OCR
Oxford Cambridge and RSA

Monday 12 October 2020 – Morning

A Level 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

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.

Answer **all** the questions.

1 **(a)** Smart home technology is increasing in popularity and is being installed in homes throughout the world. A smart home technology system involves a number of **smart objects**, known as smart home devices, being connected through a **network** and controlled from a central hub. Smart objects include light bulbs, window blinds, security cameras, kettles and other household appliances. A number of different **communication protocols** have been developed for use in smart home technology systems.

(i) State the meaning of the following terms in the context of a smart home technology system:

smart object .....

.....

network .....

.....

communication protocol .....

.....

[3]

(ii) The latest generation of simple household products, such as kettles, often contain an embedded microcontroller.

Describe **two** benefits to a designer or manufacturer of embedding a microcontroller into a kettle.

1 .....

.....

.....

.....

2 .....

.....

.....

.....

[4]

(b) **Fig. 1.1** shows a roller-blind fitted to a window. The blind is shown in the raised position but it can be lowered to cover the window.

Fig. 1.1

A smart roller-blind is being developed as part of a smart home technology system. The smart roller-blind will raise or lower automatically under the control of the smart home technology system.

Fig. 1.2 shows part of a prototype roller-blind mechanical drive system.

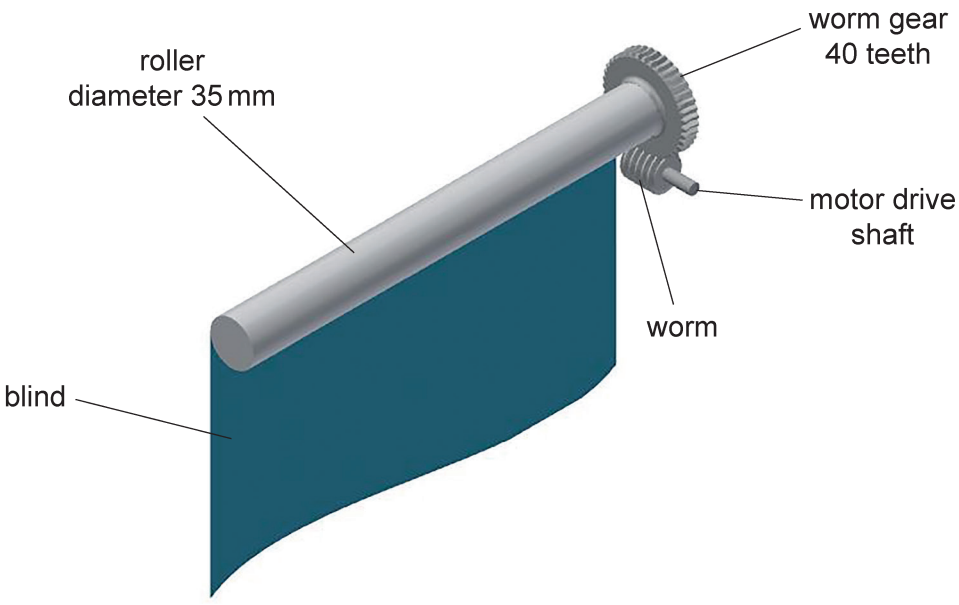

Fig. 1.2
(not to scale)

A DC motor drives the roller through a worm drive system.

(i) Explain **one** functional feature of a worm drive system which makes it useful in the roller-blind mechanical drive system shown in **Fig. 1.2**.

.....

.....

.....

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

(ii) Calculate the circumference of the roller in **Fig. 1.2** to the nearest mm.

Circumference ..... mm

[2]

(iii) It has been determined that, during operation, the roller-blind mechanical drive system should take 2 seconds to raise the blind a vertical distance of 165 mm.

Using information from **Fig. 1.2** and your answer to **part (b)(ii)**, calculate the required output speed of the DC motor in revolutions per minute (rpm). Show your working.

Assume that the diameter of the roller stays constant as the blind rises.

Motor output speed ..... rpm

[4]

(iv) During testing of the prototype system, a design engineer notices that the speed at which the blind rises does not stay constant but gradually increases throughout the raising cycle.

Study the roller-blind mechanical drive system in **Fig. 1.2** and explain **two** reasons why the speed of the blind increases throughout the raising cycle.

1 .....

.....

.....

.....

2 .....

.....

.....

.....

[4]

(v) In order to eliminate the problem observed in **part (b)(iv)**, the designer decides to add a closed loop control system to ensure that the blind is raised and lowered at a constant speed.

Draw a system diagram to show how an electronic closed loop control system would maintain a constant lifting speed throughout the raising cycle.

Your system diagram **must** include a specific sensor component for the closed loop control system. You **must** also explain the principle of operation of the closed loop control system.

.....

.....

.....

.....

[4]

(vi) Stakeholders decide that they want the smart roller-blind to be a wireless device, with no cables or wires running to it, as this improves the aesthetics and simplifies installation in the home.

Discuss the technical challenges faced by design engineers when developing wireless devices such as the smart roller-blind and identify potential solutions which would be worth further investigation during the iterative designing process.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... **[6]**

BLANK PAGE

PLEASE DO NOT WRITE ON THIS PAGE

2 **(a)** A light sensor is placed in a non-transparent tube so that it can only receive light from a specific light source.

Fig. 2.1 shows a two-dimensional side view of the tube which is 5 mm in diameter, placed perpendicular to the extended light source AB which is 100 mm wide.

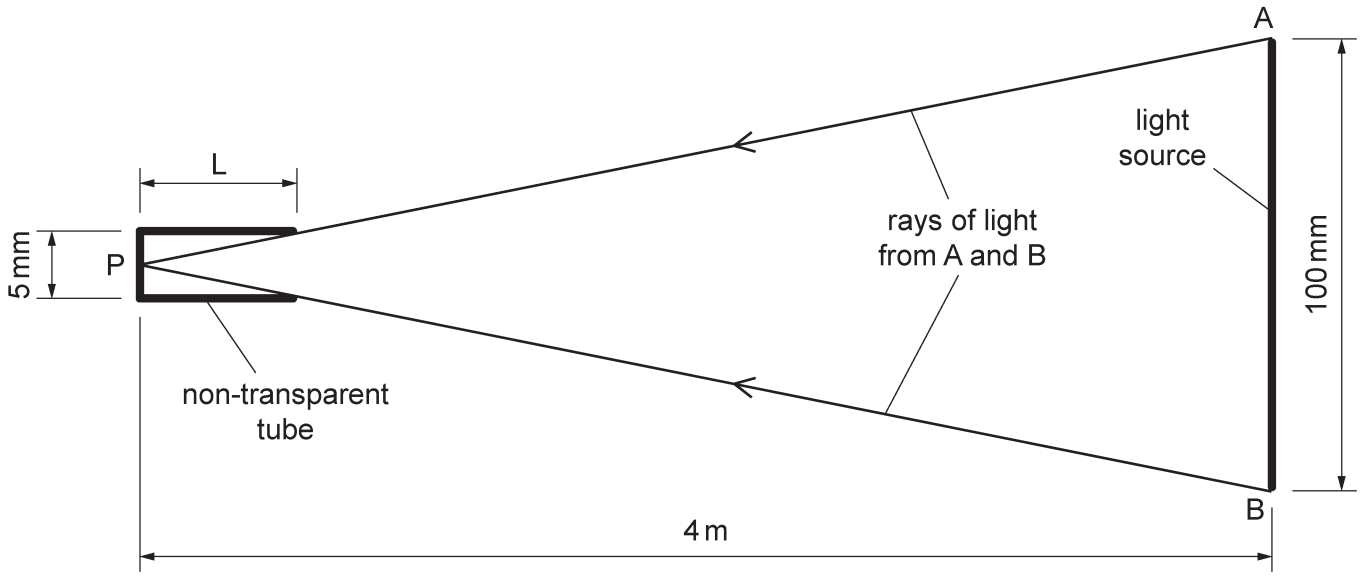

Fig. 2.1
(not to scale)

The light sensor will be placed at point P which is a perpendicular distance of 4 m from the light source AB.

Rays of light reaching point P from points A and B are drawn on **Fig. 2.1**.

Calculate the length L of tube required for this application. Give your answer in mm. Show your working.

Length L ..... mm

[3]

(b) A former is used to make sure that parts are formed or bent to the same shape.

Fig. 2.2 shows a former, made from a rectangular block of MDF measuring 180 mm wide and 75 mm thick.

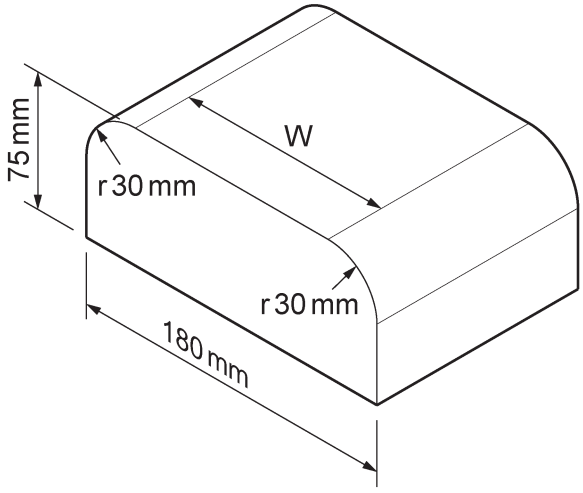

Fig. 2.2
(not to scale)

The top corners are sanded to a radius (r) of 30 mm.

All sides of the former are vertical and the top face is horizontal.

(i) Calculate the width W of the top face of the former in **Fig. 2.2**. Give your answer in mm. Show your working.

Width W ..... mm

[2]

(ii) The former in **Fig. 2.2** is used to construct the laminated wooden part shown in **Fig. 2.3**.

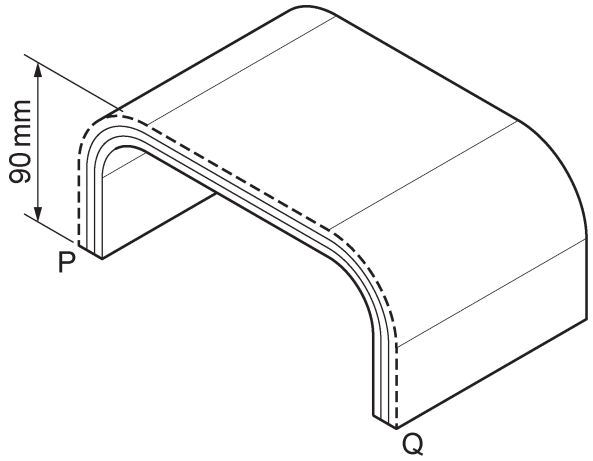

Fig. 2.3
(not to scale)

Three laminated layers are used to construct the part. Each laminate layer is 5 mm thick.

Calculate the outside length from corner P to corner Q on the laminated wooden part, indicated by the dotted line in **Fig. 2.3**. Give your answer in mm. Show your working.

You should ignore the thickness of the adhesive used between each layer.

Outside length P to Q ..... mm

[4]

(iii) The former in **Fig. 2.2** has vertical sides.

Explain why well-designed formers are **not** usually manufactured with vertical sides.

.....

.....

.....

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

(iv) The former in **Fig. 2.2** could be manufactured from an alternative material to MDF.

Name an alternative material which could be used to manufacture the former and explain the selection of material in terms of functional performance and environmental considerations.

Material .....

Functional performance .....

.....

.....

.....

Environmental considerations .....

.....

.....

.....

[5]

3 **(a)** As new technologies emerge, existing products can evolve through a process of incremental innovation.

Explain **two** ways in which an incremental innovation strategy can be beneficial to a product manufacturer.

1 .....

.....

.....

.....

2 .....

.....

.....

.....

[4]

(b)* Discuss the ways in which the intellectual property (IP) of designers can be protected.

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

.... **[8]**

BLANK PAGE

PLEASE DO NOT WRITE ON THIS PAGE

4 **Fig. 4.1** shows parts of a puzzle toy. The puzzle helps children learn to count and identify numbers.

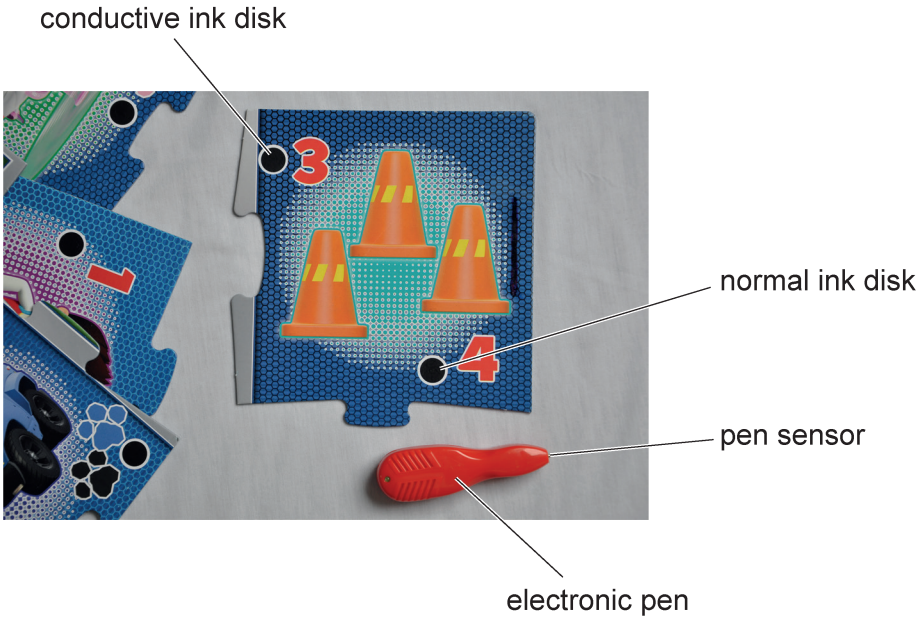

Fig. 4.1

The puzzle consists of several cardboard pieces each one with black disks printed onto them. Some of the disks are printed with conductive ink which is a smart material that conducts electricity. Other disks are printed with normal non-conductive ink.

The toy also contains an electronic pen. When the child touches the pen's sensor onto a conductive ink disk, the pen responds by producing sound and light.

(a) **Fig. 4.2** shows the sound signal waveform produced by the electronic pen.

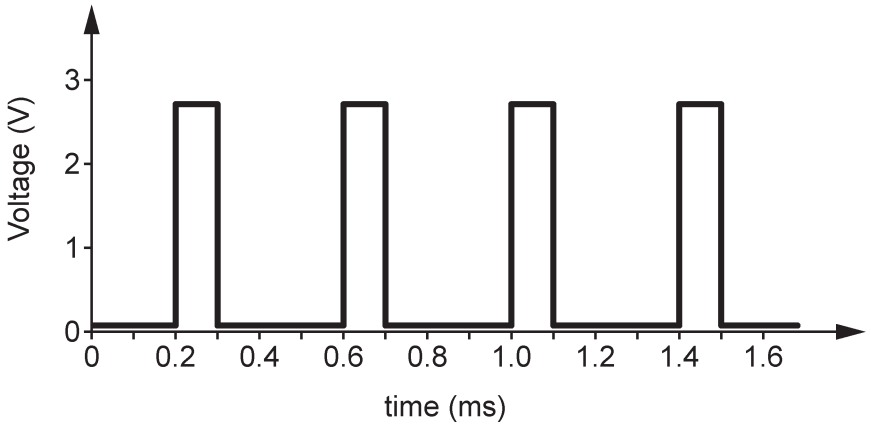

Fig. 4.2

(i) Determine the period of the signal in **Fig. 4.2**. Give your answer in ms. Show your working.

Period ..... ms

[2]

(ii) Calculate the frequency in kHz of the signal in **Fig. 4.2**.

Frequency ..... kHz

[2]

(b) (i) When the sensor probes are touching a conductive ink disk the resistance (in Ω) between the probes is given by the formula:

$$R = \rho \frac{d}{wt}$$

where:

ρ = resistivity of conductive ink (Ω m)

d = probe separation (m)

w = width of probes (m)

t = thickness of conductive ink film (m)

The conductive ink has a resistivity of 1.25 Ω m and is printed as a film of thickness 50 μm.

The sensor probes are 5 mm wide and are separated by 3 mm.

Calculate the resistance in kΩ between the sensor probes when they are touching the conductive ink. Show your working.

Resistance between probes ..... kΩ

[4]

(ii) **Fig. 4.3** shows the sensor circuit for the electronic pen.

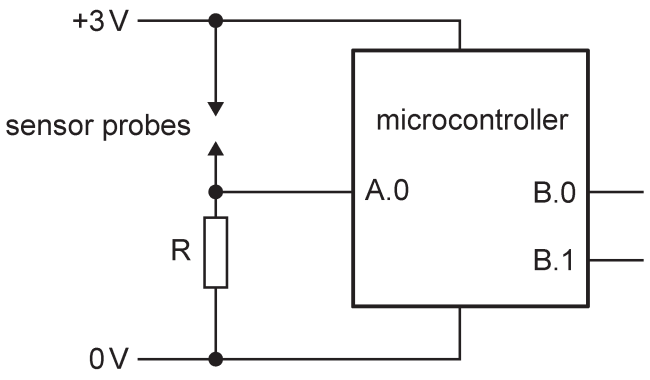

Fig. 4.3

A minimum voltage of 2 V is required at the microcontroller analogue input A.0 in **Fig. 4.3** when the sensor probes are touching a conductive ink disk.

Using your answer to **part (b)(i)**, calculate the minimum value of resistor R required in **Fig. 4.3**. Give your answer in Ω. Show your working.

Minimum value of resistor R ..... Ω

[3]

(iii) State, without calculation, the value of the voltage at the analogue input A.0 in **Fig. 4.3** when the sensor probes are touching a non-conductive ink disk.

Voltage at A.0 ..... V **[1]**

(c) **Fig. 4.4** gives information about the microcontroller input and output pins used in the electronic pen.

Pin	Type of input/output	Device connected to pin
A.0	analogue to digital converter (ADC) input	sensor probes
B.0	digital output	LED
B.1	digital output	sounder

Fig. 4.4

Fig. 4.5 shows a prototype version of a flowchart program for the microcontroller in the electronic pen.

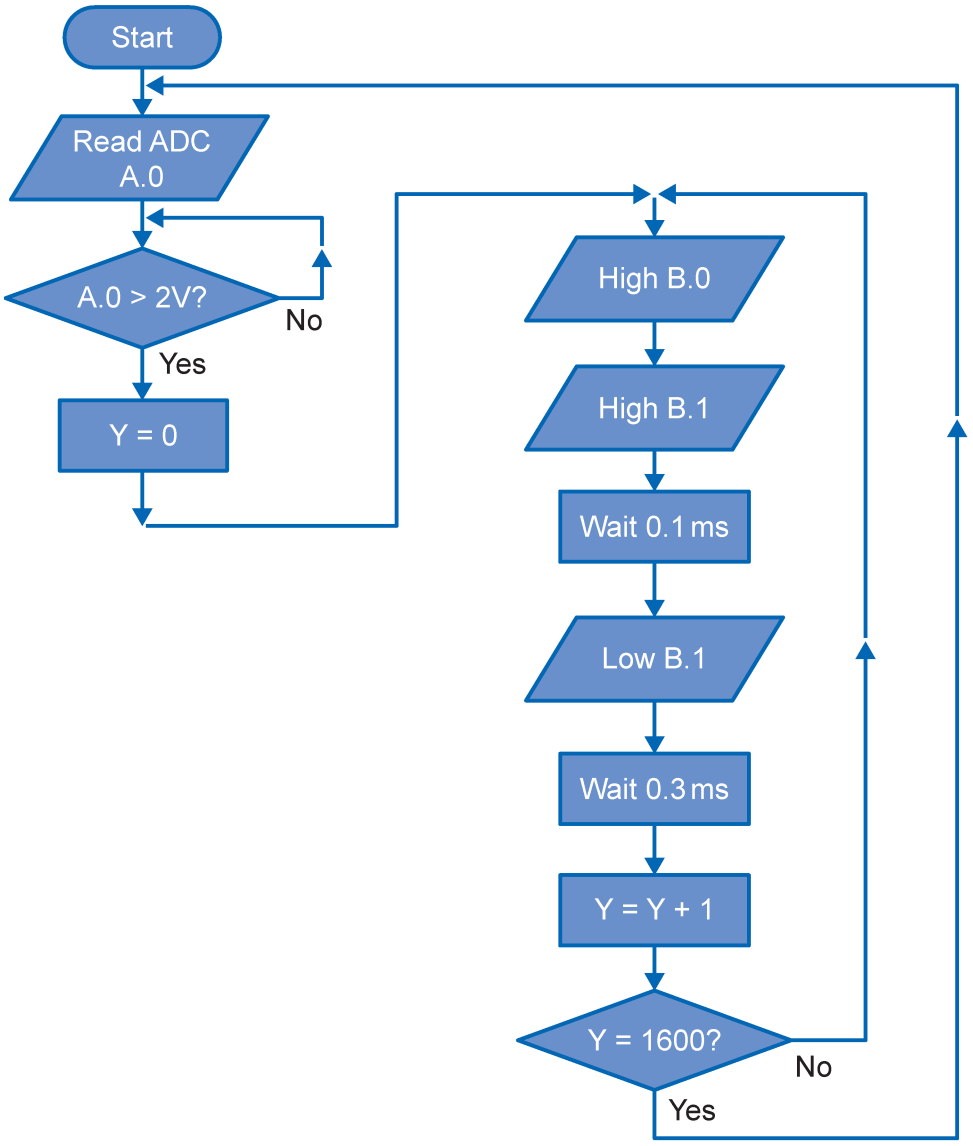

Fig. 4.5

The functional specification of the electronic pen is described as follows:

> *When the electronic pen's sensor is touched onto a conductive ink disk, an LED is illuminated and a sound is produced for a period of 1.5 seconds. After this, if the pen is no longer touching the conductive ink disk, the LED turns off and the sound stops.*

Evaluate the effectiveness of the flowchart in **Fig. 4.5** against the functional specification. You need to suggest any changes to the flowchart to ensure that the specification is met.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... **[6]**

(d) (i) Identify another smart material, apart from conductive ink, that is used to provide functionality in a product.

..... **[1]**

(ii) Describe, using an example of a product, how the properties of the smart material you have identified in **part (d)(i)** provide functionality.

.....

.....

.....

.....

.....

.....

.....

..... **[4]**

END OF QUESTION PAPER

BLANK PAGE

PLEASE DO NOT WRITE ON THIS PAGE

PLEASE DO NOT WRITE ON THIS PAGE