OCR
Oxford Cambridge and RSA

Friday 14 June 2019 – Morning

A Level in Design and Technology: Design Engineering

H404/02 Problem Solving in Design Engineering

Time allowed: 1 hour 45 minutes

7665127295

You must have:
- Resource Booklet

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

H4040 2

Please write clearly in black ink. **Do not write in the barcodes.**

Centre number | | | | | | Candidate number | | | | |

First name(s) _____

Last name _____

INSTRUCTIONS
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Answer **all** the questions.
- The recommended reading time for the Resource Booklet is **35 minutes**.
- Write your answer to each question in the space provided. If additional space is required, use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.
- Where appropriate, your answers should be supported with working. Marks may be given for a correct method even if the answer is incorrect.

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 the questions marked with an asterisk (*).
- This document consists of **16** pages.

Answer **all** the questions.

Before responding to the questions in this paper you must spend time reading and familiarising yourself with the Resource Booklet.

1* Water scarcity is a major concern for parts of the developing world. The World Health Organisation (WHO) is one organisation that is helping by fitting water pumps to extract groundwater in those rural areas worst affected.

Discuss the issues that a design engineer would need to consider when developing a new water pump for use in a remote rural village.

Refer to information on **pages 2, 3 and 4** of the Resource Booklet. **[14]**

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2 The WHO supplies the India MkIII hand-operated water pump shown in **Fig. 3** of the Resource Booklet. It also donates the DP4b water containers shown in **Fig. 10** of the Resource Booklet to villagers to transport fresh water. Each water container holds 20 litres of water.

Using the information on **page 5** of the Resource Booklet, calculate how many **complete cycles** of the pump handle will be required to fill **one** 20 litre container with water. Show your working.

The formula for calculating the volume of a cylinder is $V = \pi r^2 h$

Number of complete cycles of the pump handle .....

[6]

3 A design team is investigating whether the use of a solar-powered water pump would be more of a viable solution.

It is looking into the use of the RB500 photovoltaic panels shown in **Fig. 6** of the Resource Booklet. A number of these panels could be used together in a photovoltaic array to provide the required energy output.

It has been determined that an annual energy output of 1890 kilowatt-hours (kWh) is required for the pump to work efficiently.

Calculate the minimum number of photovoltaic panels of the type shown that would be required to produce the energy output needed for the water pump.

Use the equation below and information on **page 6** of the Resource Booklet. Show your working.

$E = A \times r \times H \times PR$

Where:

E = annual energy output from photovoltaic array (kWh)

A = total photovoltaic array area (m^2)

r = photovoltaic panel yield

H = annual average solar irradiation ($kWh\,m^{-2}$)

PR = performance ratio, coefficient of losses.

Minimum number of photovoltaic panels required .....

[6]

4 Due to the large initial cost of developing a solar-powered water pump, the WHO is reluctant to commission the design work without further research.

Critically evaluate the use of photovoltaic panels for powering water pumps in areas affected by water scarcity. Your response should consider the needs of stakeholders and users of the system.

Refer to the information on **pages 2, 3 and 6** of the Resource Booklet. **[14]**

5 A decision has been made to proceed with the design of the solar-powered water pump.

The design team has been given two immediate issues to overcome.

Issue 1

The efficiency of the photovoltaic array will vary throughout the day depending on the position of the sun in the sky. In order to improve the efficiency it has been suggested that the photovoltaic array should move so that it always faces the sun.

A system has been designed to do this which uses a motor, connected through a gearbox, to move the array. The system is controlled by a PICAXE microcontroller. **Page 7** of the Resource Booklet explains the operation of the system.

A program flowchart or code with annotation is required for the PICAXE microcontroller so that the photovoltaic array will move to follow the sun across the sky.

Issue 2

Spur gears need to be used for the gearbox to move the photovoltaic array.

A gear ratio of 32:1 is required.

Due to the remote area it is working in, the design team has a limited selection of spur gears available shown on **page 7** of the Resource Booklet.

A gear system is required using only the available spur gears that would produce the required gear ratio.

Use sketches and/or notes to determine suitable technical solutions that overcome the **two** issues identified. All of the information you need is on **page 7** of the Resource Booklet. **[16]**

Issue 1:

Issue 2:

6* During the course of a day the average family will require two containers of water of the type shown in **Fig. 10** of the Resource Booklet. Traditionally, these are collected by the women and children of the families and are sometimes carried over large distances.

The WHO is working with a company that specialises in producing heavy-duty trollies for industrial applications. The company has proposed a trolley design shown in **Fig. 11** of the Resource Booklet that could be used by families to transport water from the water source to their homes.

Critically evaluate the design of the trolley in **Fig. 11** of the Resource Booklet making suggestions for improvement for the task specified. **[14]**

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END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).