between the yield point and the ~~[illegible]~~ Fracture point. This can be seen as the 0% ENR has a yield stress of

80MPa with an elongation at fracture at aprox. 40%, while 20% ENR has 25MPa yield stress with more than 80% elongation at fracture point. This means, the higher the percentage of ENR in Nylon, the less effective it would be ~~as~~ when used for gear manafacture. ∴ 0% ENR nylon would be best

Paper 1: Question 18

This simple familiar question required students to:

- determine the force required to launch a rocket vertically from rest
- include a free-body diagram showing the forces at launch.

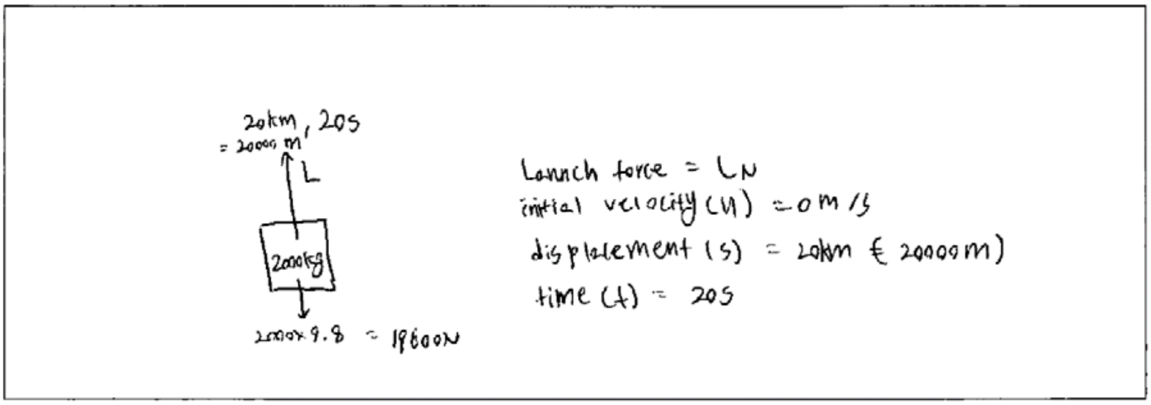
Effective student responses:

- provided an appropriate free-body diagram including both weight and launch force
- correctly determined the answer in kN to the nearest whole unit.

This excerpt has been included:

- to illustrate a high-level response that is well-structured to clearly show the steps used to determine the answer to the correct whole unit.

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.

$s = ut + \frac{1}{2}at^2$

$20000 = 0 + \frac{1}{2}a(20)^2$

$= 200a$

$\therefore a = 100 \text{ m/s}^2$

$F = ma$, $m = 2000$, $a = 100$

$\therefore F = 2000 \times 100$

$= 200000 \text{ N}$

$\Sigma F_y \uparrow = 200000$

$200000 = L - (2000 \times 9.8)$

$= L - 19600$

$\therefore L = 200000 + 19600$

$= 219600 \text{ N}$

$\therefore L = 219.6 \text{ kN}$

$\approx 220 \text{ kN}$

Paper 1: Question 20

This simple familiar question required students to:

- determine the tension in a pulley rope required to almost begin moving a generator up an incline.

Effective student responses:

- correctly determined the MA provided by the 80% efficient pulley system
- correctly determined the answer to two decimal places.

This excerpt has been included:

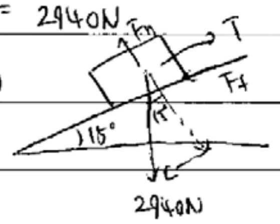
- to illustrate a high-level response that is well-structured to clearly show the steps used to determine the answer to two decimal places.

Excerpt 1

$F_w = 300kg \times 9.8N$, $\theta = 15°$, $\mu = 0.3$

$= 2940N$

FBD



$F_f = \mu F_n$, $F_n = F_w \cos 15°$

$= 2940 \cos 15°$

$= 2839.82N$

$\therefore F_f = 2839.82 \times 0.3$

$= 851.95N$

$\Sigma F_x \overset{+}{\rightarrow} = 0$

$0 = -2940 \sin 15 - 851.95 + T$

$\therefore T = 760.93 + 851.95$

$= 1612.88N$

Pulley system has $\eta = 0.8$, $VR = 3$

$0.8 = \frac{MA}{3}$, $\therefore MA = 2.4$

$2.4 = \frac{F_L}{F_E}$

$2.4 = \frac{1612.88}{F_E}$

$\therefore F_E = 672.03N$

$\therefore E = 672.03N$

Paper 1: Question 22

This complex unfamiliar question required students to:

- interpret complex written and visual information to determine the revolutions per minute of a motor used to move a conveyor that transfers luggage from an aircraft to a luggage carousel.

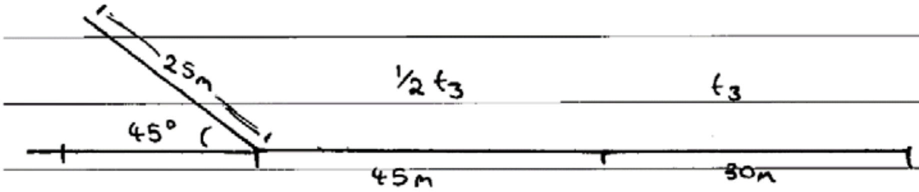
Effective student responses:

- correctly determined the time taken to travel down the Section 1 steel ramp, including identifying
  - the forces acting up and down the incline, and the net force
  - the acceleration down the ramp
- correctly determined the time taken to travel along the Section 3 ramp
- correctly determined the revolutions per minute of the conveyor motor to nearest correct whole unit.

This excerpt has been included:

- to illustrate a high-level response that is well-structured to clearly show the steps used to determine the answer to nearest correct whole unit.

Excerpt 1



20s

assume initial velocity is 0.

section 1:

$mg\sin\theta - FF = F_{total}$

$m(g\sin\theta - 0.42g\cos\theta) = F_{total}$

$m(9.8\sin45 - 0.42 \times 9.8\cos45) = F_{total}$

$F_{total} = m(4.019)$

$F_{total} = ma \qquad a = \frac{m(4.019)}{m}$

$a = 4.019\ m/s^2 \quad u = 0 \quad s = 25m$

$s = ut + \frac{1}{2}at^2$

$25 = 0 + \frac{1}{2}(4.019)t^2$

$t = 3.53$ seconds

$20 - 3.53 = 16.47\ s$

$16.47s = t_3 + \frac{1}{2}t_3$

$16.47 = \frac{3}{2}t_3$

$t_3 = 10.98$ seconds

motor-driven roller

every rotation travels π250mm

~~rpm =~~

$\therefore \frac{30m}{\pi 0.25m} = 38.$~~197~~20 rotations

in 10.98 seconds.

10.98s is 0.183 of a ~~minute~~ minute

$\therefore \frac{38.\text{~~197~~}20}{10.98} \times 60 = 3.48 \times 60$

$= 208.74$

≈ 209 rpm of the variable speed conveyor motor (section 3).

Practices to strengthen

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

- further development and application of Unit 4, in particular
  - Topic 1 subject matter knowledge in complex familiar and complex unfamiliar situations, including
    - simple machines and the concepts of mechanical advantage and velocity ratio
    - incline planes, e.g. the parallel and perpendicular components of the weight vector
  - Topic 2 subject matter knowledge in complex familiar and complex unfamiliar situations, including
    - the microstructures of carbon steels and how these relate to relevant mechanical properties and industrial applications
    - the key features of the lead-tin thermal equilibrium phase diagram
    - interpretation of the information available in stress–strain diagrams and its real-world application in industrial contexts
    - calculation of percentages of solid and liquid and, in particular, the composition solid and liquid using the inverse lever rule
  - Topic 3 subject matter knowledge, including
    - interpretation of specific conditions to create logic gate circuits that include clearly annotated inputs and outputs, e.g. on and off conditions
    - logic gates and their corresponding truth tables developed using inputs in logical order
- further development of students' abilities to fully read, interpret and understand the instructions provided in short response written and calculation questions, including understanding that
  - answers to calculation questions must be provided as specified by the question, e.g. to the nearest whole unit, or to a number of decimal places with the correct unit provided
  - written explanations must include all the relevant information as specified by the question.