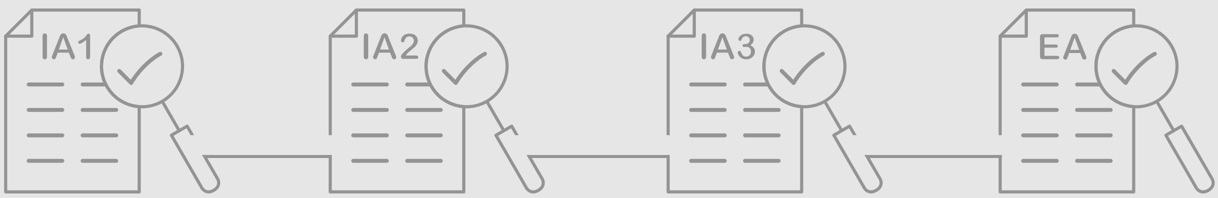
Engineering subject report

2024 cohort

January 2025



Queensland Government

Queensland Curriculum & Assessment Authority

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For all Queensland schools

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Contents

Introduction

The annual subject reports seek to identify strengths and opportunities for improvement of internal and external assessment processes for all Queensland schools. The 2024 subject report is the culmination of the partnership between schools and the QCAA. It addresses school-based assessment design and judgments, and student responses to external assessment for General and General (Extension) subjects. In acknowledging effective practices and areas for refinement, it offers schools timely and evidence-based guidance to further develop student learning and assessment experiences for 2025.

The report also includes information about:

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

The report promotes continuous improvement by:

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

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

Audience and use

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

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

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

Subject highlights

71.43%
agreement with provisional marks for IA3

96.29%
of students received a C or higher

13.73%
increase in enrolment since 2023

Subject data summary

Subject completion

The following data includes students who completed the General subject.

Note: All data is correct as at January 2025. Where percentages are provided, these are rounded to two decimal places and, therefore, may not add up to 100%.

Number of schools that offered Engineering subject report: 106.

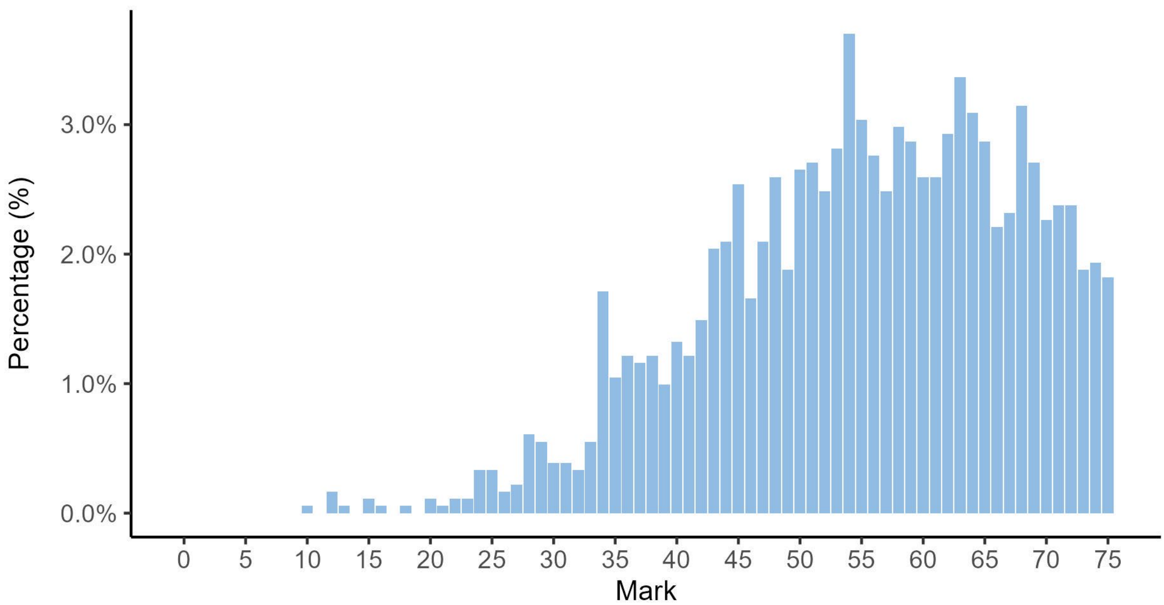
Completion of units	Unit 1	Unit 2	Units 3 and 4
Number of students completed	2,105	1,968	1,806

Units 1 and 2 results

Number of students	Satisfactory	Unsatisfactory
Unit 1	1,914	191
Unit 2	1,856	112

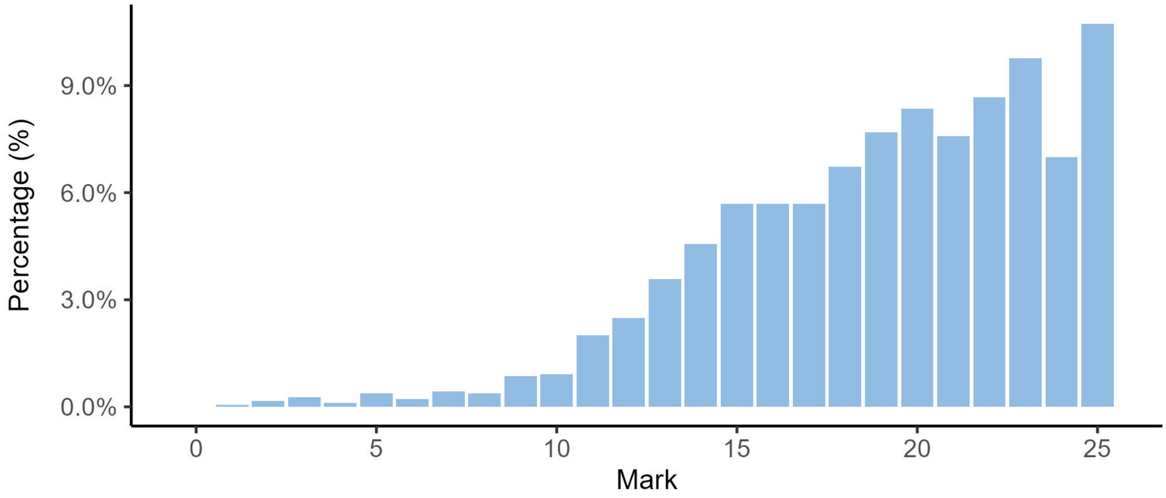
Units 3 and 4 internal assessment (IA) results

Total marks for IA

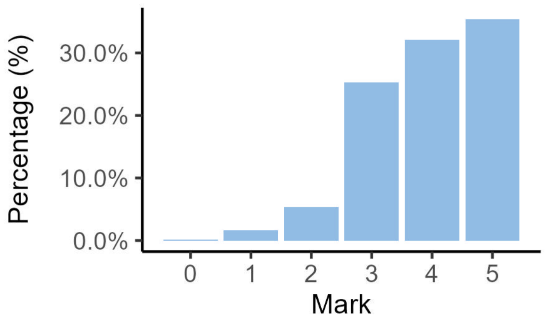


IA1 marks

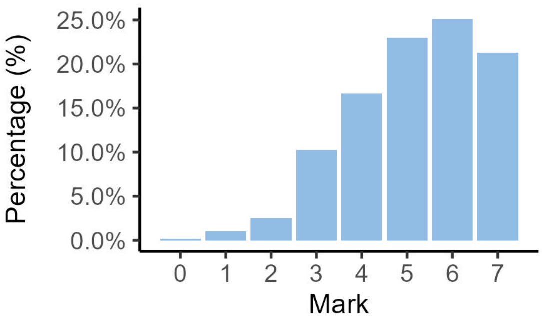
IA1 total



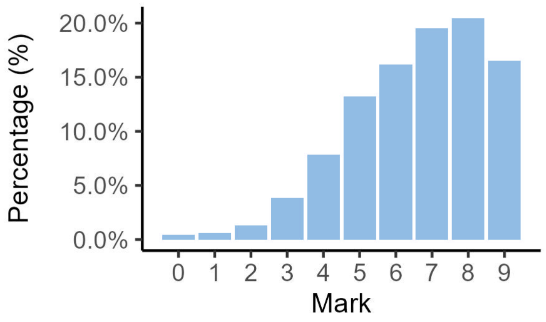
IA1 Criterion: Retrieving and comprehending



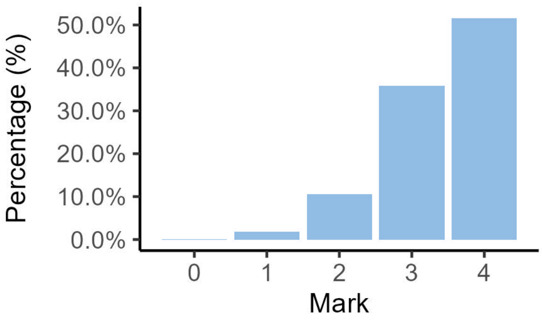
IA1 Criterion: Analysing



IA1 Criterion: Synthesising and evaluating

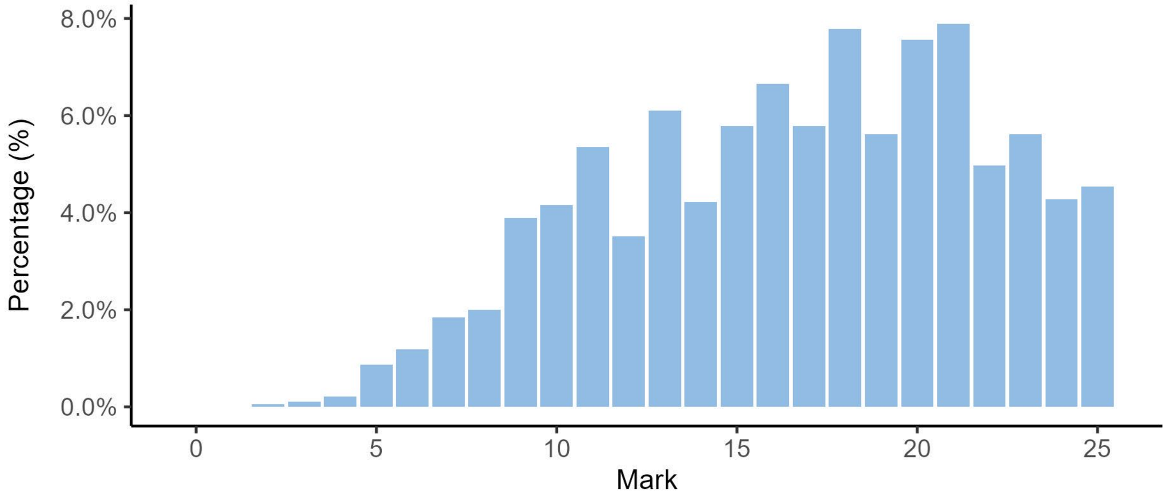


IA1 Criterion: Communicating

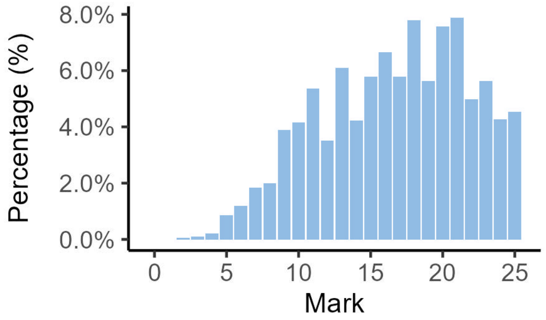


IA2 marks

IA2 total

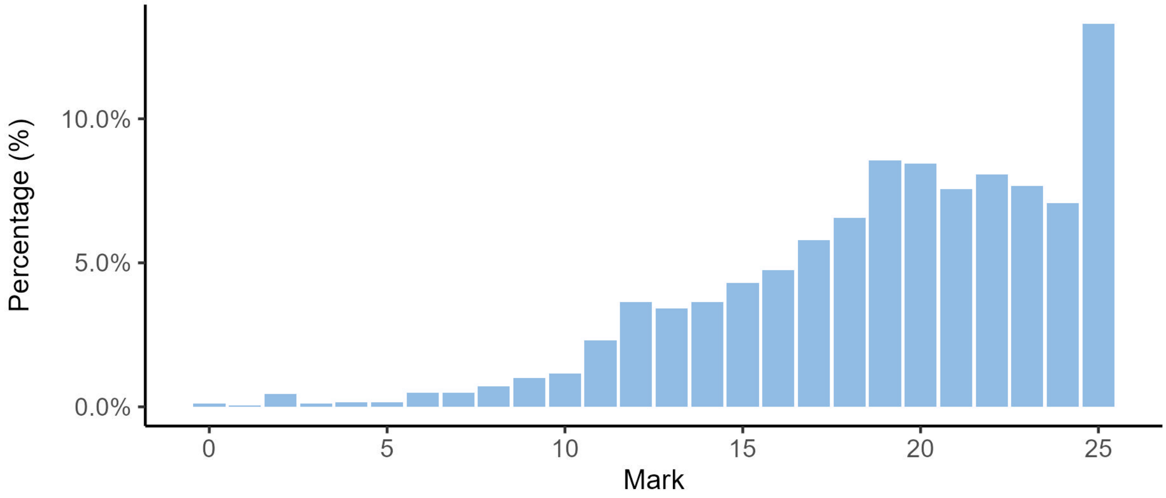


IA2 Criterion: Engineering knowledge and problem-solving

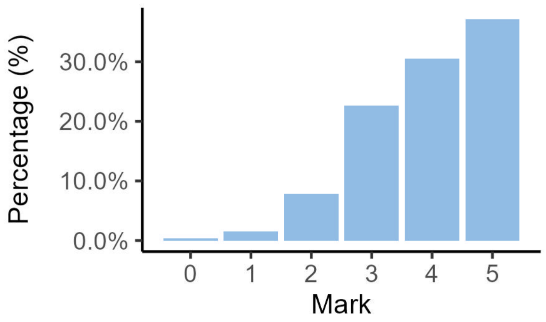


IA3 marks

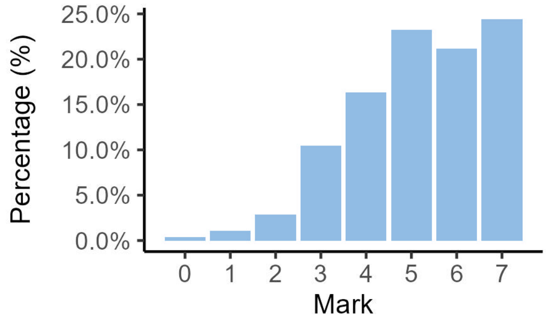
IA3 total



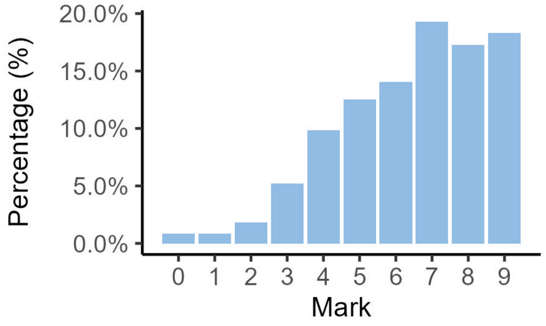
IA3 Criterion: Retrieving and comprehending



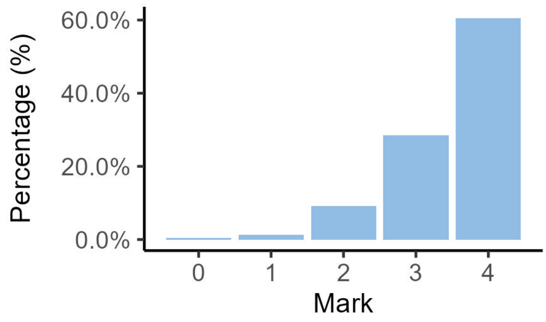
IA3 Criterion: Analysing



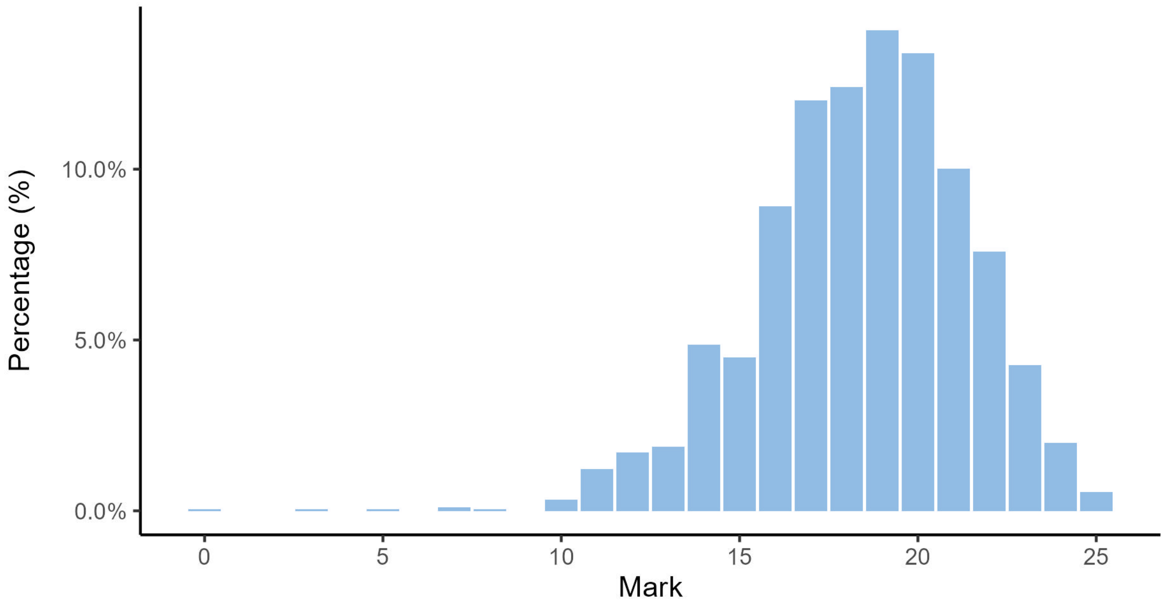
IA3 Criterion: Synthesising and evaluating



IA3 Criterion: Communicating

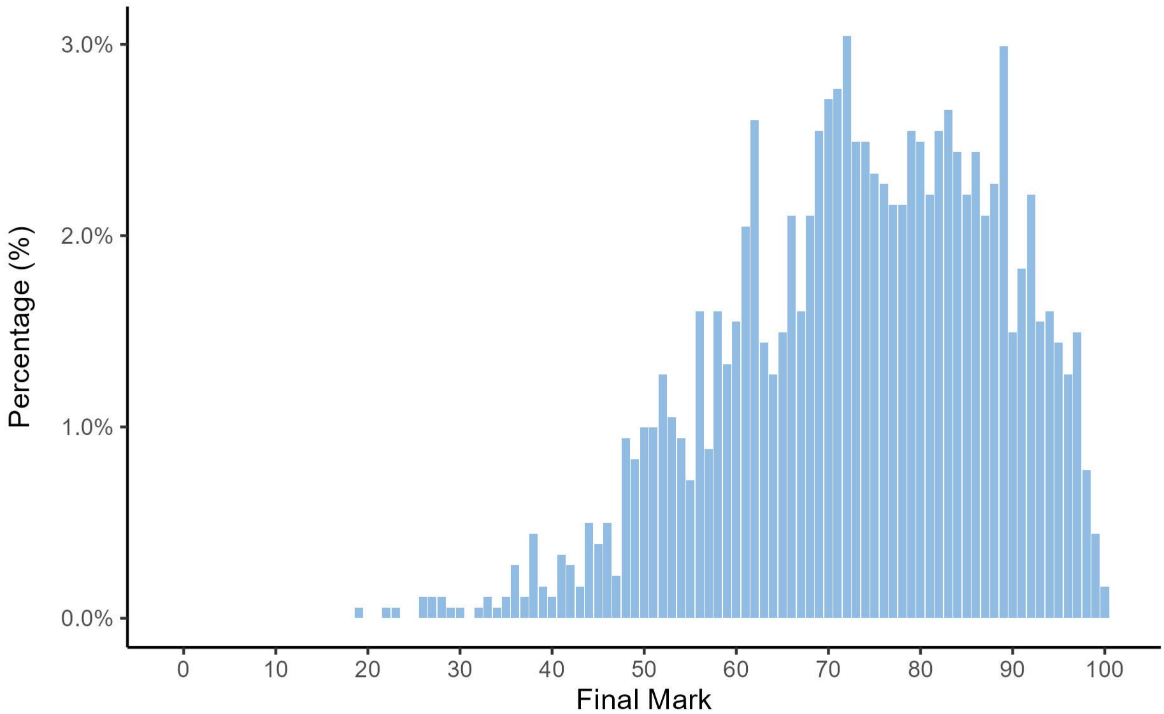


External assessment (EA) marks



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	82–68	67–46	45–19	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	567	666	506	67	0

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 assessment. An IA may have been identified more than once for a priority for assessment, e.g. it may have demonstrated a misalignment to both the subject matter and the assessment objective/s.

Refer to *QCE and QCIA policy and procedures handbook v6.0*, Section 9.5.

Percentage of instruments endorsed in Application 1

Instruments submitted	IA1	IA2	IA3
Total number of instruments	105	105	105
Percentage endorsed in Application 1	58	16	51

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 v6.0*, 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	105	736	39	52.38
2	105	737	0	100.00
3	105	730	16	71.43

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	16
Authentication	5
Authenticity	7
Item construction	12
Scope and scale	10

Effective practices

Validity priorities were effectively demonstrated in assessment instruments that provided:

- opportunity for students to
  - individually generate a virtual or physical prototype that provided valid performance data to inform refinements and recommendations for the real-world solution
  - produce unique responses by not including images of potential solutions
- an authentic, real-world-related context that explicitly stated that the solution must include a truss structure that
  - was relevant to the school or an external community
  - provided opportunity for students to explore the engineering technology knowledge concepts that were related to the real-world-related problem, and to support them to make informed decisions in relation to their solution, e.g. the social, ethical and environmental impacts of their solution on the local community and the surrounding environment.

Practices to strengthen

It is recommended that assessment instruments include:

- all information in Part A and Part B of the assessment specifications, unaltered, so students can demonstrate evidence of all characteristics of the performance-level descriptor in the ISMG
- an opportunity for students to demonstrate their knowledge of Unit 3 subject matter
- specific information about the scale of the prototype to be produced, e.g.
  - the scaling for a virtual prototype should be specified as 1:1
  - physical prototypes should have an appropriate scale that allows students to obtain valid performance data.

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	7
Layout	0
Transparency	1

Effective practices

Accessibility priorities were effectively demonstrated in assessment instruments that:

- featured a structured context and task layout that was clearly organised, providing a framework of information that gave students access to assessment objectives, specifications and the ISMG (Syllabus section 4.6.1).

Practices to strengthen

It is recommended that assessment instruments:

- refrain from using technical jargon or inappropriate language. Tasks should adhere to syllabus terminology when discussing problem-solving, solutions and solution development. Schools should use terms such as ‘develop’, ‘ideas’, and ‘engineered solutions’ instead of ‘design’, ‘designs’, or ‘design concepts’. Design-related concepts and principles are outside the scope of the syllabus and are not defined in the Engineering curriculum.

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	88.57	10.48	0.95	0
2	Analysing	65.71	34.29	0.00	0
3	Synthesising and evaluating	71.43	28.57	0.00	0
4	Communicating	90.48	9.52	0.00	0

Effective practices

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

- for the Retrieving and comprehending criterion
  - evidence supported thoughtful and astute choices in identifying the most relevant materials science and mechanics information relating to the structural problem
  - good judgment was shown when distinguishing between the known and unknown characteristics and the boundaries and assumptions that could be made when exploring the problem
- for the Synthesising and evaluating criterion
  - evidence included the production of a virtual or physical prototype solution that produced legitimate and defensible performance data to determine whether or not the proposed real-world solution would be fit for the intended purpose
  - the performance data obtained from testing the prototype was suitable for informing recommendations about improvements or enhancements that should be made to the real-world solution
- for the Communicating criterion
  - there was evidence of careful and deliberate decision-making in relation to the selection and articulate use of written features to communicate about a solution to a real-world-related structural problem with accurate spelling, grammar and appropriate technical language.

Practices to strengthen

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

- for the Retrieving and comprehending criterion, in the upper performance level, attention be given to symbolisation of ideas and a solution using visual features, such as

  - engineering drawings that facilitate the production of the prototype solution and demonstrate an understanding of basic drawing standards, e.g. correct use of layout, dimensioning and labelling conventions, aligned to Australian standards
  - sketches that demonstrate a high degree of skill and proficiency and have a sufficient level of detail to communicate how the ideas will respond to the problem, e.g. representing material selection, structural features, etc.
  - diagrams, graphs, tables and/or schemas that are selected for their value in providing additional information about ideas and a solution, and demonstrate a high level of skill and accuracy in their use, e.g. accurate and clear labelling conventions for graphs, stress–strain diagrams, free-body diagrams, shear force and bending moment diagrams
- for the Analysing criterion, in the upper performance level, attention be given to
  - demonstrating a deep understanding of the relationship between relevant materials, engineering mechanics and the structural problem, e.g. truss analysis, calculations and pretesting
  - providing success criteria determined from the analysis of the problem, and extending beyond the parameters stated in the assessment instrument that
    - include measurable attributes in relation to loading and dimensions
    - can be used to establish the merit of ideas and the success of both the prototype and the proposed real-world solution
- for the Synthesising and evaluating criterion, in the upper performance level, attention be given to
  - thoughtful, well-structured and sensible combinations of the most feasible attributes of ideas, integrated with the most relevant information from the analysis of the problem that includes materials, mechanics, environmental and sustainability considerations, and other research information to propose a possible real-world solution
  - using the solution success criteria to judge the merit of ideas and a solution
  - thoughtful and astute choices in relation to enhancements or improvements that could be made to the solution as a result of the evaluation, with recommendations that are supported by the outcome of testing the prototype solution.

Samples

The following excerpts have been included to provide examples of the Retrieving and comprehending criterion at the 4–5 performance level. They illustrate how a range of visual features have been used effectively to symbolise ideas and a solution.

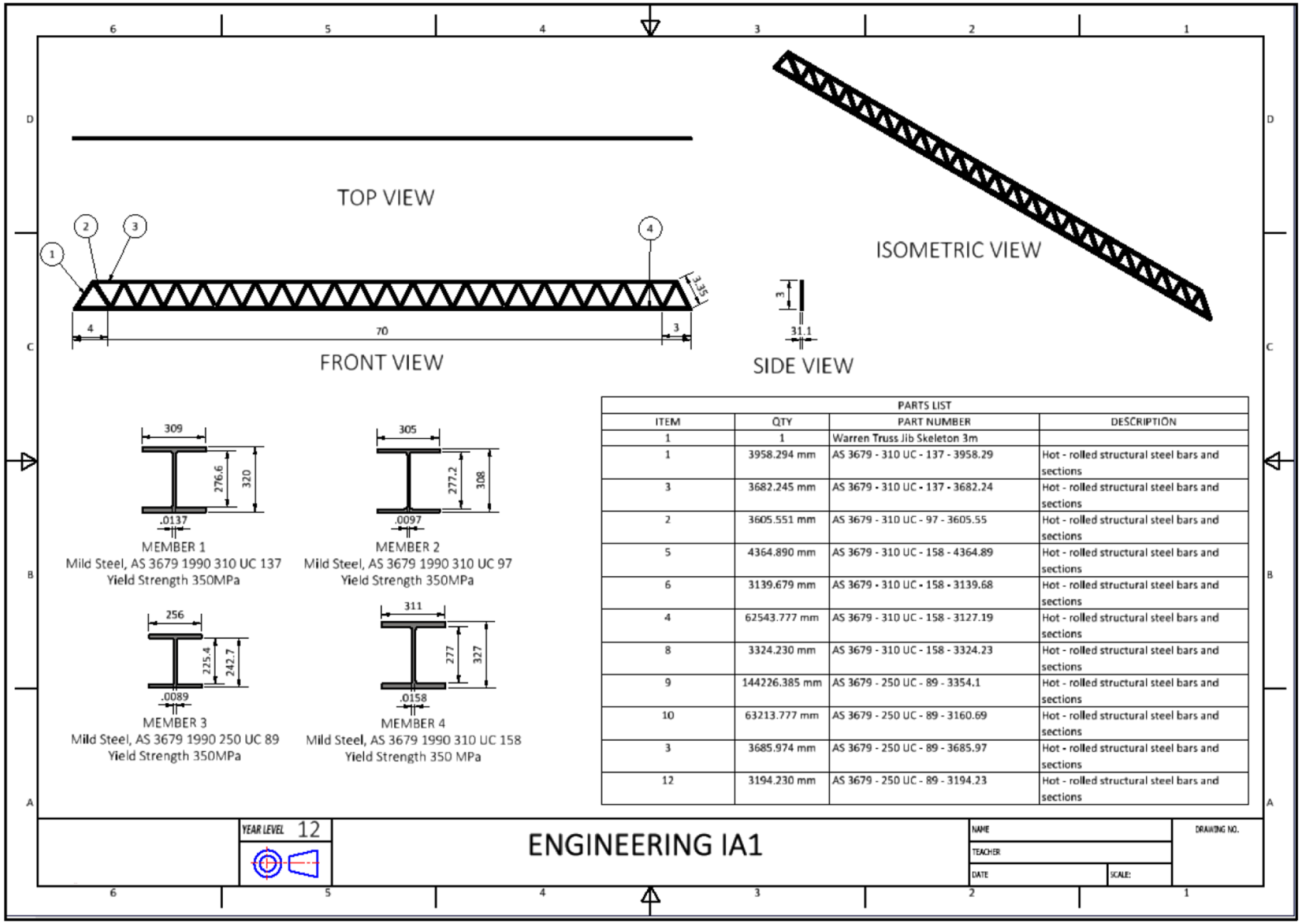
Excerpt 1 illustrates the use of an engineering drawing to facilitate the generation of a prototype solution that demonstrates a proficient understanding of basic drawing standards, including orthographic views presented in third angle projection layout that have been labelled and dimensioned appropriately.

Excerpt 2 demonstrates proficient use of sketching to communicate the known information about the problem, including loading and dimensional requirements and environmental considerations. The discerning use of a visual feature effectively communicates a range of information in a clear and succinct way with minimal use of text.

Excerpts 3 and 4 illustrate effective use of graphs, force diagrams and calculations to demonstrate insightful analysis of relevant engineering mechanics and materials science in relation to the problem.

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

Excerpt 1



PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	Warren Truss Jib Skeleton 3m	
1	3958.294 mm	AS 3679 - 310 UC - 137 - 3958.29	Hot - rolled structural steel bars and sections
3	3682.245 mm	AS 3679 - 310 UC - 137 - 3682.24	Hot - rolled structural steel bars and sections
2	3605.551 mm	AS 3679 - 310 UC - 97 - 3605.55	Hot - rolled structural steel bars and sections
5	4364.890 mm	AS 3679 - 310 UC - 158 - 4364.89	Hot - rolled structural steel bars and sections
6	3139.679 mm	AS 3679 - 310 UC - 158 - 3139.68	Hot - rolled structural steel bars and sections
4	62543.777 mm	AS 3679 - 310 UC - 158 - 3127.19	Hot - rolled structural steel bars and sections
8	3324.230 mm	AS 3679 - 310 UC - 158 - 3324.23	Hot - rolled structural steel bars and sections
9	144226.385 mm	AS 3679 - 250 UC - 89 - 3354.1	Hot - rolled structural steel bars and sections
10	63213.777 mm	AS 3679 - 250 UC - 89 - 3160.69	Hot - rolled structural steel bars and sections
3	3685.974 mm	AS 3679 - 250 UC - 89 - 3685.97	Hot - rolled structural steel bars and sections
12	3194.230 mm	AS 3679 - 250 UC - 89 - 3194.23	Hot - rolled structural steel bars and sections

Excerpt 2

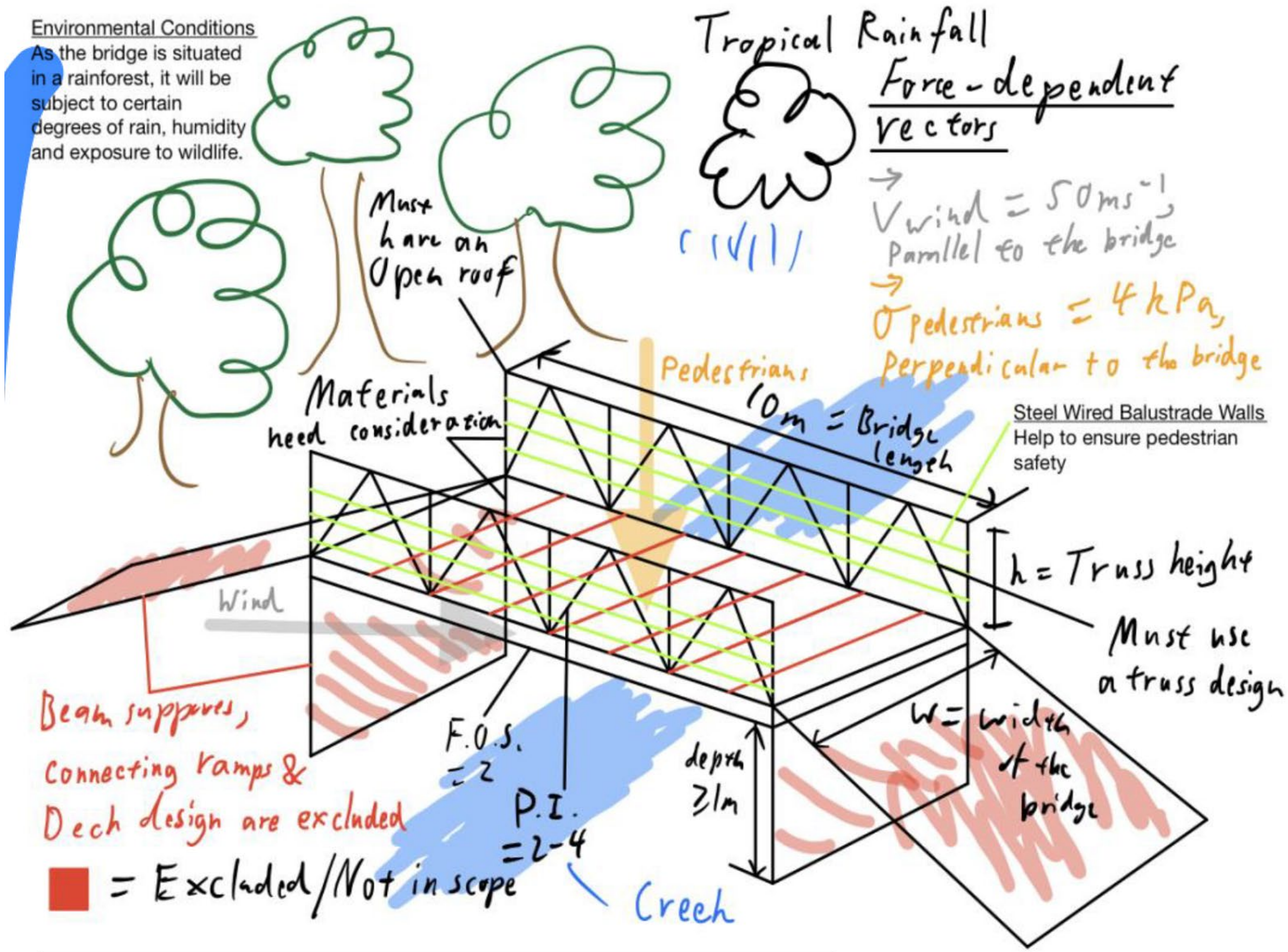


Figure 1: Sketch of Problem with annotated Knowns

Excerpt 3

Materials

Based upon the aforementioned ideal material characteristics and the established environmental knowledge of the area, materials will be separated out into two purposes: one — for the bridge, and two — for the deck. The materials of the bridge have been selected upon the criteria with respect to the recyclability and constructability, and they will be analysed to determine the most effective material for each component based upon PI. (Azo Material, 2002; University of Cambridge, 2011)

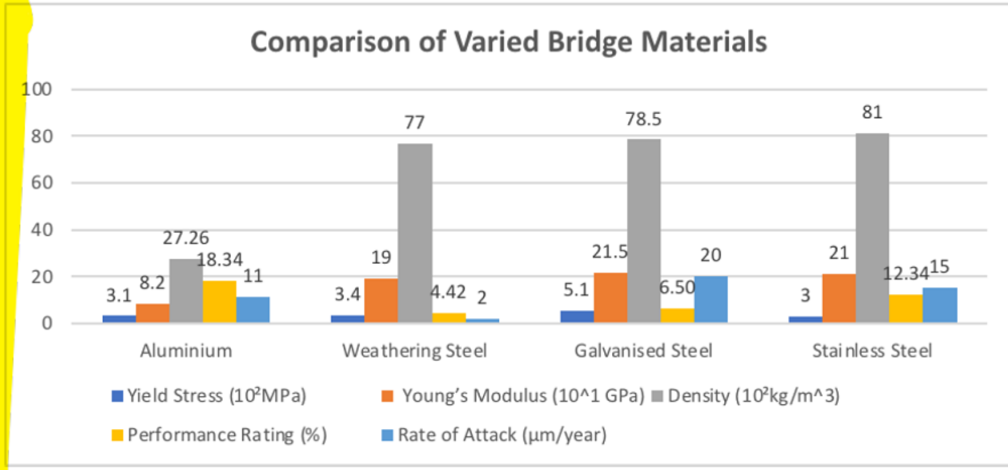
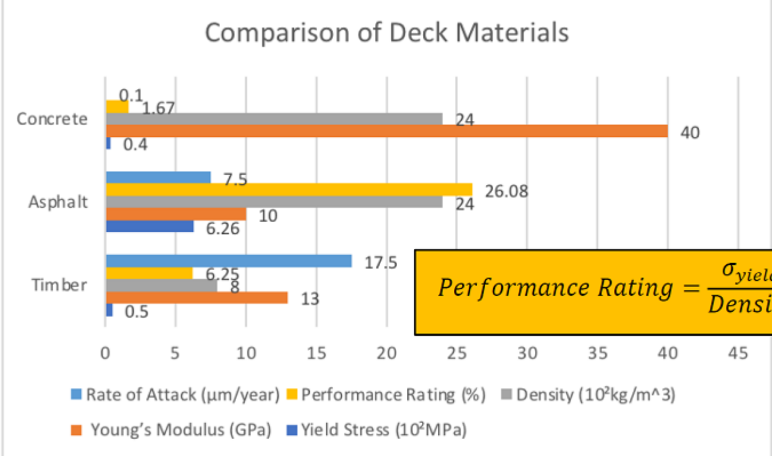


Figure 7: Comparison of different Bridge Materials



$$Performance\ Rating = \frac{\sigma_{yield}}{Density}$$

Figure 8: Comparison of different deck materials

Excerpt 4

Solving for Internal Compression Reactions

Each side of the slewing unit was analysed individually where a pin joint was assumed at the top of the tower and a roller joint at the base. The moments were taken to find the compression in the tower's internal forces.

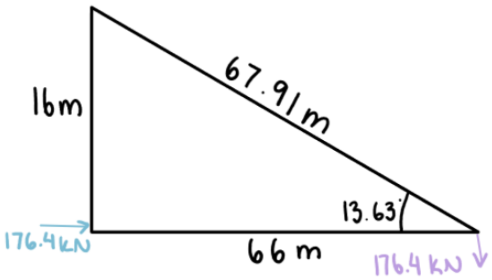
Finding the reaction at B

$$\Sigma M_A{}^{+\rightarrow} = 0 = \left(333.2 \times \frac{70}{3}\right) - (16B)$$

$$B = \frac{\left(333.2 \times \frac{70}{3}\right)}{16}$$

$$B = \frac{5831}{12} \sim 485.9kN$$

The same process was used to calculate the reactions on the jib side:



The following excerpts have been included to provide examples of the Analysis criterion at the 6–7 performance level.

Excerpt 1 demonstrates an understanding of the relationship between the relevant engineering mechanics and the structural problem, e.g. truss analysis and pretesting to determine measurable aspects in relation to loading and dimensions that are accurate and realistic and can be used to determine the solution success criteria.

Excerpt 2 illustrates solution success criteria that have been determined from the analysis of the problem, rather than simply restatements of information provided in the task sheet, and that have measurable attributes for both the prototype and real-world solution, with supporting statements, that can be used to evaluate the ideas and the solution.

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

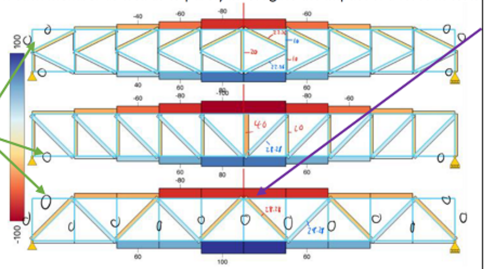
Excerpt 1

Further Testing and Research

Mechanics – Determining Optimal Truss Type

While 70kN has been calculated as the designated force applied onto the structure, it represents the scenario where all pedestrians are situated upon a single spot. While it is virtually impossible to have such extreme loading conditions, a 50kN load was still applied within Sketchalyze at the midpoint of the bridge to maximise both the performance index due to a significantly higher load and the effect on each member as well as to purely investigate the impact of a force in tests.

<u>Zero Force Members</u>
Provide rigidity to the structure at the cost of reducing performance index, and due to them theoretically taking no loads, they can be removed in future designs.



<u>Total Effective Length (TEL)</u>
By only taking the lengths of material which are experiencing force, each design can be compared as to how they are using material efficiently.

$$TEL(3) = \Sigma(L(Diagonals) + L(Frame)) = 18 + 10\sqrt{2}$$

Figure 10: Normal Force Distribution comparison of three varying truss designs.

Table 2: Calculated values sourced from Sketchalyze model.

Design	TEL (m)	TL (m)	TEL/TL (%)	Highest Compression $F\_n(kN)$	Highest Tension $F\_n(kN)$	$\Sigma F\ n(kN)$
1 (K-truss)	48.36	53.36	90.63%	80	80	-40 (Compression)
2 (Pratt)	42.14	44.14	95.47%	100	80	-297.16(Compress.)
3(Warren)	32.14	44.14	72.82%	80	100	320 (Tension)

Based upon the qualitative analysis of the three designs, it was found that the Warren truss utilised the least amount of material despite having the exact same total length (TL) as the Pratt Truss due to the presence of zero force members as shown by having a length ratio of 72.82% compared to design 1 and 2's 90.63% and 95.47%. Moreover, the Warren truss also ties with having the lowest peak compression stress value of 80kN to the K-truss, but it also demonstrates the highest tension stress of 100kN, being 25% higher than the other designs. Given that a solid member performs better in tension than in compression due to buckling, higher tension forces actually improve the effectiveness of the Warren truss, as shown by the normal force sum of 320kN of tension. However, upon qualitative analysis, design 2 manages to ensure that tension forces run along the longest members, being the diagonals, similar to that of design 1 but with greater distributions. Knowledge that longer members perform better in tension stipulates that design 2 should be better than design 1 and 3 due to ideal loading, yet Design 3, the Warren truss proves itself as the most material efficient which directly increases the structure's performance index, and thus it is most viable design for the bridge truss.

Determining Height of the Truss

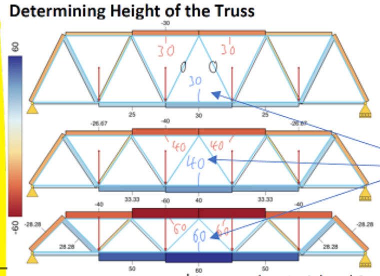


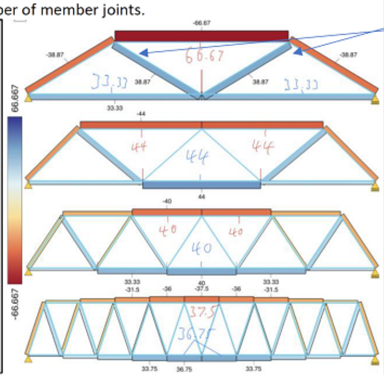
Figure 11: Testing Height of Truss

By first applying a distributed load of 50kN, which translates to 12.5kN per joint to simulate realistic pedestrian loading conditions as well as removing the zero force members present within the previous Warren truss design, three heights — 1m, 1.5m and 2m — were tested to determine the effect of variable height. As shown by figure 11, there is an <u>inversely proportional relationship between both compression and tension stress</u> such that increasing height by a factor will cause both tension and compression stress to decrease by that factor. When height doubles from 1m to 2m, tension and compression force both halve from <u>60kN to 30kN</u> with identical values. However, as 2m would directly decrease the PI due to increased material and 1m is minimum (QLD, 2017), 1.5m is selected as the optimal height..

Determining Width of Truss Type

Through determining the optimal type and height of the truss, the final variable of the width of the individual truss will be determined through testing widths of 1m, 2m, 3.3m and 5m. Additionally loading was applied proportionally to the number of member joints.

<u>Rigid Zero Force Members</u>
These members allow the system to be fixed laterally and allow the system to remain in equilibrium due to the fact that distributed loads would collapse the entire bridge without these essential members that seem to experience no force, but simply cancel out their resultant forces for equilibrium.



<u>Congruent Triangles</u>
Due to the congruency of each triangle, forces are equally distributed, with the orientation of the triangular design of a Warren truss deemed to be of little consequence but preferred upright.

<u>Correlation between Width and Material Usage</u>
There is an inversely proportional relationship between material usage and width, thus increasing constructibility through decreased material usage as less members are used.

Figure 12: Testing Variable Truss Widths from 1m to 5m.

There is a non-linear increasing relationship between truss width and compression stress, as width increases from 2m to 3.33m to 5m, compression increases from 40kN to 44kN to 66.67kN, demonstrating that increasing width drastically increases compression force. However, compression stress follows a parabolic relationship such that when width increases from 2m to 3.33m it also increases from 40kN to 44kN, but then decreases to 38.87kN at 5m. This is partly due to the fact that the highest tension force has shifted to the diagonals, but regression analysis can still be done by taking the difference of compression stress from tension stress — compression stress modelled by an exponential relationship, and tension stress modelled by quadratic — to determine the optimal width.

Determining Optimal Individual Triangular Widths using Regression Analysis

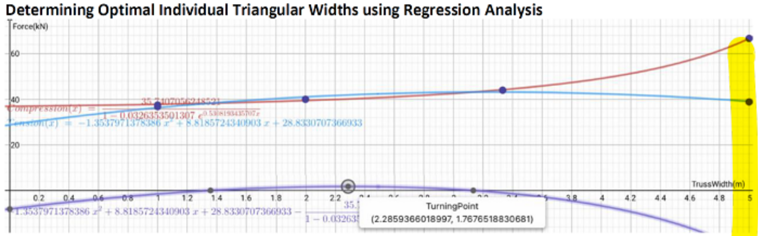


Figure 13: Optimising Truss Width with indicated maximum tension stress with CAS calculator

As seen in figure 13, regression analysis indicated that widths ranging from 1.3m and 3.13m demonstrated optimal tension stress and would thus have greater tension stresses than compression stress. However, when qualitatively analysing the bridge with widths of 2m and below, lower widths lead to decreased stress values, but they significantly increase the amount of material used in proportion to the stress reduction. Hence, smaller widths less than the peak tension stress 2.29m, will be disregarded due to their reduction in performance index, resulting in the optimal truss width ranging from 2.29m to 3.13m.

Excerpt 2

Success Criteria

Real World

- The structure must be economically viable and remain with a given budget → all expenditure on the project is highly valued.
- The usage of materials must be cost-effective → the importance of searching for cheap and reliable source of the materials used.
- The structure should minimise use of harmful chemicals especially during the process of assembly → this can cause great harm to wildlife and the surrounding ecosystem which is highly valued in remote towns.
- Consideration of Gordan Country's weather condition → effectively choosing the best material for those types of conditions which are common in the town.
- The structure must be able to withstand external forces which are not sourced from vehicles → sources like high wind speed, fast flowing water, flooding and surrounding plants growing into the structure.
- Consideration of control technology mentioned above → to make the bridge a more efficient place for drivers to travel through and collect data for future construction required on this bridge or even in Gordan Country in general.
- The structure should contain a safety factor of approximately 5 → this equates to the maximum load of the structure being 260KN.
- Structure must not be over-engineered → this mean the bridge material usage could be lower, creating a more efficient bridge while still meeting the required load.
- Structure should be sufficient enough to hold the required load → the structure was either too underdeveloped or the design used was not sufficient and effective enough to hold the required load.
- The bridge should use materials which require low maintenance → creates a cheaper bridge.
- The bridge must be easily accessible maintainable→ as in the case of required maintenance, expensive equipment is not required.
- Annual inspections to ensure safety of the vehicles and passing through the bridge.
- Sufficient clearance space of 3x3.9m for large vehicles

Prototype

- Have an adequate performance index during the static test.
- A model cart 65x86mm must be able to pass through the bridge.
- The structure must be able to withstand a dynamic test with a model cart travelling through on the road surface with an approximate weight of 11kg.
- Use of MD solids software to determine Stress within a member → using material testing data to determine the required width of that member.
- The structure must have a safety factor of approximately 5 → this equates to 1040N.
- The bridge fits the required footing → 600mm long and 150mm above the footings.
- Structure must not be over-engineered → this mean the bridge material usage could be lower, creating a more efficient bridge while still meeting the required load.
- Structure should be sufficient enough to hold the required load → the structure was either too underdeveloped or the design used was not sufficient and effective enough to hold the required load.
- Effective use of Balsa to reinforce members under great stress.

The following excerpts have been included to provide examples of the Synthesising and evaluating criterion at the 8–9 performance level.

Excerpt 1 demonstrates a well-structured, rational and valid combination of ideas and research information with information about materials science, engineering mechanics and engineering technology derived from the analysis of the problem to propose a possible solution.

Excerpt 2 demonstrates skilful and rational judgment when weighing up the strengths, limitations and implications of the solution against the success criteria, and shows intellectual perception in relation to the proposed refinements to the solution. It includes thoughtful and accurate recommendations for the real-world solution that have been supported by performance data obtained from testing the prototype solution.

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

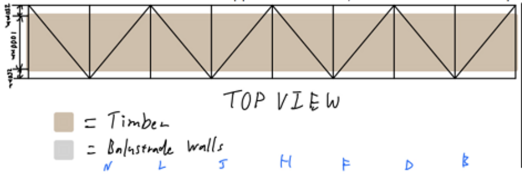
Excerpt 1

Predicting a Solution

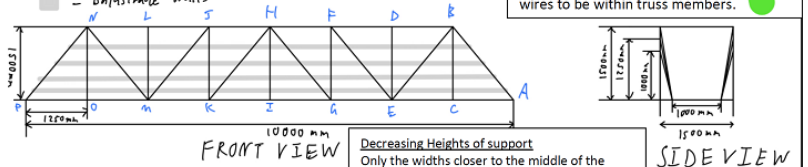
Final Solution Design

The final solution was generated based upon the integration of only the key parts from the two ideas, being primarily, the compression arch, Warren truss design and internal lateral supports in order to meet the solution success criteria. the solution first takes the idea of internal lateral supports and varies them due to reduced loading conditions as the bridge experiences a lower total compression force the closer it is to the pins, with the corresponding heights of each beam being 1.5m, 1.25m and 1m with a fixed length of 0.25m on both sides, resulting in a total truss width of 1.5m, including the pedestrian deck and internal facing supports. A fixed height of 1.5m will be utilised as it is the predetermined optimal height. Then, a synthesis between a Warren truss and a Howe truss was implemented with a single Howe truss being implemented directly in the middle to the fact that there is insufficient length to properly place the Howe truss in. The chosen width between each vertical beam on the front remained at 1.25m, creating 8 sections of the total 10m length. Finally, a Warren truss was also used for the actual support for the deck, which starts and ends upon a certain line.

Integrated Warren and Howe Truss
This design has been chosen as the middle Howe truss has been chosen to produce a greater tension than compression force, increasing PI (SC1.1, 1.3)



Success Criteria
Timber Pedestrian deck, with steel-wired balustrade walls with no enclosed roof and a correct dimensioning of the truss meet all of the relevant success criteria (SC2.1, 2.2, 2.3, 3.1, 4.1) with an adjustment to the position of balustrade wires to be within truss members.



Decreasing Heights of support
Only the widths closer to the middle of the truss will have taller supports to halve the force required and reduce material waste (SC1.1, 4.1)

Figure 20: Sketch of Final Solution with labelled Joints

Predicting Potential Failure

The total forces within both horizontal (x) and vertical directions (y) upon each joint should be equal to zero, and can be thus calculated individual for each member through method of joints as follows:

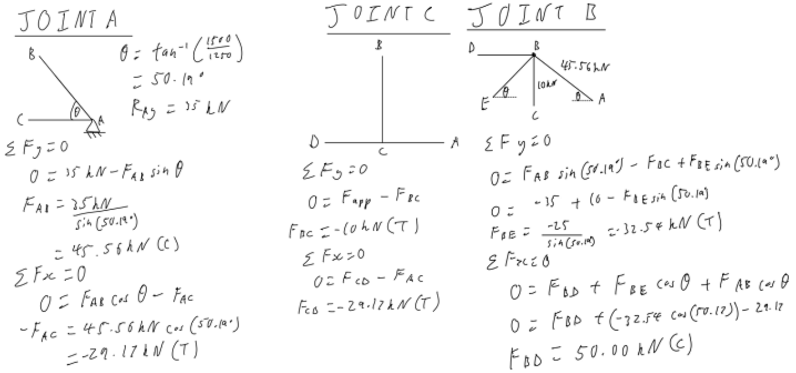


Figure 21: Method of Joints for Joints A, B and C

Sketchalyze Results

With the final solution determined, and a preliminary inspection of the forces present within three joints, which, due to the symmetry of the truss, translates to knowing six joints in total, a Sketchalyze model has been produced in order to compare the accuracy of the final results through mathematical reasoning by simulating only the two dimensional view of the front.

The presence of zero force members ED and NO indicate possible further refinement due to increased performance index; however, they are necessary to prevent buckling of the longer members in compression such as NJ and FB.

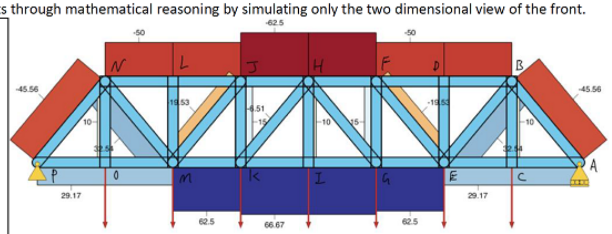


Figure 23: Sketchalyze testing of Final Solution

When comparing the two method of joints analysis, it has been determined that both the simulation and the hand calculations are both valid thus increasing the reasonableness of the results. The structural analysis reveals that the total force of 70kN should be distributed with 62.5kN of compression in horizontal members J through to F, and a maximum tensile force of 66.67kN within members K to G. Potential buckling may occur within members JM and DE due to the fact that there is a compression force of 19.52kN, requiring greater cross-sectional areas. Wind force also creates a torsional force upon the structure calculated as follows: $M = Fd$ $= 1.5 \times 1.5$ $= 2.25kNm$

Grouping Section Sizes

Based upon the distributed loads, it is clear that the higher compression forces will require a designated section size taking 62.5kN as the maximum, the tensile forces should also necessitate another section sizes with the maximum being 66.67kN and the supporting vertical and diagonal beams should also receive a separate section size, based upon a maximum tensile force of 32.54kN in BE, while factoring the force of 19.53kN in FE as part of the maximum compression force.

Chosen Material

Stainless steel will be selected as the material as it is strong, stiff and has low reactivity with water and oxygen, low rates of attack, high constructibility and provides a neutral environmental impact due to the possibility of renewable energy sources, which allows it to have a total lifespan of 100 years, requiring maintenance only every 15 years (SC3.1, 3.2, 4.2)

Chosen Real Member Section Sizes

To determine appropriate section sizes for the inventor model the following calculations have been done. By first using the F.O.S. defined within the success criteria, and the yield σ of stainless steel :

$$F.O.S. = \frac{\sigma_{yield}}{\sigma_{allowable}}$$

$$\sigma_{allowable} = \frac{\sigma_{yield}}{F.O.S.} = \frac{300}{2} = 150MPa,$$

Then the grouped forces taken from the Sketchalyze model have been taken to find an appropriate area for the section.

$$\sigma_{allowable} = \frac{Force}{Area}$$

$$Area\ (Max\ Compression) = \frac{Force}{\sigma_{allowable}} = \frac{62.5 \times 10\text{^}3}{150\ \times 10\text{^}6} = 4.1667 \times 10^{-4}m^2/2 = 208.33mm^2$$

$$Area\ (Max\ Tension) = \frac{Force}{\sigma_{allowable}} = \frac{66.67 \times 10\text{^}3}{150\ \times 10\text{^}6} = 4.4447 \times 10^{-4}m^2/4 = 111.12mm^2$$

$$Area\ (Vertical) = \frac{Force}{\sigma_{allowable}} = \frac{32.54 \times 10\text{^}3}{150\ \times 10\text{^}6} = 2.1693 \times 10^{-4}m^2/4 = 54.23mm^2$$

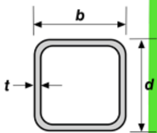


Figure 24: Square Hollow Section

As stainless steel is twice as strong in compression than tension, the cross-sectional areas have been halved, and halved again due to the presence of lateral beam supports, proving the AS sizes of 25x25x1.6 which gives 209mm^2 gross area for maximum compression and 20x20x1.6, giving an effective area of 111mm^2 for both maximum tension and vertical members. The set of three numbers correlates to the dimensions of a square hollow section which has been chosen due to its lightweight applicability in both tension and compression (Figure 24).

Excerpt 2

Recommendations and Improvements

Suggested Recommendations and Improvements based upon Success Criteria

Table 8: Success Criteria and Potential Improvements

SC#+ Success°	Recommendations and Improvements
1.1 Performance Index	To reduce the considerably high performance index to ensure that the effective performance index of the solution fits within the designated range of 2-4, there can be one main method as to how to reduce the overall PI which is to change the material into one holds a lower performance rating, effectively increasing the mass of the bridge to fit the constraints, or to reduce the actual load applied onto the bridge so that the design will not have such a large mass to support. However, both of these concepts cannot be applied readily into this prototype as it would require re-attempting the entire process of generating a final solution, but this can definitely be recommended for future designs.
1.2 Factor of Safety	The factor of safety differs by only 0.2, which is only 10% off from the required value, still demonstrates that the structure was over designed by 10%, so an appropriate recommendation would simply be to remove zero force members that are present throughout the lateral truss of the bridge.
1.3 Applied Forces	The bridge was able to withstand the forces applied with minimal difficulty, and, as such, recommendations to further improve upon the structural design of this task are not particularly required, but a generalised model of this bridge should be created to be able to work for any given loading condition. Furthermore, if the applied force did not include to predicted self-weight of the truss set at approximately 2500kg, then the predicted Performance index would be reduced to approximately 15
2.1 Dimensioning	While the bridge already conforms to the designated measurements, a multivariable investigation should be conducted as both height of a truss member and the width of a truss member both are determined to affect the performance of a truss. According to Li, et. al (2023), there are severals ways to optimise the ideal truss height and cross-sectional areas such that the volume utilised within a truss is minimal, affecting performance index and also clearly defining an alternative method to measuring corresponding lengths.
2.2 Balustrade + Open Roof	The concept of a balustrade wall has already been reduced to its simplest form, being connecting wires and the additional requirement of no enclosed roof leaves little improvement.
2.3 Triangular Width	The triangular width ties in with the optimisation of height as the width of the truss also dictates the number of possible sections due to the fact that a length of the bridge has been given, so other than recommendations to match the already provided range, it can be recommended to investigate the effect of different polygons, such as parallelograms or pentagons rather than only investigating the effect triangles have.
3.1 Material Characteristics	Stainless steel has been chosen as the primary material for the truss; however, as stated above, will require adjustment due to an excessive yield stress for performance index.
3.2 Truss Material	The constructibility and recyclability of stainless steel are kept at reasonably high levels due to the fact that stainless steel is a widely accessible resource, which is being constantly manipulated.
4.1 Material Waste	Material waste can be approximated based upon the difference in Factor of safety, where an excess of factor of safety indicates that the design can still be minimised in terms of section sizes.
4.2 Maintenance Period	Stainless steel holds a maintenance period, which aligns with that of Timber of also 15 years, which causes the material to meet the criterion, allowing infrequent maintenance.

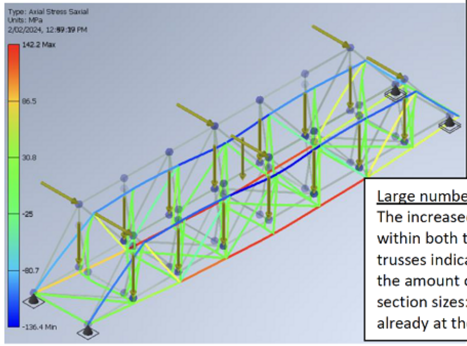
Material Considerations

A recommendation would be to switch to an alternative steel such as low carbon steel with approximately half of the yield stress, and while this would first of all significantly decrease the maintenance period as the rate of attack is approximately 13 times lower than that of stainless steel; however, given further protection from environmental factors, low carbon steel can also meet the designated maintenance period of 15 years. The purpose of changing the material is actually to further reduce the amount of material which while also resisting the forces applied (SC3.1) .

Table 6: Material Characteristics of Low Carbon Steel (Material Web, 2015)

Characteristic	Value
Yield Stress	152MPa
Density	8080kg/m^3
Performance Rating	1.8%
Young's Modulus	183GPa
Rate of Attack	202µm/year
Recyclability	100%
Constructability	Very high

Future Improvements



<u>High Compression Stress Values</u>
Present within specifically the diagonal members of the internal members, which indicates that the design can be further refined to prevent the excess compression stress from happening through either changing section sizes, which has already been done, or to add supporting members to decrease the overall compression force.

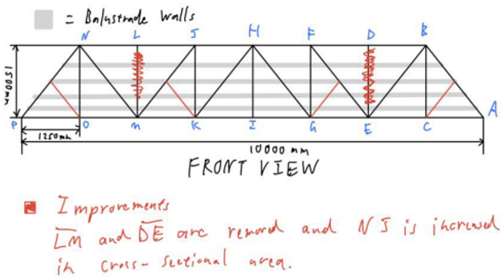
<u>Large number of zero force members</u>
The increased number of zero force members within both the lateral truss and the vertical trusses indicate that they can optimised to reduce the amount of material present within each of the section sizes: however, the section sizes are already at the smallest they can be (20x20x1.6)

Figure 29: S axial Stress of Prototype

Future Improvements

Based upon the problems or potential areas of refinement identified in Figure 29, the following improvements have been made:

- Additional bracing supports upon the members AB and PN and internal members in compression
- Removal of zero force members LM and DE to further decrease excess material and increase PI
- Increased cross-sectional area of NS and FB to compensate for the lack of vertical support from the removal of members LM and DE



<u>Additional Supports</u>
The additional bracing supports at PN, JM, FE and BA allow further distribution of the force and prevents buckling due to the excess compression force applied in those members comparatively to the other surrounding members.

Figure 30: Sketch of future improvements

Environmental Considerations

The process of obtaining and refining iron into stainless steel through an electric arc furnace consumes a considerable amount of energy; however, by taking and recycling stainless steel from other projects, the energy waste to refine and alloy stainless steel can significantly be reduced. Furthermore, stainless steel does not cause known environmental problems and will thus respect the Yugambeh and the World Heritage Site (SC4.1), thus preserving local Australian ecosystems without hazardous by-products.

Additional advice

- Schools should review the strategies
  - for managing response length and ensure strategies are consistently implemented. Where a response exceeds the assessment conditions specified in the syllabus, the school should annotate any relevant samples to indicate what strategy was applied. Refer to the *QCE and QCIA policy and procedures handbook v6.0*, Section 8.2.6
  - to ensure the correct mark is determined using the best-fit approach and correctly identify this on the ISMG to decide the provisional marks before entering results into Student Management. For more information, refer to the *Engineering ISMG webinar* (Slide. 22), available in the syllabus Resources in the Syllabuses application (app) in the QCAA Portal

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	80
Authentication	0
Authenticity	6
Item construction	2
Scope and scale	18

Effective practices

Validity priorities were effectively demonstrated in assessment instruments that:

- included a variety of item formats such as multiple-choice, single-word, sentence, short-paragraph, and calculation items
- included complex familiar and complex unfamiliar questions that were sufficiently different from the annotated sample response available on the QCAA website, to ensure that students have not been previously exposed to unseen stimulus.

Practices to strengthen

It is recommended that assessment instruments:

- feature items designed to assess
  - students' understanding of subject matter across all three topics of Unit 3
  - a balance of the required assessment objectives (1, 2, 3 and 5)
- ensure mark allocations for items are
  - balanced according to the syllabus' specified percentage of marks and degree of difficulty (Syllabus section 4.6.2)
    - simple familiar (60%)
    - complex familiar (20%)

    - complex unfamiliar (20%)
  - based on the
    - cognitive load required to respond to items
    - evidence required to be demonstrated to align with the sample response presented in the marking scheme
- avoid items that assess students' understanding of other units, as these are beyond the scope of this assessment. Items should not align to Unit 1, 2 or 4 content, e.g. levers and mechanical advantage are Unit 4 content so should not be assessed in IA2
- include items that are within an appropriate scope and scale, e.g.
  - a sufficient number and type of items, suitable for the two-hour time limit
  - short-paragraph response items that a designed such that students can answer in 100–150 words.

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	3
Language	3
Layout	7
Transparency	8

Effective practices

Accessibility priorities were effectively demonstrated in assessment instruments that:

- employed syllabus-specific language and cognitive verbs aligned with syllabus objectives, e.g. included instructions like 'explain', 'compare', or 'contrast' to clearly communicate to students the type of cognitive task involved and the specific response expected
- avoided using jargon or language unrelated to Unit 3 subject matter to maintain relevance and clarity. For instance, terms like 'king posts' or references to irrelevant contexts such as Mars.

Practices to strengthen

It is recommended that assessment instruments:

- include diagrams only when appropriate and that
  - are clear and accurate
  - avoid duplicating information already provided in the question
  - are directly relevant and aligned to the specific question
- provide appropriate space for the student response to each question.

Additional advice

- Marking schemes are not endorsed; however, they are important in supporting assessment decisions at confirmation. It is recommended that schools quality assure marking schemes to ensure they
  - align with the assessment instrument
  - are accurate
  - clearly indicate how marks will and will not be allocated to each question
  - include alternative acceptable responses and tolerances where applicable.

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:

- for the Engineering knowledge and problem-solving criterion
  - marks allocated to short response calculation items were clearly identified on the response and aligned with the mark allocations on the marking scheme. The total number of marks being allocated for each item was also clearly shown on the student response
  - full marks were awarded for responses to short response written items that addressed each requirement of the question.

Practices to strengthen

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

- the marking scheme is applied accurately and consistently across the cohort
- careful attention is given to the use of the greater than symbol in relation to applying the percentage cut-of score to correctly determine a mark out of 25 on the ISMG
- rounding up the raw percentage score for the paper to the nearest whole number is avoided as this can lead to incorrect application of percentage cut-off scores, e.g. 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.

Samples

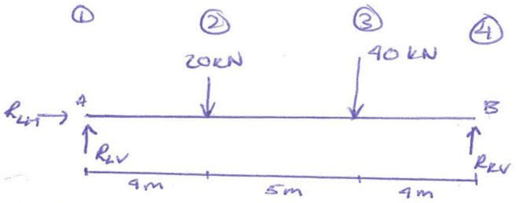
The following excerpt has been included to provide an example of the Engineering knowledge and problem-solving criterion at the upper performance level.

The excerpt demonstrates a well-structured response to a short response calculation question. The question asked students to analyse a diagram of a simply supported beam to produce shear force and bending moment diagrams. The response demonstrates insightful and accurate analysis of the diagram coupled with synthesis of prior knowledge and understanding of mechanics in relation to shear force and bending moments. Adept symbolisation is used to communicate a response that is clearly laid out and legible, showing all working.

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

Question 23 (6 marks)

Mark/s:



$\Sigma F_H = 0 = R_{LH}$

$\therefore R_{LH} = 0kN$

ΣM_A ~~@(-20x~~ $= 0 = (^-20 \times 4) + (^-40 \times 9) + (R_{RV} \times 13)$

$0 = {}^-80 - 360 + 13R_{RV}$

$440 = 13R_{RV}$

$R_{RV} = \frac{440}{13}$

$\approx 33.85kN \uparrow$

$\Sigma F_V = 0 = R_{LV} - 20 - 40 + 33.85$

$0 = R_{LV} - 26.15$

$R_{LV} = 26.15kN \uparrow$

<u>Shear Force (SF)</u>

SF at ① = 26.15kN

SF just left of ② = 26.15kN

SF just right of ② = 26.15 − 20 = 6.15kN

SF just left of ③ = 6.15kN

SF just right of ③ = 26.15 − 20 − 40 = −33.85kN

SF at ④ = −33.85 + 33.85 = 0kN

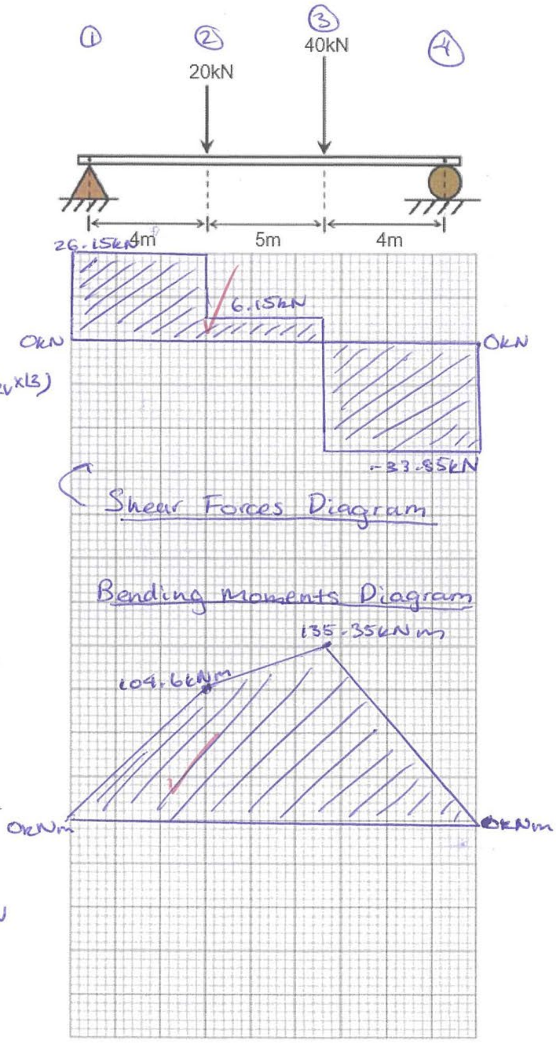
<u>Bending Moments (BM)</u>

BM at ① = 0kNm

Bm at ② = 26.15×4 = 104.6kNm

BM at ③ = 26.15×9 − 20×5 = 135.35kNm

BM at ④ = 26.15×13 − 20×9 − 40×4 = 0kNm



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Additional advice

- The marking scheme used for the assessment should be
  - capable of supporting the confirmation process by indicating how marks were awarded for each item in the assessment in each student response
  - amended to reflect unique student responses to the items and to correct any errors or omissions found during the marking process, e.g. a marking scheme should be amended when
    - the school decides that a response is worth half marks when it does not align with the requirements of the marking scheme to fully obtain one mark. The marking scheme should be updated to reflect exactly what the half mark will be awarded for
    - it is determined that a response should be awarded follow-through marks for errors in previous working and the marking scheme did not allow for this. These decisions should be applied to all responses to ensure the accurate and consistent allocation of marks across the cohort. An amended marking scheme can be updated in the Endorsement app at any time, or uploaded with the confirmation samples
  - complete at the time of confirmation. Incomplete or missing marking schemes result in confirmers being unable to support the school's assessment decisions as there is no indication of how they were determined. It is the school's responsibility to submit a complete and accurate marking scheme that can support assessment decisions at confirmation.

Internal assessment 3 (IA3)

Project f— 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	23
Authentication	2
Authenticity	5
Item construction	8
Scope and scale	22

Effective practices

Validity priorities were effectively demonstrated in assessment instruments that:

- enabled students to create prototypes or partial prototypes, whether physical or virtual, that yielded valid performance data, e.g. tasks provided students with opportunities to develop prototypes that, when tested, generated data for analysis and allowed students to make recommendations and refinements
- incorporated carefully chosen and developed real-world-related contexts that provided detailed information about a mechanical and/or mechanisms problem. These contexts allowed students to engage with Unit 4 syllabus content, e.g. contextual statements and tasks that required the application of control technologies concepts and principles in addressing real-world-related machines and/or mechanisms problem. It was evident that the development of these contexts and task requirements used knowledge from assessment specifications, objectives, the ISMG, and Unit 4 syllabus content.

Practices to strengthen

It is recommended that assessment instruments:

- contain all of the information in Part A and Part B of the assessment specifications. These should be copied and pasted from the syllabus without alteration, to avoid unintentionally omitting essential information that could limit a student's ability to demonstrate all of the characteristics required to match evidence to the ISMG
- include specific information about the scale of the prototype or partial prototype to be produced, where a
  - virtual prototype is required, the scaling should be specified as 1:1
  - physical prototype is required, an appropriate scale that allows students to obtain valid performance data should be provided.

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	3
Language	15
Layout	0
Transparency	0

Effective practices

Accessibility priorities were effectively demonstrated in assessment instruments that:

- featured a structured context and task layout that was clearly organised and provided a framework of information that allowed students access to assessment objectives, specifications, and ISMG (Syllabus section 5.6.1).

Practices to strengthen

It is recommended that assessment instruments:

- refrain from using technical jargon or inappropriate language. Tasks should adhere to syllabus terminology when discussing problem-solving, solutions, and solution development. Schools should use terms like 'develop', 'ideas', and 'engineered solutions' instead of 'design', 'designs', or 'design concepts', as design-related concepts and principles are outside the scope of the syllabus and are not defined in the Engineering curriculum
- appropriately align with the syllabus requirements in relation to the information, knowledge, and skills that students are expected to demonstrate. Tasks must include sufficient accurate dimensions and loads to ensure the data collected from prototype performance testing is valid.

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	95.24	4.76	0	0
2	Analysing	81.90	18.10	0	0
3	Synthesis and evaluation	78.10	21.90	0	0
4	Communicating	100.00	0.00	0	0

Effective practices

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

- for the Retrieving and comprehending criterion, evidence included
  - the correct identification of pertinent materials science and mechanics information, selected for their value or relevance in relation to the problem
  - intellectual perception when providing an account of the known and unknown characteristics, assumptions and boundaries of the machine and/or mechanism problem
- for the Communicating criterion, evidence included
  - articulate use of folio and referencing conventions, with in-text references selected for their value or relevance to the exploration of the problem
  - accurate spelling, grammar and appropriate technical language when written features were selected to communicate about the solution.

Practices to strengthen

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

- for the Retrieving and comprehending criterion at the upper performance level, attention should be given in relation to the symbolise and explain descriptors to the inclusion of
  - sketches that show a high level of proficiency and are capable of effectively communicating the development of ideas
  - an engineering drawing that can support the generation of a prototype solution, that is accurately laid out in third angle projection with correct labelling and dimensioning conventions
  - logic circuit diagrams and truth tables to demonstrate the exploration and development of logic control technology in the response
- for the Analysing criterion at the upper performance level, attention should be given to

  - demonstrating a deep understanding of the relationship between the relevant engineering mechanics and logic control technology and the machine and/or mechanism problem that includes, e.g. calculations and pretesting to determine realistic and accurate measurable aspects for both the prototype and the real-world solution
  - the accurate assessment of the characteristics of the problem to ascertain the most important and relevant criteria that can be used to evaluate the success of both the prototype and real-world solution. The success criteria must have been derived from the exploration of the problem and extend beyond the information that has been provided in the assessment instrument. They should include measurable aspects in relation to machines, mechanisms, materials, engineering technology and logic control technology
- for the Synthesising and evaluating criterion at the upper performance level, attention should be given to
  - the sensible and valid combining of ideas with Unit 4 subject matter information that includes simple machines, mechanisms, materials science, engineering technology and logic control technology information relevant to the problem to propose a solution
  - the generation of a prototype, either virtual or physical, that can be tested to produce performance data that is capable of predicting the performance of the real world solution
  - using the success criteria when evaluating the ideas and the proposed real-world solution
  - making thoughtful and astute choices in relation to refinements to the solution and making recommendations for the real-world solution that can be supported by the data obtained from testing the prototype.

Samples

The following excerpts have been included to provide examples of the Retrieving and comprehending criterion at the 4–5 performance level. They demonstrate how a range of visual features have been used effectively to symbolise and explain ideas and a solution in relation to a machines and/or mechanisms problem.

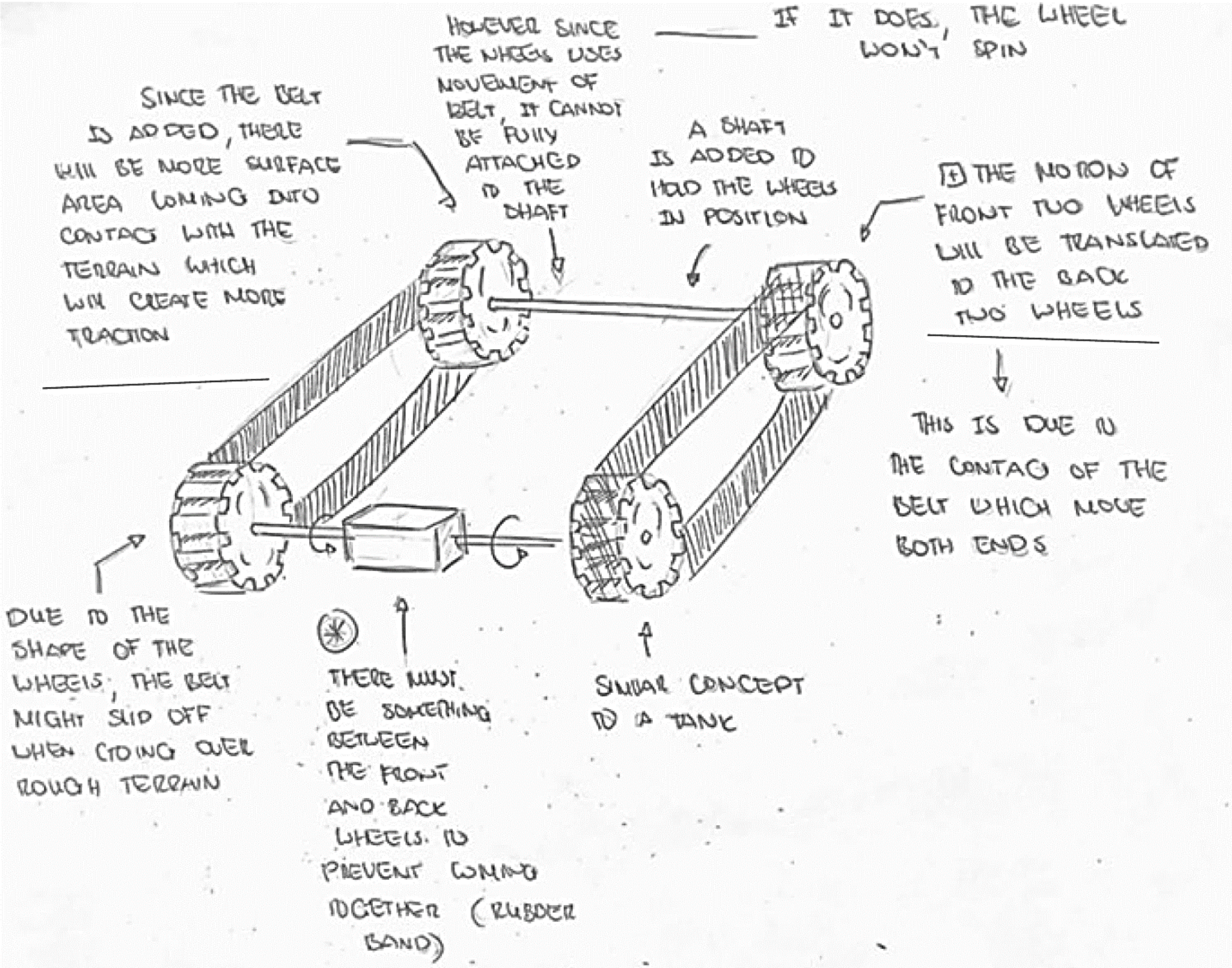
Excerpt 1 demonstrates a high degree of skill and proficiency in sketching, and includes details such as proportion, form, material texture and movement with supporting annotations to communicate ideas.

Excerpts 2 and 3 show evidence of a high level of skill in the production of engineering drawings that include accurate layout, labelling and dimensioning with sufficient detail to facilitate the generation of a prototype solution for the machine and mechanism problem.

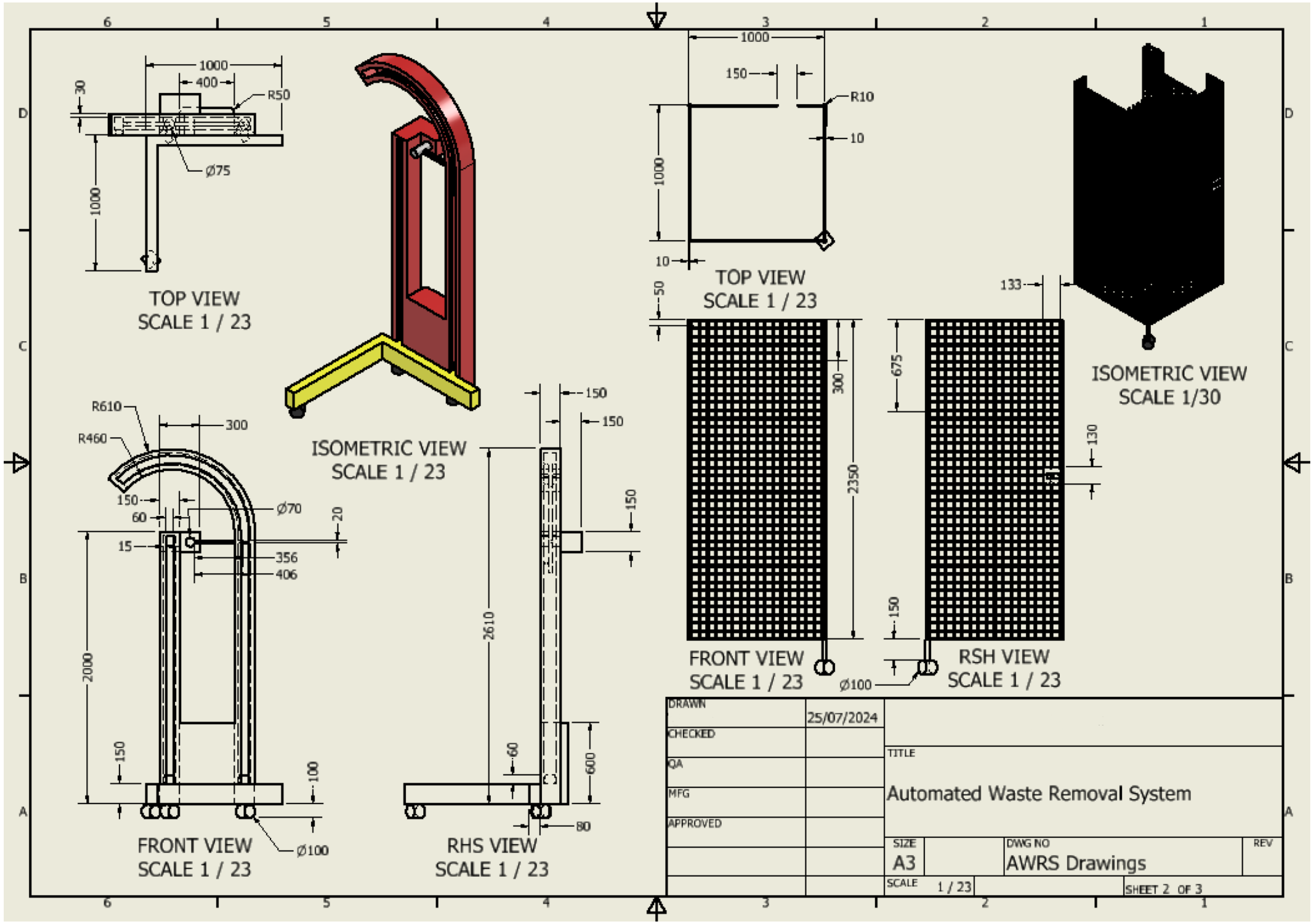
Excerpt 4 demonstrates symbolisation of Unit 4 control technology through the use of a truth table and logic circuit diagram to virtually test the control aspect of the solution.

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

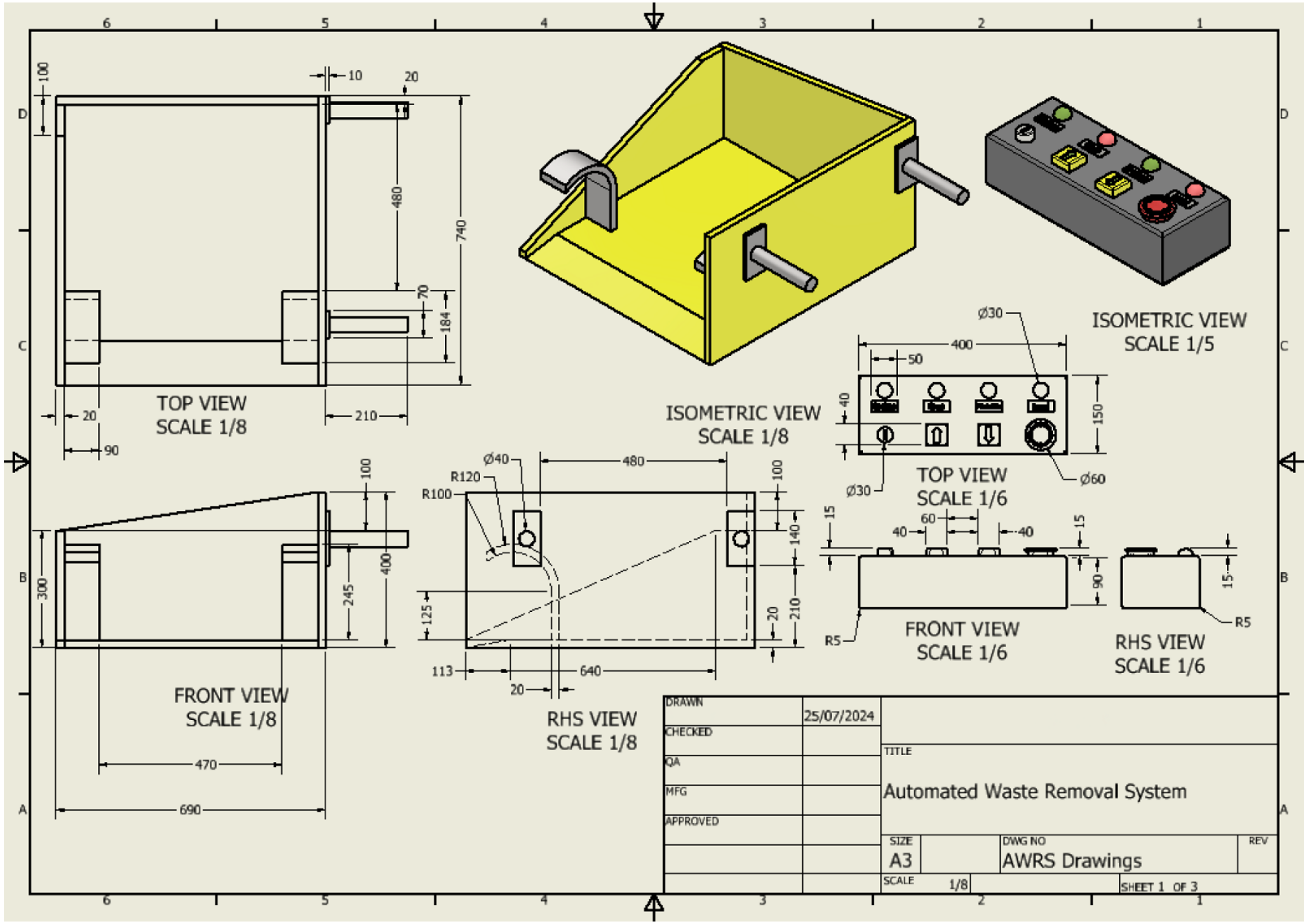
Excerpt 1


HOWEVER SINCE THE WHEELS USES MOVEMENT OF BELT, IT CANNOT BE FULLY ATTACHED TO THE SHAFT
IF IT DOES, THE WHEEL WON'T SPIN
SINCE THE BELT IS ADDED, THERE WILL BE MORE SURFACE AREA COMING INTO CONTACT WITH THE TERRAIN WHICH WILL CREATE MORE TRACTION
A SHAFT IS ADDED TO HOLD THE WHEELS IN POSITION
THE MOTION OF FRONT TWO WHEELS WILL BE TRANSLATED TO THE BACK TWO WHEELS
THIS IS DUE TO THE CONTACT OF THE BELT WHICH MOVE BOTH ENDS
DUE TO THE SHAPE OF THE WHEELS, THE BELT MIGHT SLIP OFF WHEN GOING OVER ROUGH TERRAIN
THERE MUST BE SOMETHING BETWEEN THE FRONT AND BACK WHEELS TO PREVENT COMING TOGETHER (RUBBER BAND)
SIMILAR CONCEPT TO A TANK

Excerpt 2


TOP VIEW
SCALE 1 / 23
ISOMETRIC VIEW
SCALE 1 / 23
TOP VIEW
SCALE 1 / 23
ISOMETRIC VIEW
SCALE 1/30
FRONT VIEW
SCALE 1 / 23
RHS VIEW
SCALE 1 / 23
FRONT VIEW
SCALE 1 / 23
RSH VIEW
SCALE 1 / 23
DRAWN
25/07/2024
CHECKED
QA
MFG
APPROVED
TITLE
Automated Waste Removal System
SIZE
A3
DWG NO
AWRS Drawings
REV
SCALE 1 / 23
SHEET 2 OF 3

Excerpt 3


TOP VIEW
SCALE 1/8
FRONT VIEW
SCALE 1/8
RHS VIEW
SCALE 1/8
ISOMETRIC VIEW
SCALE 1/8
ISOMETRIC VIEW
SCALE 1/5
TOP VIEW
SCALE 1/6
FRONT VIEW
SCALE 1/6
RHS VIEW
SCALE 1/6
DRAWN
25/07/2024
CHECKED
QA
MFG
APPROVED
TITLE
Automated Waste Removal System
SIZE
A3
DWG NO
AWRS Drawings
REV
SCALE 1/8
SHEET 1 OF 3

Excerpt 4

Logic Gates:

The calculations would work in conjunction with the weight system to warn users when the mechanism has reached the limit. This design would use a light system to indicate when the revolution has reached various levels of pullback to reflect the weight at which it is holding. This system would work in a 70kg to 100kg to 120kg warning system which the lightbulb colour would change to display whether it has hit the limit. Realistically, the mechanism should be able to carry up until 180 with safety factor considered however that will not be recorded on the system.

Truth Table

I1	I2	I3	O1	O2	O3
false	false	false	false	false	false
false	false	true	false	false	true
false	true	false	true	false	false
false	true	true	false	false	true
true	false	false	false	true	false
true	false	true	false	true	true
true	true	false	true	false	false
true	true	true	false	false	true

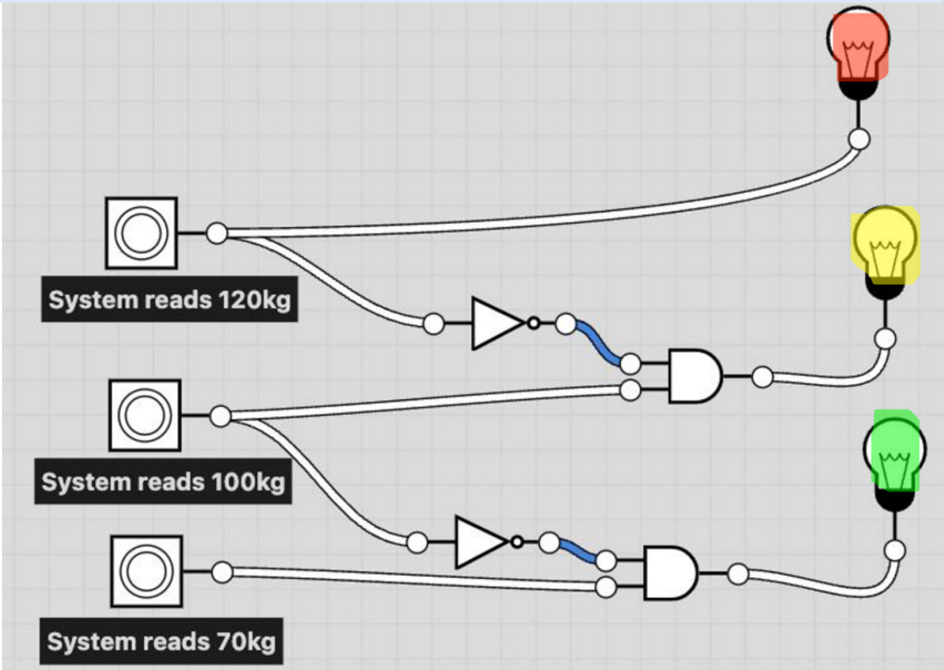


Figure 9: Logic gate system of the coloured lightbulb.

The following logic gate system shows the shear load pin working in hand with the limit light switch. Basically, once the load pin picks up a force that reflects one of the kilogram weights above, it will begin to flash either red, orange, or green to indicate its maximum carry weight. It uses a mix of AND and OR gates to allow the process to light up one of the three lightbulbs.

The following excerpts have been included to provide examples of the Analysis criterion at the 6–7 performance level.

Excerpts 1 and 2 demonstrate a deep understanding of the relationship between the relevant materials and engineering mechanics and the problem. The materials and mechanical aspects of the problem have been broken down and examined in detail to identify the essential characteristics that will be important for developing a solution to the problem. The excerpts include calculations and pretesting to determine measurable aspects that can be used to determine the essential success criteria.

Excerpts 3 and 4 demonstrate an understanding of control technologies that are relevant to the machine and mechanisms problems. Importantly, while Excerpt 2 explores a variety of ways to include an element of control in the solution, it includes Unit 4 subject matter in the form of logic control.

Excerpt 5 illustrates success criteria derived from the exploration of the problem that have measurable attributes for both the prototype and real-world solution that can be used to evaluate the ideas and the solution. It demonstrates an accurate assessment of the characteristics of the problem with the inclusion of supporting statements. The success criteria have been prioritised to highlight the importance of the criteria for ascertaining a suitable solution.

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

Excerpt 1

Mechanics

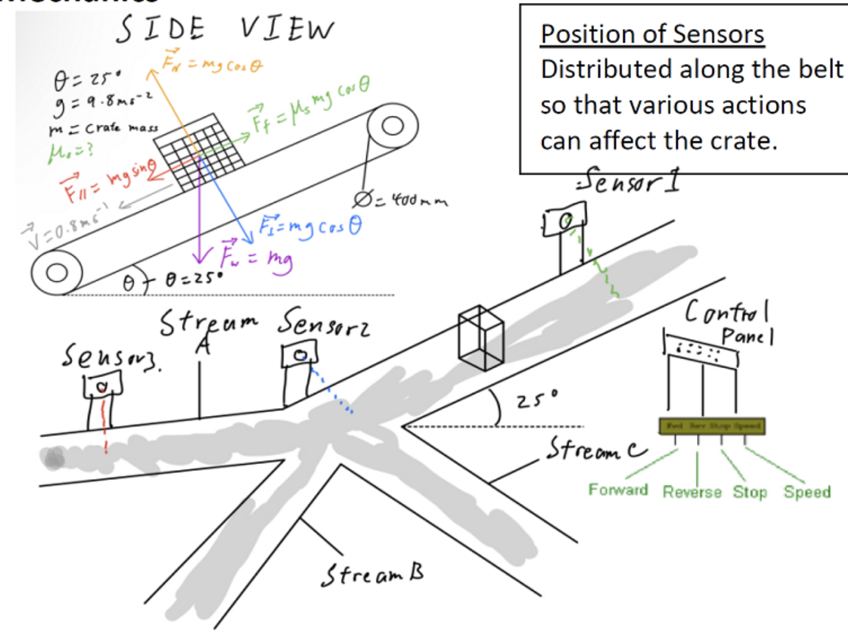


Figure 2: Free Body Diagram of Inclined Conveyor

Position of Sensors
Distributed along the belt so that various actions can affect the crate.

Using the given information within the task of the 0.8m/s speed and diameter of 0.4m, the time for each revolution can be determined and thus the number of revolutions per second can be determined.

$$t_{rev} = \frac{d}{s}$$
$$= 0.2 \times \frac{2\pi}{0.8}$$
$$\omega(rps) = \frac{1}{t}$$
$$= \left(0.2 \times \frac{2\pi}{0.8}\right)^{-1} rps$$
$$\omega(rpm) = \left(0.2 \times \frac{2\pi}{0.8}\right)^{-1} \times 60$$
$$= 38.20 rpm$$

Given that the angle of the conveyor is 25°, the coefficient of static friction can be determined from the following:

$$\mu_s = \tan(\theta)$$
$$= \tan(25°)$$
$$= 0.466$$

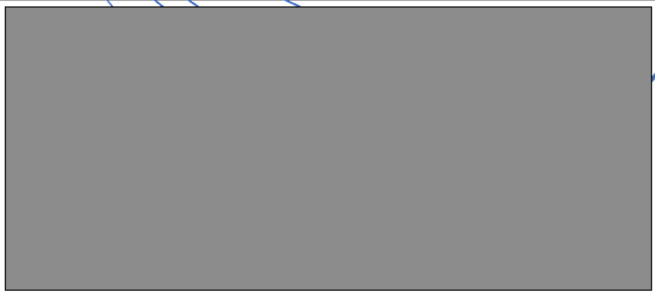


Figure 5: Controls of the Conveyor Unit (Bhatt, 2013)

Variable Sensor
Based upon the required inputs, the system should be able to process and take those inputs into 4 or more discrete outputs.

Control Technology

The Sorting system should be able to compute and detect:

- Analogously:
  - Weight of each crate to maintain safe handling limit
  - Temperature to ensure groceries stay fresh and edible
  - Capacity of each crate so the food can fit within it
- Digitally
  - The presence of the label to follow client instructions
  - Storage room availability to prevent further mishaps
  - One of the three paths to follow for easy management

Excerpt 2

Mechanics of the Conveyor

By manipulating formulas for forces upon an incline plane, a theoretical expression for the amount of torque, τ , can also be determined to compare with the given speed to thus calculate the theoretical power needed to lift the crate.

$$W = Fs$$
$$P = Fv$$
$$= \mu_s mgcos(\theta) \times v$$
$$= 0.466 \times 16 \times \cos(25°) \times 0.8$$
$$= 5.4059446881 \approx 5.406W$$

However, given that the coefficient of friction is actually 0.9 (Engineering Toolbox, 2012) instead of 0.466, the new input power is:

$$P = \mu_s mg\cos(\theta)v$$
$$= 0.9 \times 16 \times \cos(25°) \times 0.8$$
$$= 10.4406657067 \approx 10.44W$$

The initial power is then interpreted to provide the torque required (τ_r) and given (τ_g) by the conveyor belt:

$$P = \tau_r \omega$$
$$\tau_r = \frac{P}{\omega}$$
$$= (60 \times 5.406)/(2\pi \times 38.20)$$
$$= 1.35N.m$$

$$\tau_g = \frac{P}{\omega}$$
$$= (60 \times 10.44)/(2\pi \times 38.20)$$
$$= 2.61N.m$$

The gear ratio can be determined using the given torque values, which also thus can be compared to actual motors with corresponding power values.

$$Gear\ Ratio = \tau\_2/\tau\_1$$
$$= 1.35/2.61$$
$$= 1.93$$

When comparing the input angular velocity, ω, (rpm) to industry standard (ANSI/ISO) angular velocities of typical conveyor belt motors, it was found on average, the highest angular velocity would be 1800rpm, with the lowest being still 600rpm (Bulk et. al, 2021). As such, using an input angular velocity of 600rpm with an energy efficiency of approximately 80%, a new gear ratio with power can also be determined, also providing a new torque.

Further Mechanics of the Conveyor

Given that energy efficiency (η) is 0.8,

$$\eta = \frac{P_{output}}{P_{input}}$$
$$0.8 = \frac{10.44}{P_{input}}$$
$$P_{input} = 13.05W$$

$$\tau_m = \frac{P}{\omega}$$
$$= \frac{13.05 \times 60}{2\pi \times 600}$$
$$= 0.207N.m$$

$$Gear\ Ratio = \frac{\omega_{motor}}{\omega_{conveyor}}$$
$$= \frac{600}{38.2}$$
$$= 15.71$$

As such, the following values are produced for the motor:

Table 3: Angular velocity and Torque

Type	ω(rpm)	τ (N.m)
13.05W DC motor	600	0.207
Conveyor belt	38.20	0.207

Excerpt 3

Automation and Control Technologies

Through the use of automation and control technologies, a product of higher quality and increased ease of use can be attained. Due to the nature of the school environment in which the product is to be used, an optimised balance of efficiency and ease of use versus cost effectiveness and mechanical durability must be integrated into the design process.

HYDRAULICS

Hydraulics utilise the movement of pressurised liquid to facilitate mechanical movement. Due to the principle that liquid will not change its volume when compressed, mechanical action is transferred from an initial piston through the liquid and into a final piston. In order to maintain the constant pressure of the hydraulic liquid around 3000 to 5000 psi, often times a reservoir and motor powering a hydraulic pump is linked into the closed loop system *(Hydraulics and Pneumatics Guide, 2023).* Typically, hydraulics are used for heavy-duty applications like lifting, clamping, and pressing.

Figure 5: Hydraulics and Pneumatics *(whyps, 2023)*

Hydraulics are marginally more efficient due to the recyclability of hydraulic fluid and energy efficiency, however require consistent maintenance to minimise corrosion. Hydraulics could be used in the removal system as the primary lifting mechanism due to its high load bearing capacity and long term use case.

PNEUMATICS

Pneumatics use pressurised air to transfer mechanical movement. While an air reservoir and a pump motor is still required to maintain pressure, they require only minimal 100 psi to run. Pneumatics are considered slightly less force and energy efficient due to energy lost to compression, but provide a much more sharp, quick and repetitive motion. Low load actions like clamping, gripping, and stacking are ideal for pneumatics. Less maintenance is required compared to that of hydraulics, as fresh air is used once the pressurised air has been exhausted. Pneumatics could be used in secondary roles in the waste removal system like a locking pin mechanism, a tipping correction system, or a repetitive knocking system to ensure all waste is jettisoned from the bin *(Hydraulics and Pneumatics Guide, 2023).*

PIC MICROCONTROLLERS

PIC (Peripheral Interface Controller) microcontrollers are key silicon elements responsible for multitudes of tasks in modern circuitry *(Ryan, 2017)*. These microcontrollers can be programmed with logic gates that perform basic logical functions, turning two binary signals into a single resolved binary signal. As they are based on a binary system, the inputs and outputs can only be affirmative or negative, represented by a 1 and a 0 respectively. There are seven types of logic gates, each providing a different binary output, based on the combination of binary inputs provided *(Gillis, 2023)*. Logic gates are particularly useful in safety systems as they will not allow an affirmative mechanical action without first receiving affirmative safety signals from elsewhere in the circuit. Using logic gates it can be ensured that the hydraulic arm will not lift the bin without first receiving an affirmative signal from a pressure and key lock sensor.

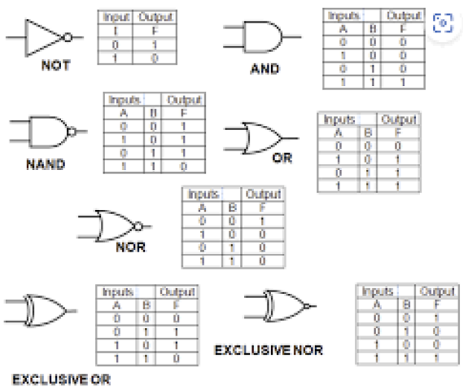
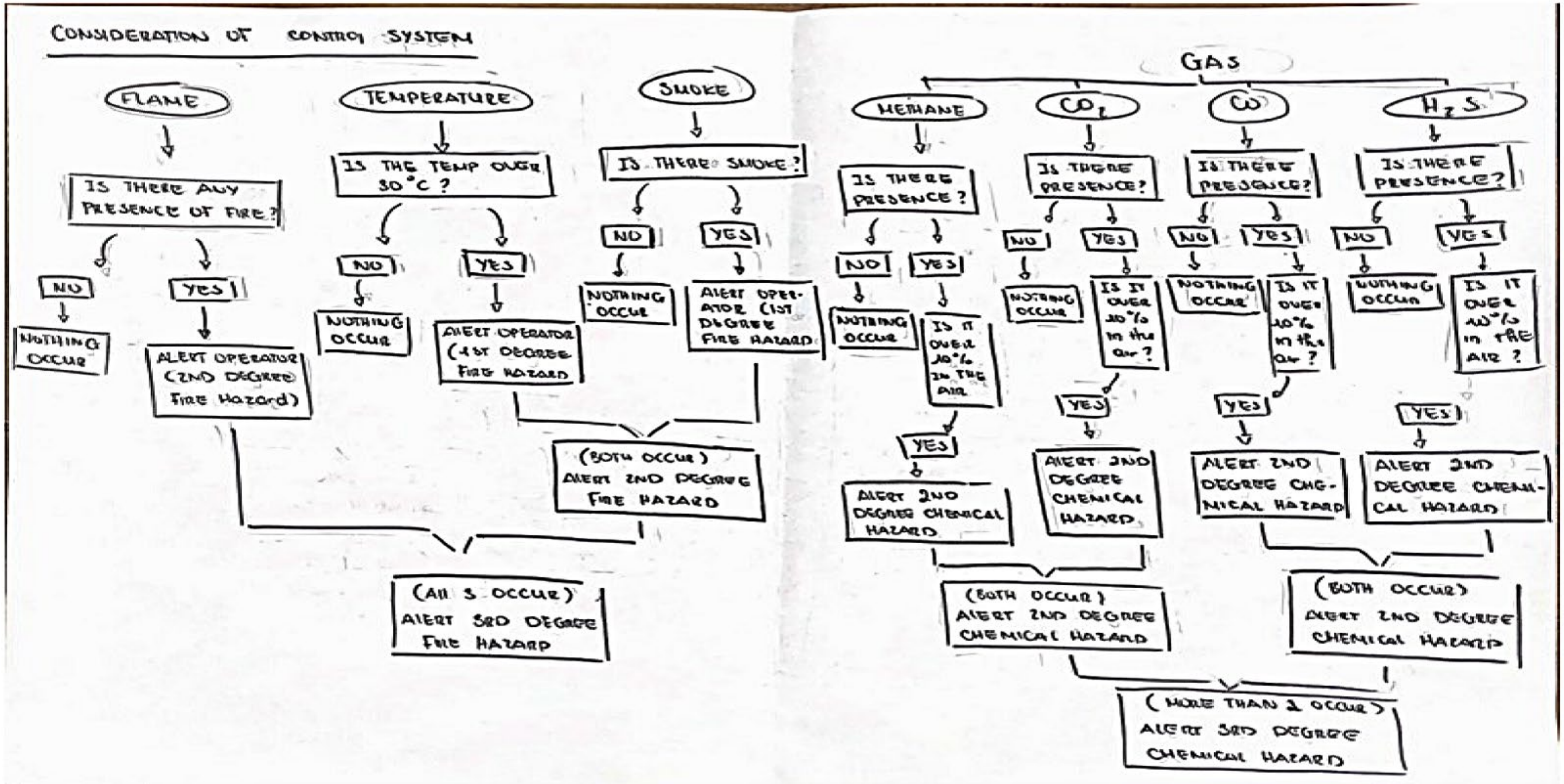


Figure 6: Common logic gates and their function *(Sharma, 2015)*

Excerpt 4


CONSIDERATION OF CONTROL SYSTEM
FLAME
IS THERE ANY PRESENCE OF FIRE?
NO
NOTHING OCCUR
YES
ALERT OPERATOR (2ND DEGREE FIRE HAZARD)
TEMPERATURE
IS THE TEMP OVER 50°C ?
NO
NOTHING OCCUR
YES
ALERT OPERATOR (1ST DEGREE FIRE HAZARD)
SMOKE
IS THERE SMOKE?
NO
NOTHING OCCUR
YES
ALERT OPERATOR (1ST DEGREE FIRE HAZARD)
(BOTH OCCUR) ALERT 2ND DEGREE FIRE HAZARD
(ALL 3 OCCUR) ALERT 3RD DEGREE FIRE HAZARD
GAS
METHANE
CO2
CO
H2S
IS THERE PRESENCE?
NO
NOTHING OCCUR
YES
IS IT OVER 10% IN THE AIR?
YES
ALERT 2ND DEGREE CHEMICAL HAZARD
(BOTH OCCUR) ALERT 2ND DEGREE CHEMICAL HAZARD
(MORE THAN 2 OCCUR) ALERT 3RD DEGREE CHEMICAL HAZARD

Excerpt 5

Success criteria

- The all-terrain robot vehicle can pass over obstacles in its path up to 0.3m tall (average height of hummock grass). Converting this to the scaled prototype, it will be deemed successful if there is a ground clearance of at least 50mm.
- Prototype can climb objects up to 60mm tall using independent suspension on at least two wheels.
- Motors and gear ratio systems provide a controlled speed less than 0.2m/s, the approximate equivalent of walking pace for the real-world solution. Fuel efficiency should also be considered.
- Vehicle can climb inclined planes covered in gravel and sand up to 30° due to tread design and torque.
- Materials chosen for the final product are lightweight (density less than $2g/cm^3$), corrosion resistant, able to withstand high temperatures, humidity and salinity, and the main structure's strength to weight ratio is at least 200 $kN \cdot m/kg$ (chassis and body).
- Features automation and sensors that fully considers a seed deployment mission and responds dynamically to changing environmental conditions to maximise functionality and efficiency.
- Includes seed containment/deployment, ground preparation mechanisms and strategies for successful planting, with a consideration of dynamic forces.
- The vehicle design should be highly stable (considering points of contact and centre of gravity), and factor in weight reduction methods.

The following excerpts have been included to provide examples of the Synthesising and evaluating criterion at the 8–9 performance level.

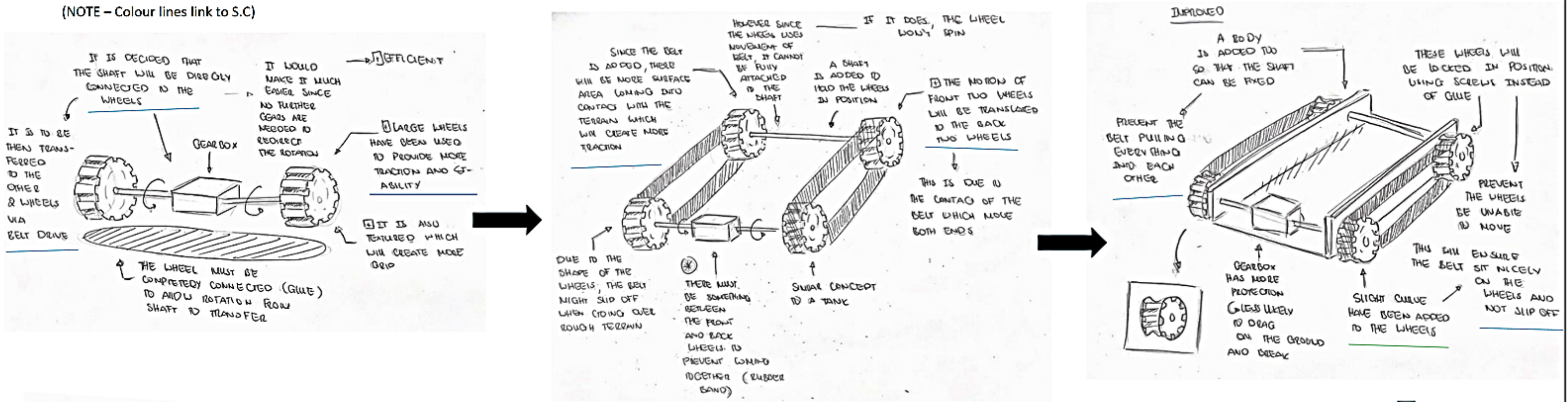
Excerpts 1 and 2 demonstrate a well-structured, rational and valid combination of ideas and research information with information about materials science, engineering mechanics and engineering technology that has been derived from the analysis of the problem to propose a possible solution. The layout and use of connecting arrows and plus symbols clearly communicates the flow and development of ideas. Furthermore, the excerpts provide evidence of skilful and rational judgment when weighing up the strengths, limitations and implications of the solution against the success criteria and show intellectual perception in relation to the proposed refinements to the solution. They include thoughtful and accurate recommendations for the real-world solution that have been supported by performance data obtained from testing the prototype solution. The use of colour coding, underlining and connecting arrows communicate the reference to the success criteria in a clear and succinct way.

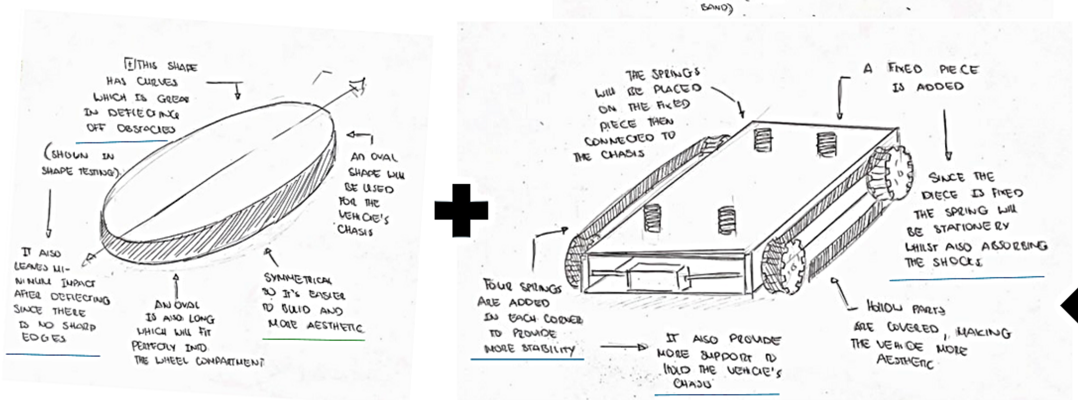
Note: The characteristic/s identified may not be the only time the characteristic/s occurred throughout a response.

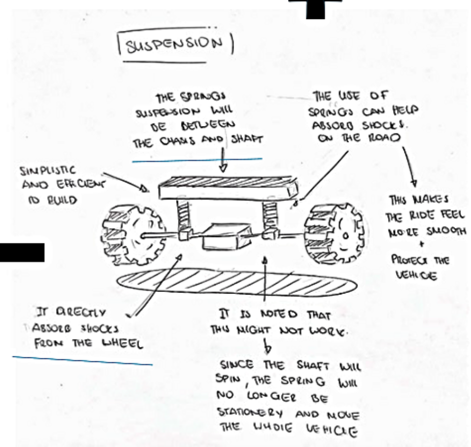
Excerpt 1

Develop: Brainstorming and Refining Ideas

(NOTE – Colour lines link to S.C)







Strengths	Limitations	Refinements
Drive System – The use of belt drive provides more traction and stability which is suitable for a mine environment Drive system – large wheel usage allows the vehicle to traverse through mudholes as well as providing more surface area for traction Drive system – use of springs suspension helps it absorb shocks from the road and make the ride smoother and safer Drive system – all the components of the vehicle should be simplistic to build	Drive system - Initially, the belt sitting on the wheels can easily slip off due to having no barrier stopping it. Drive system – there is no support between the front and back wheels. As a result, the belt used can pull them together, breaking the whole system Drive system – the spring were placed directly on the shaft. When the shaft rotates, the spring system will move which will break it	Drive system – a groove is added to the wheel where the belt can sit nicely without slipping off Drive system - A fixed body is used so that the shaft can be glued on. This will prevent the front and back wheels from being pulled together by the belt. Drive system – the spring is added on top of fixed piece so that it won't rotate and break

Excerpt 2

Develop: Final Solution

DRIVE SYSTEM

Upon consideration, the elastic band will make lots of contact with the surface. Since the band has high tensile strength and made of rubber, it can effectively absorb shocks. Thus, the use of suspension system will be deemed not needed and will not be used for the final solution (SC.1)

It will be made of stainless steel (mostly the outer shell). This is because the material is very durable suitable for the rough environment like the mine. It also does not have high thermal expansion and is rust resistant which can be very effective in hotter and moister areas inside the mine.

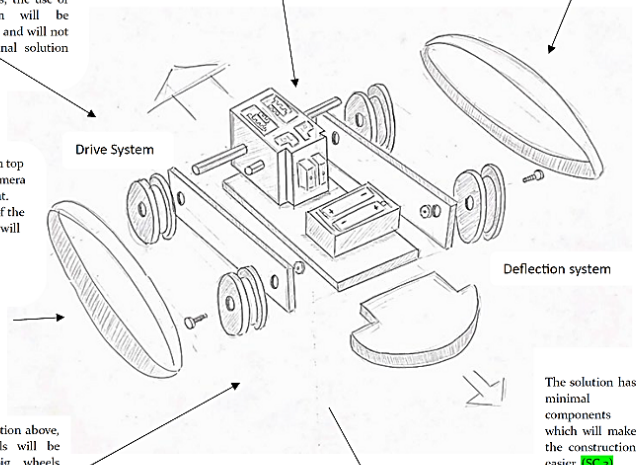
Final Drive Ratio: (SC.1)

Gear ratio from gearbox = 38.2:1

Wheel and axle ratio = $\frac{25}{2}$ = 12.5:1

Total drive ratio = 38.2 x 12.5 = 477.5:1

Sensors will be placed on top of the vehicle and the camera will be placed at the front. This is because the top of the vehicle will be open and will not have interference, allowing for the best collection of data (SC.2)



The solution has minimal components which will make the construction easier. (SC.3)

Based on the exploration above, medium-sized wheels will be utilised. Whilst, big wheels provide great traction and stability, the functionality of rolling over high obstacles (Figure ..)can be dangerous inside the mine. Hence, in order to reduce the chance of that occurring, slightly reducing the wheel size will hypothetically improve. (SC.1)

Since the suspension system is not longer used, the construction process will be much more simplified, cheap and more lightweight. (SC.1)

The round oval like shape is implemented at the front bezel of the vehicle. The main purpose of this addition is to help the vehicle deflect off obstacles. This configuration at the front will ensure that the rounded bezel will come into contact with all the obstacles first and allows it to deflect. (SC.1)

Strengths	Limitations	Refinements
Smart arrangement of sensors and cameras for the most optimal collection of information as well as control for the operator. The combination of belt drive (elastic), medium sized wheels and round-shaped front bumper will hypothetically provide sufficient traction, stability, deflection and shock absorption ability for the vehicle to effectively travel through the mine. Control system – The control system provides effective communication using different degree of hazards. The logic gate system is also very simplistic yet effective to construct. Drive system – all the components of the vehicle should be simplistic to build and hence the production cost should also be relatively affordable.	Control system – a potential issue is the number of indicators going off if there are many inputs present, which will make it more difficult to track and understand.	Having an order at which the indicators go off will help reduce confusion. For instance, the second hazard indicator will go off before the first hazard indicator since it is more critical and needs to be addressed first. This will also increase safety by prioritising dangers.

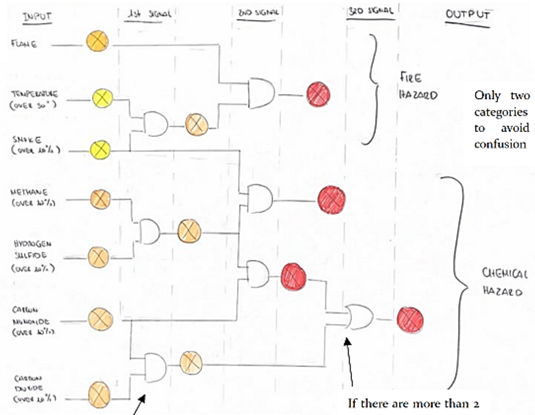
CONTROL SYSTEM

Based on the flow chart above, the following logic gates are created

To ensure the safety of the workers, even first-degree hazard will be notified to the operator

Smoke is in both category since it can occur in chemical and fire hazard

Use of colour as indicator will make it easier to recognise and process (SC.2)



Only two categories to avoid confusion

LEGEND:

1st degree – can enter but will require extra caution and safety equipment

2nd degree – requires a special team to remove the hazard

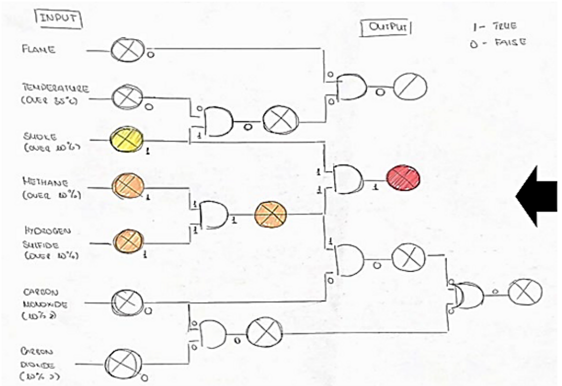
3rd degree – must wait for 3 days before the special team can enter and clear out the hazard. The workers can then enter after that

The use of AND gates are used to determine different degrees of hazard. Every degree will require two or more things to occur.

Only methane and hydrogen sulphide are imputed with smoke due because smoke itself is made up of CO and CO_2 already

If there are more than 2 gases present, even professionals will have a difficult time removing it, which can be dangerous. Hence, a third-degree hazard is made to give time for some of the gas to escape

Knowing what actions to take in response to the level of hazard will make it more efficient and safer (SC.2)



Example of the logic gate working if smoke, methane and hydrogen sulphite are present

Additional advice

- Schools should
  - use the correct ISMG when making judgments about the response (*QCE and QCIA policy and procedures handbook v6.0,* Section 7.3.3). While assessing the same objectives, the ISMG for IA1 and IA3 assess different characteristics as the contexts of Unit 3 and Unit 4 are different. References to control technology should not be removed from the ISMG
  - ensure that the marks indicated on the IMSG are transcribed correctly into Student Management when submitting provisional marks.

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 multiple choice questions (10 marks)
- Paper 1, Section 2 consisted of short response written questions (33 marks)
- Paper 1, Section 3 consisted of short response calculation questions (36 marks).

The examination consisted of questions derived from the context of Unit 4 subject matter (79 marks).

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	3.18	7.92	11.54	**77.08**
2	3.63	11.49	41.89	**42.55**
3	10.04	**70.38**	7.75	11.49
4	11.99	20.36	**60.57**	6.58
5	**82.65**	8.92	5.41	2.68
6	4.68	**89.91**	2.12	3.01
7	**66.87**	10.49	18.01	4.13
8	**88.85**	6.58	2.06	2.12

Question	A	B	C	D
9	8.42	9.26	**74.51**	7.31
10	1.39	17.62	58.06	**22.48**

Effective practices

Overall, students responded well when they:

- noted the known and unknown information in complex familiar and complex unfamiliar calculation questions as this assisted them to effectively determine the most suitable formulas and methods to respond correctly
- produced succinct responses for short response written questions that provided only the required information
- analysed written or visual stimulus provided in the question and made clear reference to it to provide a response
- demonstrated synthesis of Unit 4 subject matter knowledge in relation to how engineers use their experience to benefit the communities with information provided in the context of complex unfamiliar questions.

Practices to strengthen

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

- advise students to respond in the correct response space for each question and that if they need to respond in an additional response space, that the response is clearly labelled with the correct question number
- encourage students to highlight important information provided in short response written questions and to pay attention to the cognitions and number of marks as this will guide them to respond appropriately
- encourage students to make a note of the known and unknown information in short response calculation questions and to compare this to the formula book to help them to determine the most appropriate method of solving the problem
- discourage students from taking short cuts in calculation questions. The questions are designed to assess a range of Unit 4 subject matter, and students risk losing marks if they arrive at an incorrect response when using a different method than the one outlined in the subject matter. Alternative response methods can be awarded full marks only when the answer is correct.

Samples

Short response

The following excerpt is from Question 11. It required students to explain the concepts of mechanical advantage and work done in the context of a crowbar and to support the explanation with an annotated sketch.

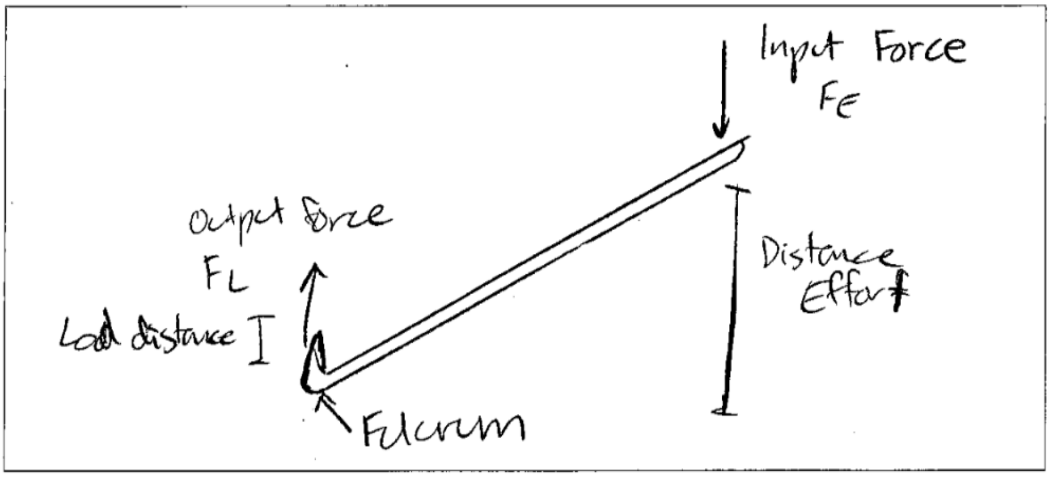
Effective student responses provided:

- an annotated sketch that clearly indicated the effort and load force and/or the effort and load distance to support the response
- a clear written explanation of the purpose of a crowbar that indicated that effort was reduced

- a clear written explanation of mechanical advantage that indicated that less force was required to move the load as the effort was amplified
- a clear written explanation of velocity ratio that indicated that the effort distance is divided by the effort load.

This excerpt has been included:

- to provide a high-level response that shows an understanding of how a crowbar provides mechanical advantage through the use of a fulcrum and demonstrates how an annotated sketch may be used to reinforce key points highlighted in an appropriate explanation concerning the concepts of mechanical advantage and velocity ratio.



A crowbar is a simple machine that increases mechanical advantage as a first class lever by increasing the velocity ratio. By having the pivot point so close to the load, the output force is increased due to the large distance to the input force. The user must push the crowbar handle a further distance than the distance the load moves but this allows a greater output force to be exerted (higher VR, higher MA)

Mathematically, $MA = \frac{F_L}{F_E}$ $VR = \frac{D_E}{D_L}$

$F_L > F_E$ $D_E > D_L$

The following excerpt is from Question 12. It required students to analyse information provided in a table about two polymers; PVC and polyethylene, to determine the most suitable material for wastewater pipes in the home. Students were required to refer to properties from the table to justify their response.

Effective student responses:

- determined that PVC was the most suitable material for the application of wastewater pipes in the home
- included an appropriate description of four properties, identified from the table, to justify the suitability of PVC for the application.

This excerpt has been included:

- to provide an example of a high-level response that articulately explains the suitability of the material using knowledge of the properties and applications of PVC and four relevant properties identified from the table to clearly justify why PVC is the preferred option for wastewater pipes in the home. The student has been able to demonstrate their understanding of materials science in relation to two polymers to determine which properties provided in the table are most relevant for the given industrial application.

Firstly, with regards to chemicals PVC is better as it has better chemical resistance (including corrosive chemicals) than PE (polyethylene). And since wastewater pipes would ~~have~~ be exposed to chemicals it is vital to have chemical resistance. Both PVC and PE have good mechanical properties and even though PVC has limited flexibility this is not too important for wastewater pipes. Additionally, PVC has a greater young's modulus than PE hence PVC is more stiff and therefore ~~less~~ it ~~likely to~~ is a strong material. Moreover, PVC also has a greater tensile strength hence when undergoing impact in a tensile manner, PVC is less likely to break or fracture than PE. However, PE does have better thermal resistance yet PVC also has some good thermal resistance. Thermal resistance is also not a major impact for wastewater pipes in the home. Furthermore, PVC has a low manufacturing cost therefore more can be made without creating economical issues for homes rather than polyethylene. Therefore, PVC would be a more suitable material for waste water pipes.

The following excerpt is from Question 13. It required students to identify two industrial applications for high carbon steel and for each application to provide a description of why high carbon steel is suitable with reference to two mechanical properties.

Effective student responses:

- included two industrial applications for high carbon steel
- provided a description of two mechanical properties of high carbon steel that contribute to its suitability for each.

This excerpt has been included:

- to provide a high-level response that shows a deep understanding of materials science knowledge through the accurate recognition of appropriate uses for high carbon steel from Unit 4 subject matter with discerning descriptions of relevant mechanical properties of the material that make it suitable for the applications.

Application 1: Cutting tools. High carbon steel has very high strength and hardness, making it ideal for cutting tools that are required to withstand large forces and effectivly cut other materials without recieving any damage itself. These properties make high carbon steel cutting tools highly durable and effective.

Application 2: High strength springs. High carbon steel's strength, stiffness and hardness make it suitable for this application, providing it with the ability to undergo large repeated forces and have excellent durability and wear resistance. All properties that these springs need, meaning high carbon steel is highly suited to this ~~ap~~ application

The following excerpt is from Question 16. It required students to analyse a community problem in the context of disaster response to describe how engineers use their expertise of materials, mechanics and control technology to benefit communities using machines and/or mechanisms.

Effective student responses:

- provided a suitable example of a machine that could be used to help communities affected by a flood event that would have been developed by a mechatronics engineer

- described how mechatronics engineers use their expertise of materials science, mechanics and control technology in relation to the identified machine to respond to the problem
- described two benefits that the machine provides to the community, relevant to the problem.

This excerpt has been included:

- to provide an example of a high-level response that shows insightful analysis of the written stimulus to identify problems experienced by the community in the given flood event scenario to identify a suitable machine that could be used to help the community, e.g. a drone. The excerpt demonstrates coherent and logical synthesis of materials science, engineering mechanics and control technology to provide discerning descriptions of how mechatronics engineers have used their expertise of these concepts to develop a drone and provides two examples of how the communities would benefit from the use of a drone with specific relevance to the given scenario.

The major problem that floods create is accessibility to help – supplies and healthcare. Additionally, the risk of rain creates additional requirements for the engineered solution. To solve this global issue, mechatronics engineers designed suitable drones to help communities. They used their expertise of control technology to design a system of sensors and actuators to navigate cities, detect humans in need, and deliver aid. Knowledge of material science is crucial to ensure the durability of the drones and their ability to withstand water corrosion while also having strength to carry supplies. Thus, most drones are made of strong yet lightweight metal alloys with protective coatings to prevent corrosion. Finally, mechanics is required to calculate force required to fly, air resistance, forces required in changing direction, and thrust from the rotating blades required to hold loads; this allows them to utilise suitable power systems and employ weight reduction. Overall, communities can recieve help, supplies, first aid, and have safety officials notified of their location, increasing efficiency of flood rescue and reducing deaths.

The following excerpts are from Question 18. It required students to analyse written and visual information in relation to a screw jack to calculate work done and power.

Effective student responses:

- demonstrated appropriate mathematical reasoning to calculate the effort distance
- correctly determined the work done on the screw jack lever arm
- correctly calculated the input power for the screw jack.

These excerpts have been included:

- to provide examples of high-level responses that
  - illustrate two valid methods to determine the work done and power
  - are well-structured to clearly show the processes used.

Excerpt 1

$F_E = 120$ $r = 300mm = 0.3m$

Total rotations $= \frac{150}{12}$

$= 12.5$

$W = F \times d$

1 rotation Distance $= 2\pi r$

$= 2 \times 0.3 \times \pi$

$= \frac{3\pi}{5}$ m

$W = F_E \times$ total rotations $\times$ rotation distance

$= 120 \times 12.5 \times \frac{3\pi}{5}$

$= 2827.4$ J

or 2.8 kJ

$P = \frac{W}{t}$

$P = \frac{2827.4}{180}$

$= 15.71$ W

Excerpt 2

$$\# \text{ rotations} = \frac{\text{distance moved}}{\text{pitch}}$$
$$= \frac{150}{12}$$
$$= 12.5 \text{ rotations.}$$

$$\text{Circumference} = 2\pi r$$
$$= 2\pi \times 0.3$$
$$= 1.88 \text{ m.}$$

$$\text{Distance moved by lever arm} = 1.88 \times 12.5$$
$$= 23.56 \text{ m.}$$

$$W = Fd$$
$$= 120 \times 23.56$$
$$\boxed{= 2827.43 \text{ J}}$$

$$P = \frac{W}{t}$$
$$= \frac{2827.43}{180}$$
$$\boxed{= 15.71 \text{ W } (2\text{d.p})}$$

The following excerpts are from Question 20. It required students to analyse written information to determine the mass of a parcel that slides down an inclined plane.

Effective student responses demonstrated an understanding of the:

- forces acting on the parcel
- horizontal and vertical components of the weight force of the parcel.

These excerpts have been included:

- to provide examples of high-level responses that show that illustrate two valid methods to determine the mass of the parcel.

Excerpt 1

$F_N = 98.2N$. $F_N = mg\cos 20$

$F_N = m \times 9.8 \times \cos 20$

$98.2 = m \times 9.8 \times \cos 20$ $\left(\frac{98.2}{9.20898}\right)$

$m = 10.66kg$. ∴ mass of parcel ~~is~~ is 10.66 ~~kg~~. Kg.

Excerpt 2

$F_f = \mu_k \times F_N$ $F_{NET} = 0$

$= 0.37 \times 98.2$ ∴ $F_f = F_{\parallel}$

$= 36.334\ N$ $36.334 = mg\sin 20$

$m = \frac{36.334}{9.8\sin 20}$

$m = 10.84kg$

Excerpt 3

Constant velocity ⇒ no acceleration ⇒ no net force.

$F_{\parallel} = F_f$. (parcel is already moving, so ignore static friction).

$F_f = \mu_k F_N$

$= 0.37 \times 98.2$

$= 36.334\ N$.

If forces are balanced, $F_{\parallel} = F_f$.

$36.334 = mg\sin\theta$.

$m = \frac{36.334}{9.8 \times \sin 20°}$

$\boxed{= 10.84\ kg}$

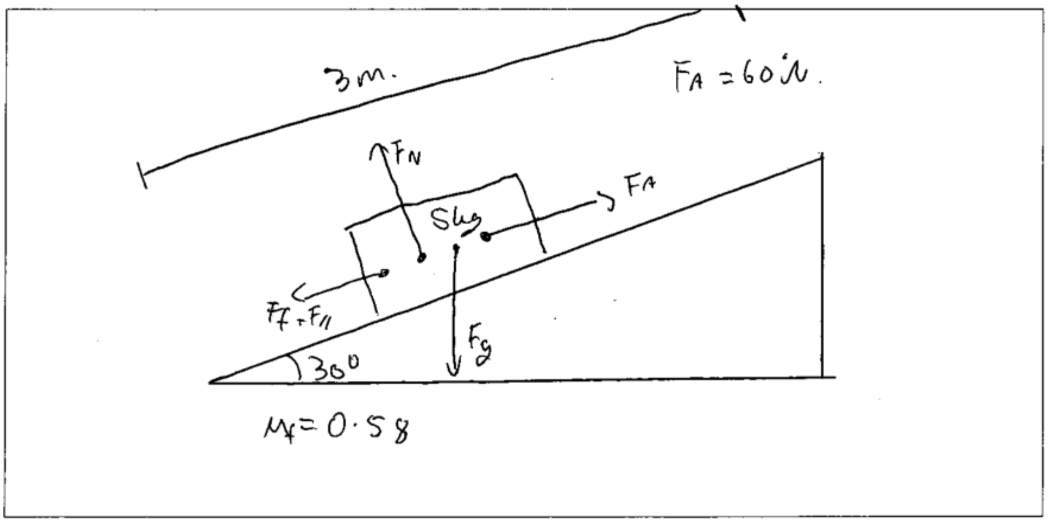
The following excerpt is from Question 22. It required students to analyse written information within the context of a sorting conveyor in a recycling plant to determine the time taken for the cart to move up the incline of the sorting conveyor. Students were required to include a sketch of a free-body diagram with their response.

Effective student responses:

- included a clearly labelled sketch of a free-body diagram showing all the forces involved
- correctly determined the time taken to move the cart, including determining the
  - normal force
  - frictional force
  - parallel force
  - net force
  - acceleration.

This excerpt has been included:

- to provide an example of a high-level response that shows insightful and accurate analysis of the information provided in the written stimulus to recognise the correct procedure required to determine the time. Additionally, the response shows a highly adept symbolisation of the forces acting on the sorting cart to support the analysis and synthesis of information to solve the problem.



$F_{\parallel} = mg \sin\theta \qquad mg = 5 \times 9.8 = 49N.$

$= 49 \times \sin 30$

$= 24.5N. \qquad F_{down\ plane} = 24.5 + 24.61$

$= 49.11N.$

$F_f = \mu F_N$

$= 0.58 \times 49 \times \cos 30 \qquad F_{net} = 60 - 49.11$

$= 24.61N \qquad = 10.89N$ up plane.

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

$10.89 = 5 \times a \qquad 3 = 0 + \frac{1}{2} \times 2.178 \times t^2$

$a = 2.178\ ms^{-2} \qquad 3 = 1.089t^2$

$t^2 = 2.755$

$t = 1.66$ seconds.

~~The cart~~ It took 1.66 seconds to take the ~~cart.~~ ~~Cart~~ cart up the incline.

Additional advice

- When performing a multi-step calculation, it is recommended that students leave rounding until the end of the calculation to reduce the risk of responses being out of acceptable tolerance ranges.