OCR
Oxford Cambridge and RSA

Accredited

A Level in Design and Technology:

Design Engineering (H404/02)

Problem Solving in Design Engineering

Sample Question Paper

Date – Morning/Afternoon

Time allowed: 1 hour 45 minutes

You must have:
- Resource Booklet

You may use:
- a scientific calculator
- a ruler
- geometrical instruments

First name	
Last name	
Centre number	
Candidate number	

INSTRUCTIONS
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Complete the boxes above with your name, centre number and candidate number.
- Answer **all** the questions in **Part 1** and **Part 2**.
- The separate Resource Booklet will be found inside this document.
- The recommended reading time for the Resource Booklet is **35 minutes**.
- Write your answer to each question in the space provided. Additional paper may be used if necessary, but you must clearly show your candidate number, centre number and question number(s).
- Where appropriate, your answers should be supported with working. Marks may be given for a correct method even if the answer is incorrect.
- Do **not** write in the bar codes.

INFORMATION
- The total mark for this paper is **70**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended responses will be assessed in questions marked with an asterisk (*****).
- This document consists of **12** pages.

Before responding to the questions in either PART you must spend time reading and familiarising yourself with the information in the Resource Booklet.

A design engineering company has been approached by the Ministry of Defence to provide possible products to solve specific requirements of the army when on overseas deployment.

PART 1

1.* One of the solutions that the Ministry of Defence is looking to introduce is a portable water heater to provide a personal supply of heated water that does not rely on any mains electricity or the use of fire that may attract attention in close environments.

There are multiple reasons why a soldier might need a personal supply of hot water:

- Boiling water is needed for cooking, making tea/coffee and for sterilising drinking water
- Warm water is needed for washing equipment and for personal hygiene.

Critically evaluate the wider issues that the design engineers would need to consider when developing prototype designs for the portable water heater for the army. Refer to the information on **Pages 2 and 3** of the Resource Booklet.

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2. There are a variety of technical issues that the design engineers will need to investigate before conceptualising a design solution.

Outline and justify appropriate technical features and materials from the existing products shown in the Resource Booklet to support the technical requirements of a portable water heater that is suitable for use in the army. Refer to the existing products and information on **Pages 2 and 5** of the Resource Booklet.

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3. One option of energy source being considered by the design engineers for use in the portable water heater is a solar panel.

Carry out appropriate calculations to determine the minimum length of time needed, in optimal conditions, for a rigid solar panel to produce sufficient energy to boil one average cup of water with a volume of 330 cm^{-3}. Refer to the information on **Page 5** of the Resource Booklet.

You may use, $P = IV$ and, time taken $= \frac{\text{energy}}{\text{power}}$

Density of water = 1 g cm^{-3}

You **must** explain any assumptions you make **and** show your working out.

Time for solar panel to boil a cup of water = ……minutes **[6]**

PART 2

The military are also called upon to provide help to communities across the world in times of natural disasters such as earthquakes, landslides, tsunamis and floods.

4.* Recent flooding in the UK resulted in small bridges being washed away, causing isolation of entire villages for weeks after the flooding.

Problems resulting from this isolation included:

- People not easily getting emergency medical help
- Children could not get to school
- People ran out of food and other essential provisions.

Critically evaluate the issues and specific requirements for the construction of a bridge to solve these problems. Refer to the information on **Pages 6 and 7** of the Resource Booklet.

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5. The design engineers have drawn up an initial design for the pedestrian bridge, shown in **Fig. 3** with a person of a mass of 80 kg standing at the mid-point. Only the unsupported part of the bridge across the 5.0 m gap is shown.

The structure consists of two parallel box section beams made from mild steel. The walkway is made from sheets of 12 mm plywood laid across the beams.

It is suspected that there are several problems with this design.

(a) Calculate the total mass of the bridge shown in **Fig. 3**, plus the person, in kg.

Total mass of the bridge = ...kg **[3]**

(b) To analyse the structural integrity of the bridge, a design engineer is considering **one** of the steel box section beams across the 5.0 m gap.

The total weight of the bridge plus the person is effectively concentrated entirely at the mid-point of the bridge. Each beam supports half of the total weight.

Use the formula below, and data from **Pages 7 and 8** of the Resource Booklet to show that the deflection of a single beam under the loading conditions described above will be greater than 25 mm.

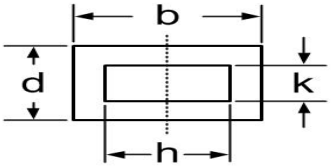
You must clearly explain any assumptions you make and clearly show and explain each stage of your calculations.

$\delta = \frac{FL^3}{48EI}$ where:

- δ is the deflection at the centre of the beam (m)
- F is the total force acting at the centre (N)
- L is the length of beam between the supports (m)
- E is Young's modulus for the beam material (Pa)
- I is the second moment of area of the beam, given by the formula:

$I = \frac{bd^3 - hk^3}{12}$

(All dimensions in m)



Deflection of beam = …….. mm **[3]**

(c) Following consideration of the structural integrity, the design engineers need to consider how to make technical improvements to the bridge. Refer to the information on **Pages 7 and 8** of the Resource Booklet.

The Ministry of Defence would like to have an initial 25 emergency relief bridges manufactured.

Use sketches and notes to show how the concept bridge shown in **Fig. 3** could be manufactured.

In your response you must include:

- technical details of methods of manufacture
- how to make the most efficient use of materials
- an explanation of how technical modifications could be used to improve its fitness for purpose and its structural rigidity.

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END OF QUESTION PAPER

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OCR
Oxford Cambridge and RSA

…day June 20XX – Morning/Afternoon

A Level in Design and Technology: Design Engineering
H404/02 Problem Solving in Design Engineering

SAMPLE MARK SCHEME

Duration: 1 hour 45 minutes

MAXIMUM MARK 70

This document consists of 28 pages

PREPARATION FOR MARKING

SCORIS

1. Make sure that you have accessed and completed the relevant training packages for on-screen marking: *scoris assessor Online Training*; *OCR Essential Guide to Marking*.

2. Make sure that you have read and understood the mark scheme and the question paper for this unit. These are posted on the RM Cambridge Assessment Support Portal http://www.rm.com/support/ca

3. Log-in to scoris and mark the **required number** of practice responses ("scripts") and the **required number** of standardisation responses.

   YOU MUST MARK 10 PRACTICE AND 10 STANDARDISATION RESPONSES BEFORE YOU CAN BE APPROVED TO MARK LIVE SCRIPTS.

MARKING

1. Mark strictly to the mark scheme.

2. Marks awarded must relate directly to the marking criteria.

3. The schedule of dates is very important. It is essential that you meet the scoris 50% and 100% (traditional 50% Batch 1 and 100% Batch 2) deadlines. If you experience problems, you must contact your Team Leader (Supervisor) without delay.

4. If you are in any doubt about applying the mark scheme, consult your Team Leader by telephone, email or via the scoris messaging system.

5. Work crossed out:
   a. where a candidate crosses out an answer and provides an alternative response, the crossed out response is not marked and gains no marks
   b. if a candidate crosses out an answer to a whole question and makes no second attempt, and if the inclusion of the answer does not cause a rubric infringement, the assessor should attempt to mark the crossed out answer and award marks appropriately.

6. Always check the pages (and additional objects if present) at the end of the response in case any answers have been continued there. If the candidate has continued an answer there then add a tick to confirm that the work has been seen.

7. There is a NR (No Response) option. Award NR (No Response)
   - if there is nothing written at all in the answer space
   - OR if there is a comment which does not in any way relate to the question (e.g. 'can't do', 'don't know')
   - OR if there is a mark (e.g. a dash, a question mark) which isn't an attempt at the question.

   Note: Award 0 marks – for an attempt that earns no credit (including copying out the question).

8. The scoris **comments box** is used by your Team Leader to explain the marking of the practice responses. Please refer to these comments when checking your practice responses. **Do not use the comments box for any other reason.**
   If you have any questions or comments for your Team Leader, use the phone, the scoris messaging system, or email.

9. Assistant Examiners will send a brief report on the performance of candidates to their Team Leader (Supervisor) via email by the end of the marking period. The report should contain notes on particular strengths displayed as well as common errors or weaknesses. Constructive criticism of the question paper/mark scheme is also appreciated.

10. **Annotations**

Annotation	Meaning
BP	Blank page
✔	Point where mark is awarded
✘	Incorrect response
L1	Level one response
L2	Level two response
L3	Level three response
ECF	Error carried forward
BOD	Benefit of doubt accepted
REP	Repetition
SEEN	Noted, but no credit given
PD	Poor Diagram offering unclear response

11. **Subject-specific Marking Instructions**

INTRODUCTION

Your first task as an Examiner is to become thoroughly familiar with the material on which the examination depends. This material includes:

- the specification, especially the assessment objectives
- the question paper
- the mark scheme.

You should ensure that you have copies of these materials.

You should ensure also that you are familiar with the administrative procedures related to the marking process. These are set out in the OCR booklet **Instructions for Examiners**. If you are examining for the first time, please read carefully **Appendix 5 Introduction to Script Marking: Notes for New Examiners**.

Please ask for help or guidance whenever you need it. Your first point of contact is your Team Leader.

The breakdown of Assessment Objectives for A Level in Design & Technology

	Assessment Objective
AO3	**Analyse and evaluate –** • **design decisions and outcomes, including for prototypes made by themselves and others** • **wider issues in design and technology**
AO3.1a	Analyse design decisions and outcomes, including for prototypes made by themselves and others
AO3.1b	Evaluate design decisions and outcomes, including for prototypes made by themselves and others
AO3.2a	Analyse wider issues in design and technology
AO3.2b	Evaluate wider issues in design and technology
AO4	**Demonstrate and apply knowledge and understanding of –** • **technical principles** • **design and making principles**
AO4.1a	Demonstrate knowledge of technical principles
AO4.1b	Demonstrate understanding of technical principles
AO4.1c	Apply knowledge and understanding of technical principles
AO4.2a	Demonstrate knowledge of design and making principles
AO4.2b	Demonstrate understanding of design and making principles
AO4.2c	Apply knowledge and understanding of design and making principles

Question			Answer	Marks	Guidance	
1	*		Indicative content: • Senior army officials have noted that an 80% solution available now is better than a 100% solution in years. Therefore, the evaluation of any design solution may expose weakness or inadequacies in the design which may need to be accepted as a satisfactory outcome. For example, the water heater may only manage to boil a proportion of the required volume of water. • Troops already need to carry around a lot of equipment so an extra piece of kit is always going to be problematic if the impact isn't seen to be beneficial. Therefore considering a multi-purpose product, reducing the number of parts, or reducing the size should be considered. • Since soldiers already have to carry several batteries for other electronic equipment, and these add significantly to their load, there may be opportunities to develop power solutions which could also deliver energy to other equipment, rather than focussing on a power source solely for the water heater. • The geographical locations where troops are currently deployed illustrates the wide range of environmental conditions to which the water heater may be exposed: o Large temperature ranges may cause some materials to become brittle or soft o High relative humidity may cause unprotected steel to rust and cause problems for unprotected electronics o Prolonged levels of sunshine may cause plastics to degrade and become brittle • When at high altitude in mountainous terrain, water will boil at significantly lower than 100°C and this may	**14** **AO3** **2 x 2a** **AO3** **2 x 2b** **AO4** **4 x 1c** **AO4** **6 x 2c**	**Content** All responses must be in relation to the wider issues of developing a portable water heater for the army that respond to the outlined requirements for soldiers need for a hot water supply. Candidates may extract information from any part of Section A in the Resource Booklet. Any such lifted information can be used in support of the critical evaluation but no marks should be awarded simply for duplicating text. Credit should be given for responses which identify issues evident in the supplied information and which are then critically analysed and evaluated in terms of their significance to the given scenario and relating to design and technical principles. Candidates can draw on practical experience of iterative designing an product analysis to support	**Levels of response** **Level 4 (11–14 marks)** The candidate produces a detailed and comprehensive critical evaluation of wider issues that design engineers will need to consider when developing prototype designs for the portable water heater for the army. Analysis and synthesis of information is thorough, bolstered by sustained lines of argument which consider the diverse range of wider issues that need taking into consideration. The use of information from Pages 2 and 3 of the Resource Booklet is effective and fully substantiates the points being made. This results in a narrative that is sophisticated and fully appropriate to the context being addressed. There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated with the use of examples.

Question			Answer	Marks	Guidance	
			cause problems when the water heater is being used to sterilise water. The use of a pressure lid in a design may help in this respect. • Solar power as a source of energy may be a viable option in the very sunny climates but may be essentially useless in the locations with low daily sunshine hours. This may also vary throughout the year, so a solar powered product that works in July may not function satisfactorily in January. • Locations with high rainfall, humidity or temperature may offer alternative energy source options by extracting thermal energy from the atmosphere. • It should be possible to use renewable energy sources even whilst the soldier is trekking or engaged in other duties. This means, for example, that the water heater could be heating the water throughout the day so that it is ready for use in the evening. • The volume of the heater will need consideration. Domestic kettles have much larger volumes (around 5 full cups) but they also use high power heaters powered by mains electricity. The smaller heaters are about one tenth the power of the kettles but they only heat small volumes of water. • All army equipment will need to be durable and straightforward to set up and use. Reliability is essential, so that a soldier knows that the product will work first time when they take it out of their kit bag. • Energy requirements will be reduced by careful thought about reducing heat loses from the water heater. So the use of thermally insulating materials and lids etc. should be considered. **Award credit for any other appropriate response**		their response to this question. Candidate operating at Level 4 will access the majority of the AO4 (1c/2c) marks, the two AO3 (2a) marks and at least one of the AO3 (2b) marks. Candidate operating at Level 3 will access at least five of the AO4 (1c/2c) marks, at least one of the AO3 (2a) marks and at least one of the AO3 (2b) marks. Candidate operating at Level 2 will access at least two of the AO4 (1c/2c) marks, at least one of the AO3 (2a) marks and at least one of the AO3 (2b) marks. Candidate operating at Level 1 will access some of the AO4 (1c/2c) marks.	**Level 3 (7–10 marks)** The candidate produces a good level of detailed critical evaluation of wider issues that design engineers will need to consider when developing prototype designs for the portable water heater for the army. Analysis and synthesis of information is for the most part well-considered, bolstered by sustained lines of argument which consider the diverse range of wider issues that need taking into consideration although one or two opportunities for developing these issues are missed. The use of information from Pages 2and 3 of the Resource Booklet is effective and for the most part substantiates the points being made. This results in a narrative that has a good level of detail and is appropriate to the context being addressed. There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and

Question			Answer	Marks	Guidance	
						substantiated with the use of examples. **Level 2 (4–6 marks)** The candidate produces a sufficient critical evaluation of wider issues that design engineers will need to consider when developing prototype designs for the portable water heater for the army. Analysis and synthesis of information adequately bolsters lines of argument which consider wider issues that need taking into consideration. The use of information from Pages 2 and 3 of the Resource Booklet goes some way to backing up points being made. This results in a narrative that adequately addresses the context. There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence. **Level 1 (1–3 marks)**

Question			Answer	Marks	Guidance	
						The candidate produces a basic explanation of wider issues that design engineers will need to consider when developing prototype designs for the portable water heater for the army. Any understanding is basic, resulting in limited exploration of wider issues that need taking into consideration. The use of information from Pages 2 and 3 of the Resource Booklet is limited and adds little value to the points being made. This results in a narrative that is dislocated from the context being addressed. There is no analysis or evaluation. The information has some relevance and is presented with limited structure or detail The information is supported by limited evidence. **Level 0 (0 marks)** No response or no response worthy of credit.
2			Indicative content:	**14** **AO3**	**Content** All responses must be in relation to the technical	**Levels of response** **Level 4 (12–14 marks)**

Question			Answer	Marks	Guidance	
			• Many kettles have an auto switch-off feature when they reach boiling point. Such a feature could be useful in the army water heater as it will stop valuable energy being wasted needlessly boiling water. A development of this feature is an adjustable thermostat that could allow the water to be heated to a given temperature and then maintained at this temperature, ready for use. • Cordless kettles are always more convenient than products which are tethered by a power lead. It may be possible to develop a similar technology for the army heater to free-up the product when it is in use. • The use of thermopolymers to create the body of the water heater is very beneficial as they can be injection moulded allowing the design of complex shapes. Polymers also possess quite good thermal insulation properties. Of the polymers listed, they all have similar densities which are much lower than the metals or glass so this would potentially make the product much lighter in weight, although it is not clear whether a polymer kettle body might need a thicker wall, counteracting possible weight benefits. Particular polymer issues include: ○ Polypropylene is already used in kettle body manufacture so is a proven technology, even though it has the lowest tensile strength of the polymers listed. Its maximum operating temperature is well above that likely to be encountered in use ○ ABS is not going to be very reliable for the kettle body due to its limited operating temperature. ○ Nylon outperforms the other polymers in all aspects, but it isn't clear whether it could be	**2 x 1a** **AO3** **2 x 1b** **AO4** **6 x 1c** **AO4** **4 x 2c**	features and materials that would be appropriate when developing a portable water heater for the army that respond to the outlined requirements for soldiers need for a hot water supply and in relation to the environments outline in the Resource Booklet. The highest level responses will make valid use of quantitative data. Candidates may extract information from the Resource Booklet. Any such lifted information can be used in support of the product analysis but no marks should be awarded simply for duplicating text. Credit should be given for responses which identify issues relevant to the context and analysed in relation to relevant design and technical principles. Candidates can draw on practical experience of iterative designing an product analysis to support	The candidate produces a detailed and comprehensive product analysis of the existing products to appropriately select a range of technical features and materials from this product range that would meet the requirements of a portable water heater used by the army. The use of Pages 2 to 5 of the Resource Booklet to support the response is wholly effective and fully substantiates the points being made. Any technical features and materials will be thoroughly justified and the candidate will be able to effectively align their suggestions with the context provided in the question. The narrative is logical and coherent. **Level 3 (9–11 marks)** The candidate produces a good level of analysis of the existing products and for the most part selects a range of technical features and materials from this product range that would meet the requirements of a portable water heater used by the

Question			Answer	Marks	Guidance	
			manufactured into a kettle as no listed products use this material. • Some transparency in the heater's body would allow the user to see at a glance how much liquid is remaining. Whilst this may compromise the thermal insulation, it does allow the user to see the water level without removing the lid and losing valuable heat from the water. • Glass is relevant for use as a material in domestic kettles and it carries some aesthetic and functional benefits. In an army environment, there would be a concern regarding its durability as it is known to be very brittle, but there may be ways to improve its strength whilst maintaining its other benefits. • Aluminium is also a viable material, in terms of its durability, light weight, and ability to be machined. It is also a tried and tested material for kettle manufacture. • Expanded polystyrene is known to be a good thermal insulator so it could find use as a technical material for reducing heat loss from the water heater. Its low tensile strength means it would not be suitable as a main material for the body. • The thermal keep-liquid-warm products make use of a double-walled vacuum technology which is worth consideration in the army water heater, to make the most efficient use of scarce renewable energy sources. Both featured products use stainless steel for their construction and this is a proven method which is also very durable in use. • Leak-proof lid technology would be useful as this would allow the water heater to be carried at any orientation whilst in use without fear of spilling the water.		their response to this question. Candidate operating at Level 4 will access the majority of the AO4 (1c/2c) marks, the two AO3 (1a) marks and at least one of the AO3 (2b) marks. Candidate operating at Level 3 will access at least seven of the AO4 (1c/2c) marks, at least one of the AO3 (1a) marks and at least one of the AO3 (1b) marks. Candidate operating at Level 2 will access at least three of the AO4 (1c/2c) marks, at least one of the AO3 (1a) marks and at least one of the AO3 (1b) marks. Candidate operating at Level 1 will access some of the AO4 (1c/2c) marks.	army. The use of Pages 2 to 5 of the Resource Booklet to support the response is for the most part effective and substantiates the points being made. Any technical solutions will be to a large extent justified and the candidate will be able to align their suggestions to a good level with the context provided in the question. There is evidence of points being made which are logical which on occasion lack coherence. **Level 2 (5–8 marks)** The candidate produces a sufficient analysis of the existing products to appropriately select a range of technical features and/or materials from this product range that would meet the requirements of a portable water heater used by the army. The use of Pages 2 to 5 of the Resource Booklet to support the response goes some way to substantiate the points being made. Some of the technical solutions will be justified but this justification will be

Question			Answer	Marks	Guidance	
			• Low voltage heater technology is clearly available in the form of 12V devices powered from a car electrical supply. This implies that the technology could be modified to work from a range of low voltage power supplies. • The thermal insulation technology from the pizza bag could inspire a insulated jacket for the water heater and the polymer foam liner together with reflective film could be used to make a customised solution for the water heater. • The Li-ion battery provides a very high energy density (mAh per kg) and is rechargeable. It is also compact and is a proven technology used in mobile phones and thousands of other portable applications. Different sizes and capacities mean that this technology could provide a multiple power source for several pieces of soldier's equipment. • The use of the wind generator or solar panels (or some combination of both) could be viable. Wind generators appear to be more unwieldy and fragile, and they rely on rotating parts which could snag on other equipment or get damaged during use. Solar panels are perhaps more robust and easier to implement, although they must be kept facing the sun for efficiency. The flexible backpack solar panel would allow solar energy to be harvested whilst the soldier is trekking. The output from a solar panel is lower than from the wind generator. • The use of renewable generators to recharge a battery eliminates problems of sporadic output when the wind doesn't blow or the sun doesn't shine. Batteries can be charged throughout the day/night and be ready for use when they are needed. **Award credit for any other appropriate response**			underdeveloped and the candidate will not consistently align their suggestions with the context provided in the question. There is evidence of points being made which can at times appear illogical and lack coherence. **Level 1 (1–4 marks)** The candidate produces only a basic selection of technical features or materials from this product range that would meet the requirements of a portable water heater used by the army. The use of information in the Resource Booklet is limited and adds little value to the points being made. Any technical features or materials may be described but will remain unjustified and will provide only a basic alignment with the context in the question. Any points made will be largely superficial and incoherent. There is no analysis or evaluation. **Level 0 (0 marks)**

Question			Answer	Marks	Guidance	
						No response or no response worthy of credit.
3			Rigid solar panel maximum output: 12V 1.3A Therefore, the maximum power output is: P = IV P = 1.3 × 12 P = 15.6 W (✓) One cup of water is 330 cm^3 (from question in paper) Mass of water is: Mass = density × volume Mass = 1 × 330 (there is no error carried forward in this instance as it is given and this is the first time it is used) Mass = 330 g = 0.33 kg (✓) Assume a start temperature of 10 °C (award credit for any sensible start temperature, especially if the candidate has justified their choice) (✓) Heat energy needed to boil water: Q = mcΔT Q= 0.33* × 4200 × (100-10) Q = 1.24 × 10^5 J (✓) Time taken to boil water = energy / power Time = 1.24 × 10^5* / 15.6* Time = 7948 seconds ÷ 60 = 132 mins (✓) **Award credit for any other appropriate method**	**5** **AO3** **1 x 1b** **AO4** **4 x 1c**	1 mark for analysing information on **Page 5** of the booklet on rigid solar panels and calculating power. 1 mark for calculating mass of water 1 mark for valid assumption of the start temperature of the water. 1 mark for calculating the energy needed to boil the water 1 mark for calculating the time taken to boil the water in minutes. *Allow error carried forward (ECF) where correct working out is shown. **Correct answer scores full marks**	

Question			Answer	Marks	Guidance	
4	*		Indicative content:	**14**	**Content**	**Levels of response**

Question			Answer	Marks	Guidance	
			• Storage of a large bridge may be an issue so it may be advantageous to store the bridge flat-packed. This has to be weighed against the time take to assemble the bridge when it is needed at short notice. • The need to span a 5.0m gap implies that the bridge structure would need to be longer than this to overhang the 'banking' to provide support. A 1m overhang on each side would make a 7m bridge which will still just fit on a UK car trailer. • Consideration would need to be given to how the bridge can be secured to each bank. It is possible that the weight of the bridge leads to it not needing to be secured, but consideration should be given for safety reasons. • The method of placing the bridge across the gap needs to be considered. The weight of an assembled bridge may be too heavy even for 6 persons to lift. Even if they could lift it, it would be unlikely that they could place it across the gap without some sort of mechanical aid. This might take the form of a hoist or crane which might be able to be carried on the trailer, or it may need extra transport logistics. • Consideration should be given to erecting the bridge on site and building it across the gap in the same manner that some civil engineering bridges are constructed. This would require it to be firmly anchored to one bank and then built as a cantilever across the gap. • It is acknowledged that military equipment is generally more expensive than civilian assets. The higher budget may allow for a better quality specification, higher quality materials and manufacturing methods to be considered.	**AO3** **1 x 1a** **AO3** **2 x 1b** **AO3** **1 x 2a** **AO3** **2 x 2b** **AO4** **4 x 1c** **AO4** **4 x 1c**	All responses must be in relation to the technical features and materials that would be appropriate when developing a portable water heater for the army that respond to the outlined requirements for soldiers need for a hot water supply and in relation to the environments outline in the Resource Booklet. The highest level responses will make valid use of quantitative data. Candidates may extract information from the Resource Booklet. Any such lifted information can be used in support of the critical evaluation but no marks should be awarded simply for duplicating text. Credit should be given for responses which identify issues evident in the supplied information and which are then critically analysed and evaluated in terms of their significance to the given scenario and relating to design and	**Level 4 (11–14 marks)** The candidate produces a detailed and comprehensive critical evaluation of the given context. The narrative is thorough, bolstered by sustained lines of argument which consider what wider issues need to be overcome and the technical requirements needed to construct a bridge of this type. Evidence will be prioritised effectively in terms of wider issues and specific requirements and the use Pages 6 and 7 of the Resources Booklet will fully substantiate the points being made. This results in a narrative that is sophisticated and fully appropriate to the context being addressed. There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated with the use of examples. **Level 3 (7–10 marks)** The candidate produces a

Question			Answer	Marks	Guidance	
			• There are issues of safety for the pedestrian bridge users. Hand rails, guard rails, non-slip surfaces should all be considered. • The bridge should be rated for a maximum number of concurrent users and this should be clearly indicated for users to see. The bridge specification should include a safety factor which should include loading outside the normal operating envelope, e.g. people jumping up and down on the bridge and wind loading. • Material degradation should be taken into account, e.g. rusting of steel or swelling/warping/rotting of plywood, effects of prolonged sunlight. This may be particularly relevant for a bridge after it has seen previous service and then been stored. The design should allow for easy safety checks to be carried out and for repairs/replacement parts to be fitted. • The bridge might need to be left in place for months until repairs to the local infrastructure can be completed. Therefore, durability is an issue. **Award credit for any other appropriate response**		technical principles. Candidates can draw on practical experience of iterative designing and product analysis to support their response to this question. Candidate operating at Level 4 will access the majority of the AO4 (1c/2c) marks, both the AO3 (1a/2a) marks and at least two of the AO3 (1b/2b marks. Candidate operating at Level 3 will access at least five of the AO4 (1c/2c) marks, at least one of the AO3 (1a/2a) marks and at least one of the AO3 (1b/2b) marks. Candidate operating at Level 2 will access at least two of the AO4 (1c/2c) marks, at least one of the AO3 (1a/2a) marks and at least one of the AO3 (1b/2b) marks. Candidate operating at Level 1 will access some of the AO4 (1c/2c) marks.	good level of detailed critical evaluation of the given context. The narrative is for the most part well-considered, bolstered by sustained lines of argument which consider what wider issues need to be overcome and the technical requirements needed to construct a bridge of this type. Evidence will for the most part be prioritised effectively in terms of wider issues and specific requirements and the use Pages 6 and 7 of the Resources Booklet will to a large extent substantiate the points being made. This results in a narrative that has a good level of detail and is appropriate to the context being addressed. There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated with the use of examples. **Level 2 (4–6 marks)** The candidate produces a sufficient critical evaluation

Question			Answer	Marks	Guidance	
						of the given context. The narrative is reasonable and bolstered by lines of argument which consider a narrow range of wider issues that need to be overcome and/or the technical requirements needed to construct a bridge of this type. Evidence will be prioritised in a haphazard way and the use Pages 6 and 7 of the Resources Booklet will go some way to substantiate the points being made. This results in a narrative that adequately goes some way to addressing the context. There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence. **Level 1 (1–3 marks)** The candidate produces a basic explanation of wider issues. Any understanding is basic, resulting in limited exploration of the wider issues or the technical requirements needed. There

Question			Answer	Marks	Guidance	
						will be little prioritisation of evidence and the use of the Resources Booklet is limited and adds little value to the points being made. This results in a narrative that is dislocated from the context being addressed. There is no analysis or evaluation. The information has some relevance and is presented with limited structure or detail The information is supported by limited evidence. **Level 0 (0 marks)** No response or no response worthy of credit.
5	**(a)**		Mass of steel beams = 2 x length × mass per unit length = 2 × 5 × 6.8 = 68 kg (✓) Mass of 12 mm Plywood = area of plywood x mass per unit area = 5 × 0.6 × 7.3 = 21.9 kg (22 kg) (✓) Total mass = mass of steel beams + mass of plywood sheets + mass of person = 68* + 21.9* + 80 = 169.9 kg (170 kg) (✓) **Award credit for any other appropriate method**	**3** **AO4 1c**	1 mark for calculating mass of beams in kg. 1 mark for calculating mass of plywood. 1 mark for calculating total mass. *Allow error carried forward (ECF) where correct working out is shown. **Correct answer scores full marks**	

Question			Answer	Marks	Guidance	
5	(b)		Total weight of bridge = mass x gravitational field strength = 169.9 × 9.8 = 1 665 N (✓) Each beam carries half of this total weight 1 665* ÷ 2 = 832.5 N (✓) $I = \frac{bd^3-hk^3}{12}$ = ((0.1 × 0.05³) – (0.094 × 0.044³)) ÷ 12 = 3.74 × 10^{-7} (m^4) (✓) Using the deflection formula: $d = \frac{FL^3}{48EI}$ = (832.5* × 5³) / (48 × 200x10^{9}* × 3.74 × 10^{-7}*) = 0.028 m = 28 mm (✓) **Award credit for any other appropriate method**	**4** **AO3** **2 x 1a** **AO4** **2 x 1c**	1 mark for analysing data on **Pages 7 and 8** of the Resource Booklet to calculate the total weight of the bridge. 1 mark for analysing **Fig.3**, identifying that each beam carries half the weight. 1 mark for calculating the second moment of area for box section beam. 1 mark for using the formula to calculate the deflection. *Allow error carried forward (ECF) where correct working out is shown. **Correct answer scores full marks**	
5	(c)		Indicative content: Method of manufacture: • The bridge structure consists of box section pieces which would be purchased in the lengths available. The box sections would be cut to length using jigs for repeatability. Joining of sections of	**16** **AO3** **2 x 1a** **AO3** **2 x 1b**	**Content** All responses must be in relation to technical modifications and batch production of the concept bridge shown in **Fig. 3** in the Resource Booklet.	**Levels of response** **Level 4 (13–16 marks)** The candidate produces a detailed and comprehensive analysis of how the concept bridge could be manufactured. Wide ranging

Question			Answer	Marks	Guidance	
			mild steel (see triangulation below) could be done through welding (for a permanent structure), brazing or using fasteners such as nuts/bolts and joining plates or clamps. • Use of joining clamps gives the option of assembling the bridge on-site, whilst welding would result in a ready-assembled bridge which would be delivered as a finished product. • Consideration should be given to the finish on the mild steel, which would need painting/galvanising to protect it from rusting in the outdoor environment. • The walkway would need to be attached to the beams to prevent it sliding. This could be achieved with nuts/bolts through the flooring and beams, or locating pegs, guide slots etc. • The walkway sheets would be cut from larger sheets using a panel saw (circular saw) in the case of plywood. • The plywood would need a protective, non-slip finish which could also act as a protection from the weather. Efficient use of materials • The aim is to reduce quantity of materials and, consequently, the weight without excessively sacrificing rigidity. This might be achieved by using angle or U-shaped cross section for the beams instead of box section. • Analysis (using CAE) could be carried out on using sections with different wall thicknesses to investigate the optimum dimension to reduce materials but maintain rigidity. • The solid walkway flooring could be replaced by a lattice structure which would reduce materials,	**AO4 8 x 1c** **AO4 4 x 2c**	This question assesses applied knowledge of technical principles to the existing design, so responses that focus on redesigning the existing solution should not be rewarded. Candidates can draw on practical experience of iterative designing and product analysis to support their response to this question. Candidate operating at Level 4 will access the majority of the AO4 (1c/2c) marks, both the AO3 (1a) marks and at least one of the AO3 (1b) marks. Candidate operating at Level 3 will access at least seven of the AO4 (1c/2c) marks, at least one of the AO3 (1a) marks and at least one of the AO3 (1b) marks Candidate operating at Level 2 will access at least three of the AO4 (1c/2c) marks, at least one of the AO3 (1a) marks and at least one of	and appropriate consideration is given to important technical information that needs to be taken into account with all key areas in the question (i.e. methods of manufacture and how to make the most efficient use of materials) covered. The use of Pages 6 and 8 of the Resource Booklet to support the response is wholly effective and fully substantiates the points being made through clear and detailed notes and sketches. The candidate is able to explain how technical modifications could be used to improve its fitness for purpose and structural rigidity and there is evidence of logical and coherent points being made. **Level 3 (9–12 marks)** The candidate produces a good level of analysis of how the concept bridge could be manufactured. Wide ranging and for the most part appropriate consideration is given to important technical information that needs to be taken into account (i.e.

Question			Answer	Marks	Guidance	
			reduce weight, allow surface water to drain and provide an inherently 'grippy' surface. • Consideration should be given to replacing the steel with aluminium or an engineering plastic which could achieve rigidity whilst reducing weight and cost. Some engineering plastic beams are made from recycled material so there is a potential environmental attraction too. Technical modifications: • The bridge has no guard rails or hand rails to assist pedestrians. The addition of these could also increase the rigidity of the structure and its ability to resist bending under load. • The width is very narrow and would not permit two people to pass each other on the bridge. Increasing the width should not affect the rigidity of the structure and might even improve its resistance to twisting (torsion). • Plywood may not be an ideal material for the walkway – it is quite heavy and can be slippery when wet. Water can also puddle on its surface. The addition of a non-slip surface would help, or replace the walkway with an alternative material such as an aluminium grille or ridged wooden slats. • The structural rigidity of the bridge can be improved by the principle of triangulating the structure. This can be done in all three planes to reduce bending and torsion. (Sketches may be shown to illustrate this, or the candidate may describe the principle). Triangulated structures can be added above the bridge (perhaps in the form of hand rails) or underneath the bridge, although consideration should be given to the		the AO3 (1b) marks Candidate operating at Level 1 will access some of the AO4 (1c/2c) marks	methods of manufacture and how to make the most efficient use of materials) although one or two areas could be further developed. The use of Pages 6 and 8 of the Resource Booklet to support the response is for the most part effective and substantiates the points being made through clear and detailed notes and sketches. The candidate is able to a good level of explanation of how technical modifications could be used to improve its fitness for purpose and structural rigidity. There is evidence of logical points being made which occasionally lack coherence. **Level 2 (5–8 marks)** The candidate produces a sufficient analysis of how the concept bridge could be manufactured. Adequate consideration is given to important technical information that needs to be taken into account (i.e. methods of manufacture and/or how to make the most efficient use of

Question			Answer	Marks	Guidance	
			available height above the water. Triangulation can also be added horizontally, under the walkway, to reduce torsional instability.			materials) although evidence at times is patchy and could be developed much further. The use of Pages 6 and 8 of the Resource Booklet to support the response goes some way to substantiate the points being made through for the most part clear and detailed notes and/or sketches. The candidate is able to adequately explain how technical modifications could be used to improve its fitness for purpose and/or structural integrity. There is evidence of points being made which can at times appear illogical and lack coherence. **Level 1 (1–4 marks)** The candidate produces only a basic explanation of how the concept bridge could be manufactured. Limited consideration is given to important technical information that needs to be taken into account (i.e. methods of manufacture or how to make the most efficient use of materials) with some of these areas

Question			Answer	Marks	Guidance	
						being omitted entirely from the candidate's response. The use of information in the Resource Booklet is limited and adds little value to the points being made with sketches or notes at times being misleading. The candidate is able to explain in a limited way how technical modifications could be used to improve its fitness for purpose or structural integrity. Any points made will be largely superficial and incoherent. There will be no analysis or evaluation. **Level 0 (0 marks)** No response or no response worthy of credit.

Assessment Objectives (AO) grid

Question	AO3	AO4
1*	4	10
2	4	10
3	2	4
4*	6	8
5a		3
5b	1	2
5c	4	12
Total	21	49
Overall	70	

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