OCR
Oxford Cambridge and RSA

Monday 2 June 2025 – Morning

A Level in Design and Technology: Design Engineering

H404/01 Principles of Design Engineering

Time allowed: 1 hour 30 minutes

You can use:
- a ruler (cm/mm)
- a scientific calculator
- geometrical instruments

* H 4 0 4 0 1 *

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

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

First name(s) _____

Last name _____

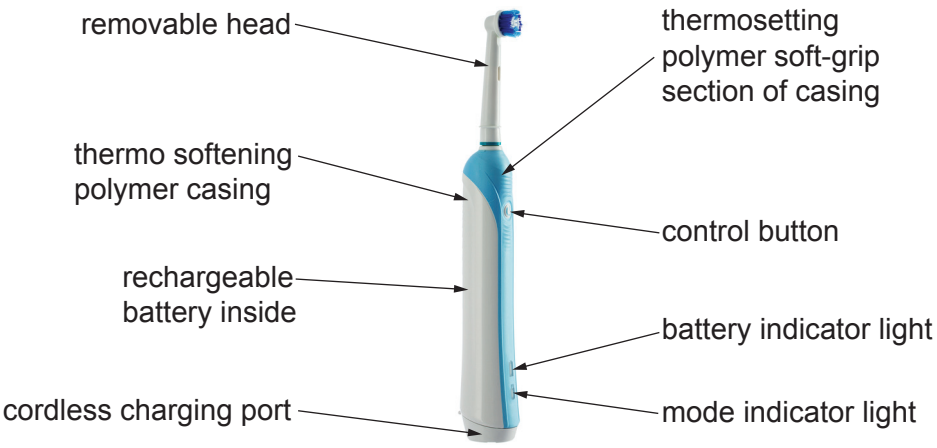
INSTRUCTIONS
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. You can use extra paper if you need to, but you must clearly show your candidate number, the centre number and the question numbers.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

INFORMATION
- The total mark for this paper is **80**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- This document has **24** pages.

ADVICE
- Read each question carefully before you start your answer.

1 **Fig. 1.1** shows an electric toothbrush.

Fig. 1.1



(a)

(i) Identify **three** functional reasons why the electric toothbrush has a removable head.

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[3]

(ii) Identify **two** properties of a thermo softening polymer that make it suitable for the casing of the electric toothbrush.

Justify **each** of your answers.

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[4]

(iii) The manufacturer chose to include a soft-grip section on the casing of the electric toothbrush.

The soft-grip material is a thermoplastic elastomer (TPE) which is a type of thermosetting polymer.

Describe **two** challenges to the manufacturer of including a soft-grip section on the casing of the electric toothbrush.

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[4]

Fig. 1.2 shows an electric toothbrush on a charging base. The base is used to charge the battery inside the electric toothbrush.

Fig. 1.2

(b)

(i) The electric toothbrush contains a 3.7 V rechargeable battery.

A current of 0.1 A is passed through the battery when it is charging.

Calculate the power in watts (W) put into the battery during charging. Show your working. **[2]**

Power ..... W

(ii) The efficiency of the charging system for the electric toothbrush is 74%.

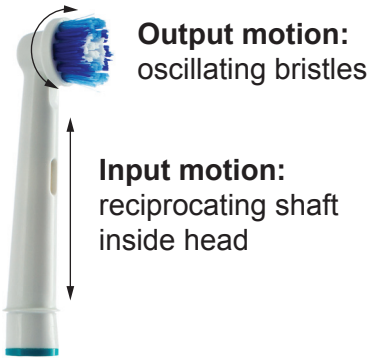
Use your answer from **part (b)(i)** to calculate the power drawn from the mains power supply during the charging process. Give your answer in W and show your working. **[2]**

Power ..... W

(c) An electric toothbrush head contains a mechanism that converts reciprocating motion of a shaft into oscillating motion of the bristles.

Fig. 1.3 shows the input and output motions.

Fig. 1.3



Draw an annotated sketch to show a mechanism capable of producing the required conversion of motion in the electric toothbrush head. **[2]**

(d) Discuss the ergonomic design features of the electric toothbrush shown in **Fig. 1.1**.

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2

(a) A student wants to 3D print a hollow sphere.

(i) The sphere must have an **internal** volume of 45 cm^3.

The student requires the sphere to have a wall thickness of 3 mm.

Calculate the **external diameter** of the hollow sphere. Give your answer in mm to **3** significant figures and show your working.

Use the rearranged formula: $r^3 = 45 / \frac{4}{3}\pi$
where:
r = radius **[5]**

External diameter of hollow sphere ..... mm

(ii) 3D printing is an additive manufacturing method. The printer builds the 3D part by depositing PLA thermo polymer on to the printer bed.

The PLA is supplied as a filament wire with a diameter of 1.75 mm.

The 3D printer software predicts that 2.2×10^4 mm^3 of PLA will be used to produce the sphere and the associated support structure.

Calculate the length in mm of PLA filament wire that will be used. Show your working.

Use the formula: $V = \pi r^2 l$
where:
V = volume of a cylinder
r = radius
l = length **[4]**

Length of PLA filament wire ..... mm

(b) 35 000 parts are made in a batch as part of an industrial manufacturing process.

There is a probability during the process that each part could suffer from two independent manufacturing faults.

Probability of fault A occurring = 0.02
Probability of fault B occurring = 0.01

(i) Calculate the number of parts in the batch that are likely to suffer **fault A**. Show your working. **[2]**

Number of parts .....

(ii) A part is rejected if it suffers from both faults.

Calculate the number of parts in the batch that are likely to suffer from **both faults**. **[2]**

Number of parts .....

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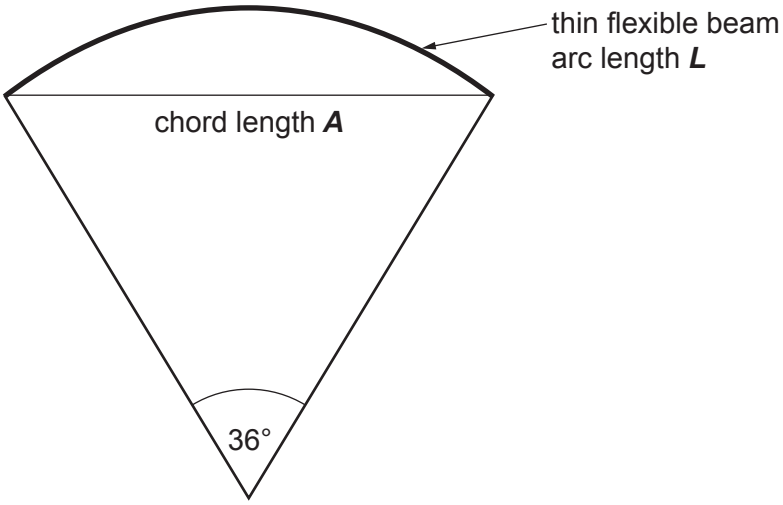
(c) **Fig. 2.1** shows a thin, flexible curved beam made from plywood.

Fig. 2.1



(not to scale)

The beam is an arc taken from a circle of radius 1000 mm.

The arc subtends an angle of 36° at the centre of the circle.

(i) Use **Fig. 2.1** and the given formula to calculate the arc length ***L*** of the plywood beam. Give your answer to the nearest mm and show your working.

$L = 2\pi r \times$ (subtended angle / 360) **[2]**

Arc length ***L*** ..... mm

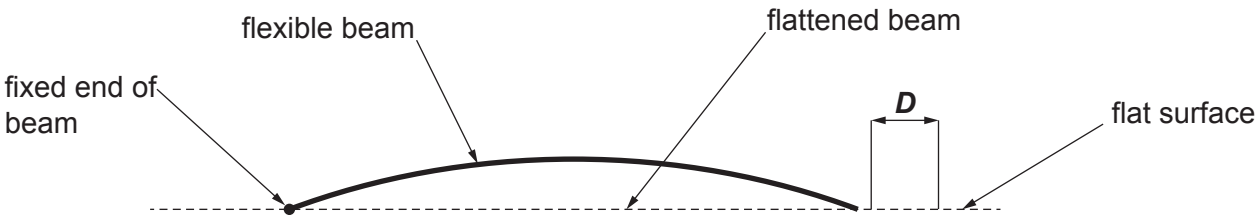
(ii) Use **Fig. 2.1** to calculate the chord length ***A***. Give your answer to the nearest mm and show your working.

Use the formula: $\boldsymbol{A} = \sqrt{a^2 + b^2 - 2ab\cos 36}$ **[2]**

Chord length ***A*** ..... mm

(iii) The flexible plywood beam is placed on a flat surface as shown in **Fig. 2.2**.

Fig. 2.2



(not to scale)

The left end of the flexible beam is fixed in position and a load is placed on top of the beam. This causes the beam to flatten as indicated by the dashed line in **Fig. 2.2**.

Use your answers from **part (c)(i) and part (c)(ii)** to calculate the distance ***D*** moved by the right end of the flexible beam as it is flattened. Give your answer in mm and show your working. **[2]**

Distance ***D*** moved ..... mm

3

(a) Design Engineers design products with repair and maintenance in mind.

Describe the principle of designing a product for repair and maintenance.

Use an example of a product in your answer.

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(b)* Cobalt is a key component of the batteries used in electric cars and many other electronic devices.

Cobalt is extracted by mining. There is concern that miners are exploited and exposed to dangerous conditions.

Discuss the responsibilities of manufacturers to ensure that the materials they use are sourced responsibly.

Use examples of **social**, **ethical** and **environmental** issues in your answer.

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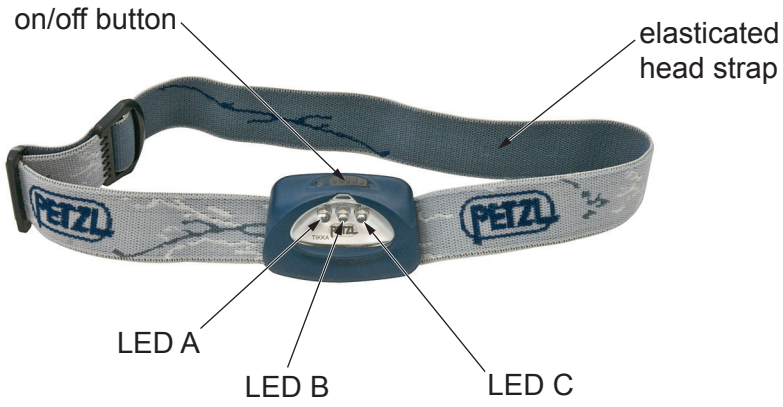
4 **Fig. 4.1** shows the basic version of a head torch.

Fig. 4.1



(a)

(i) Identify **one** reason why physical testing would be carried out on a pre-production prototype of the head torch.

Justify your answer.

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(ii) Identify and describe **one** destructive test that could be carried out on a manufactured head torch.

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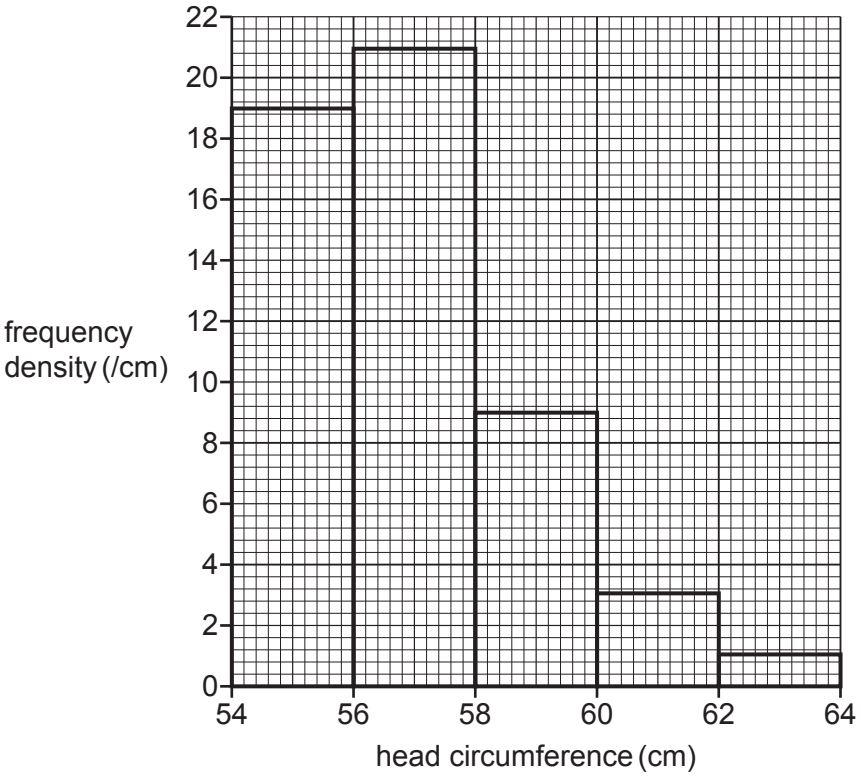
(b) The manufacturer collected head circumference data from a sample of people to determine the length of the strap for the head torch.

The data was grouped and presented in a histogram.

The histogram and supporting data is shown in **Fig. 4.2**.

Fig. 4.2



Head circumference range (cm)	Frequency
54–56	38
56–58	42
58–60	18
60–62	6
62–64	2

(i) Use the information in **Fig. 4.2** to calculate the number of people used in the sample. Show your working. **[1]**

Number of people .....

(ii) Use the information in **Fig. 4.2** and your answer to **part (b)(i)** to estimate by calculation the mean head circumference of the sample. Give your answer in cm and show your working. **[3]**

Mean head circumference of the sample ..... cm

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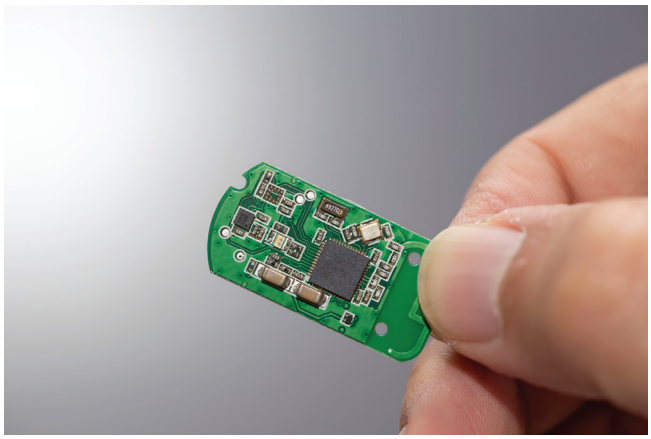
(c) The head torch contains an embedded microcontroller.

The microcontroller and other electronic components are mounted on a printed circuit board (PCB) using surface mount technology (SMT).

A PCB from a similar product is shown in **Fig. 4.3**.

Fig. 4.3



The PCB is batch manufactured using a pick-and-place machine and a reflow soldering oven.

(i) Describe the meaning of the term **pick-and-place machine**.

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..... **[2]**

(ii) Describe the meaning of the term **reflow soldering oven**.

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..... **[2]**

(d) The manufacturer intends to develop the basic head torch. It wants the user to be able to change the brightness by repeatedly pressing the button.

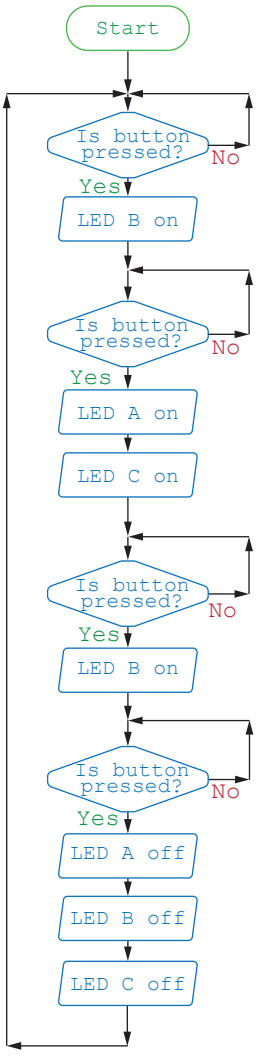
Fig. 4.4 shows how the LEDs will switch on or off in a cycle.

Fig. 4.4

Button press number	Mode	LED A	LED B	LED C
1	Dim	OFF	ON	OFF
2	Normal	ON	OFF	ON
3	Bright	ON	ON	ON
4	Off	OFF	OFF	OFF

During the development, the head torch microcontroller is programmed with the flowchart shown in **Fig. 4.5**.

Fig. 4.5

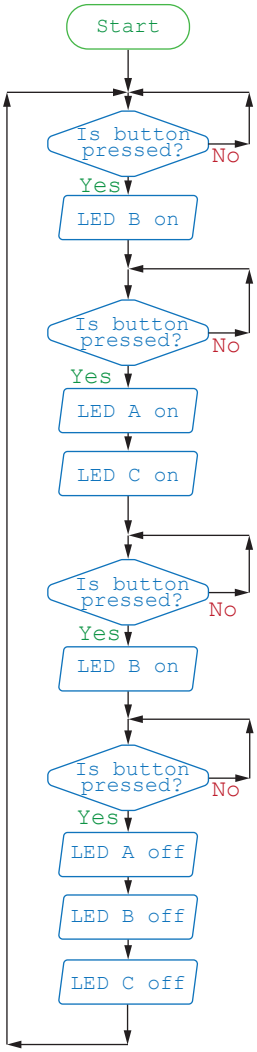


The flowchart program does not perform as expected.

Analyse the information in **Fig. 4.4**. On the flowchart below identify the following using annotations and drawings:

- the errors
- the changes that are needed to make it function correctly.

The flowchart below is a repeat of **Fig. 4.5**. **[4]**



(e) As part of its business strategy, the manufacturer plans to release three models of the head torch.

Fig. 4.6 summarises the three models.

Fig. 4.6

Models	LED function	LED colour
Basic version	Simple on/off function, no brightness control	White
Intermediate version	Three brightness levels	White
Advanced version	Several brightness levels, plus flashing function	Selectable white or red

The manufacturer wants to release the three different models with minimal changes to its manufacturing system.

Discuss how the use of surface mount technology (SMT) and the inclusion of an embedded microcontroller make it straightforward for the manufacturer to do this.

Refer to **hardware** and **software** in your answer. **[8]**

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