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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.

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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.

[14]

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.

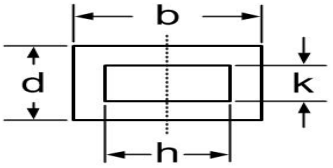
You must clearly explain any assumptions you make and clearly show and explain each stage of your calculations.

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