OCR
Oxford Cambridge and RSA

Friday 7 June 2019 – Morning

A Level Design and Technology: Design Engineering

H404/01 Principles of Design Engineering

Time allowed: 1 hour 30 minutes

7665014040

You may use:
- a scientific calculator
- a ruler
- pencils/pens
- geometrical instruments

H404/01

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.
- 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 **80**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended response will be assessed in the question marked with an asterisk (*).
- This document consists of **20** pages.

Answer **all** the questions.

1 A home lift can be installed in a house where one or more occupants may have mobility problems and may not be able to use stairs easily.

Fig. 1.1 shows an electrically-powered home lift. The first image shows the lift on the ground floor. The second image shows the lift on the upper floor.

Fig. 1.1

(a) Identify **three** ways in which the manufacturer of the home lift can ensure the safe operation of the lift by its users.

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2 .....

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3 .....

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[3]

(b) The home lift in **Fig. 1.1** uses a screw thread and nut mechanism in which the nut is attached to the lift and rotated through a double chain drive by an electric motor. The screw thread is held in position and does not move. **Fig. 1.2** shows the mechanism.

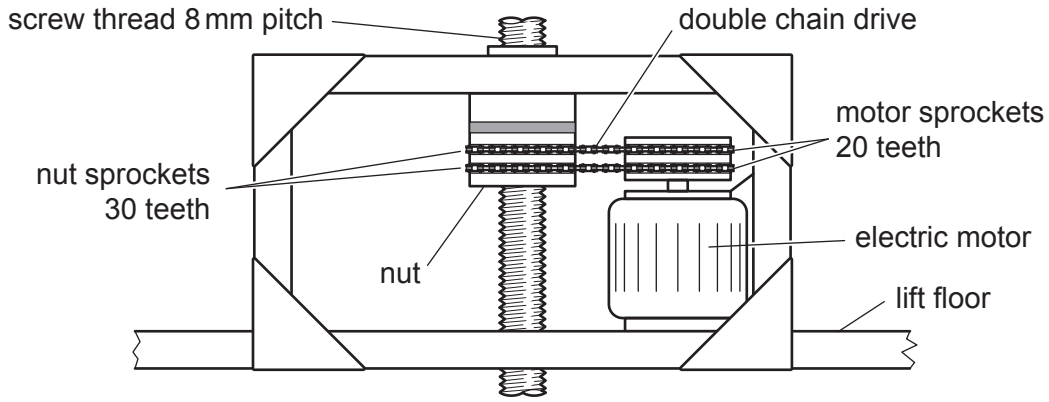

Fig. 1.2
(not to scale)

(i) The lift moves at a speed of $0.08\,m\,s^{-1}$.

Calculate the time taken in seconds (s) for the lift to rise between floors which are 2800 mm apart. Show your working.

Time ..... s

[3]

(ii) Analysing the data in **Fig. 1.2**, calculate the motor rotational speed required in revolutions per minute (rpm) to cause the nut to climb up the thread at a speed of $0.08\,m\,s^{-1}$. Show your working.

Motor rotational speed ..... rpm

[3]

(iii) Give **two** reasons why a double chain drive is used in this application.

1 .....

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2 .....

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[2]

(iv) The maximum total mass of the lift and occupants is 350 kg.

Calculate the power required in watts (W) to raise the 350 kg lift at a velocity of 0.08 m s^{-1}. Show your working.

gravitational potential energy = mgh $\qquad$ *power* $= \frac{E}{t}$

gravitational field strength, g = 9.81 N kg^{-1}

Power ..... W

[3]

(v) Conventional lifts usually use a cable mechanism with an electric motor located at the top of the lift shaft.

Explain **one** advantage and **one** disadvantage of using a screw thread and nut mechanism in a lift.

Advantage .....

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Disadvantage .....

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[4]

(c) Discuss, using examples, the significance of good user interface design in engineered products.

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..... **[8]**

2 **(a)** A manufacturer wishes to ship items in the cardboard box shown in **Fig. 2.1**. The cardboard box is a cuboid shape.

Fig. 2.1

The box has internal dimensions of 305 × 215 × 100 mm.

Calculate the maximum straight part length which can be shipped in this cardboard box. Give your answer in mm to 1 decimal place and show your working.

Maximum straight part length ..... mm

[3]

(b) **Fig. 2.2** shows an orthographic (two-dimensional) diagram of a part manufactured from brass. Dimensions are given in mm.

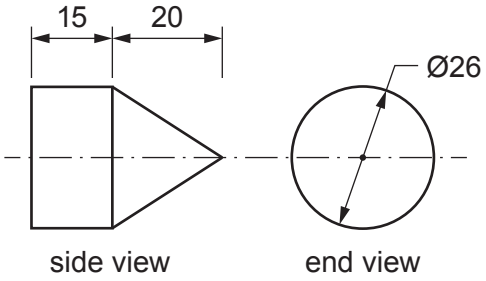

Fig. 2.2
(not to scale)

(i) Name an instrument which could be used to measure the diameter of the part shown in **Fig. 2.2** to a precision of 0.02 mm.

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

(ii) Calculate the mass in grams (g) of the part shown in **Fig. 2.2**. Give your answer to 1 decimal place and show your working.

Area of a circle = $\pi d^2/4$

Volume of a cone = $\frac{1}{3}$ × *base area* × *height*

Density of brass = $8.73\,g\,cm^{-3}$

Mass .....g

[5]

(iii) The part in **Fig. 2.2** is to be turned on a centre lathe from a cylindrical brass bar with diameter 30 mm and length 35 mm.

Calculate the volume in mm^3 of the waste brass generated. Give your answer to 1 decimal place and show your working.

Volume ..... mm^3

[2]

(iv) The diameter of the part must be 26.00 mm with a tolerance of ±2%.

Calculate the **minimum** allowable diameter in mm of the part. Show your working.

Minimum diameter .....mm

[2]

(c) A machine is being developed to help tennis players practise their serve. The machine projects a tennis ball vertically to a height, s, of 2.5 m.

Use the formula, $v^2 = u^2 + 2as$, to calculate the initial velocity, u, at which the ball needs to leave the machine so that it just reaches the required height of 2.5 m. Give your answer in $m\,s^{-1}$ and show your working.

Acceleration, a, due to gravity in this situation is $-9.81\,m\,s^{-2}$

Initial velocity ..... $m\,s^{-1}$

[2]

3 **(a)*** To certify that products conform to a standard set by the British Standards Institute (BSI), many products carry the BSI Kitemark® shown in **Fig. 3**.

Fig. 3

Discuss the implications to manufacturers of producing Kitemark® approved products.

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(b) (i) Explain what is meant by **'enterprise'** in the context of designing.

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

(ii) Describe **two** ways in which enterprise can help drive the development of new product ideas.

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2 .....

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[4]

4 **Fig. 4.1** shows a robotic lawnmower.

Fig. 4.1

(a) A 12 V battery is used to power the robotic lawnmower. The robotic lawnmower returns to a charging station placed at the edge of the lawn to recharge its battery. The charging station requires a source of power.

Identify **two** issues associated with providing power to the charging station.

1 .....

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2 .....

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[2]

(b) The case of the robotic lawnmower is made from a thermo softening polymer.

Fig. 4.2a and **Fig. 4.2b** show two views of a typical thermo softening polymer part from a similar garden product.

Fig. 4.2a

Fig. 4.2b

(i) Describe how the rigidity of the thermo softening polymer part in **Fig. 4.2a** and **Fig. 4.2b** is achieved through effective designing.

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

(ii) State the industrial method used to manufacture the thermo softening polymer part and identify **one** piece of evidence from either **Fig. 4.2a** or **Fig. 4.2b** that leads you to this conclusion.

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

(iii) The >PP< marking that is visible on the surface of the product in **Fig. 4.2b** identifies the type of thermo softening polymer that has been used.

Explain **one** reason why a plastic manufacturer marks the type of plastic used on their product in this way.

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

(c) Compare the use of DC motors and stepper motors for driving the wheels of a robotic lawnmower.

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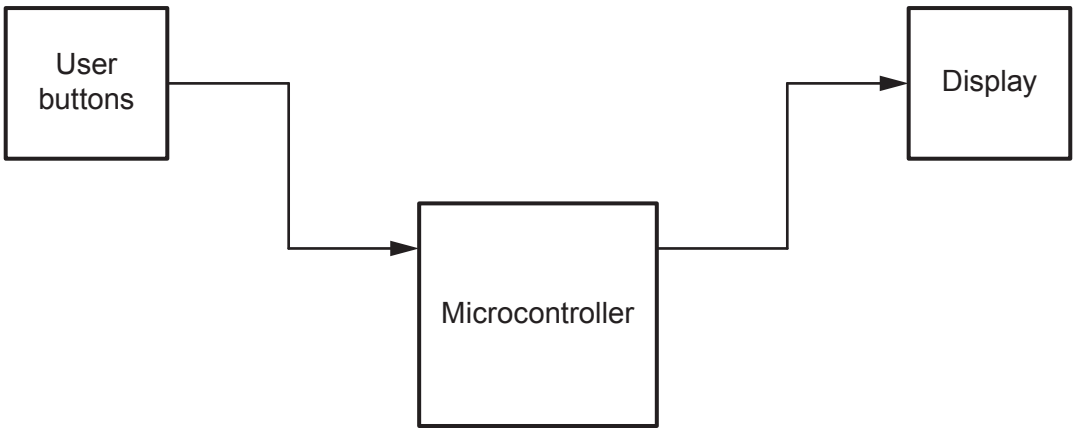
..... **[4]**

(d) The robotic lawnmower is controlled by an electronic system with a number of sensors, user-operated controls and outputs. The robotic lawnmower function is described below:

- The user sets the lawnmower to operate at a set time every day using buttons and a display.
- At the set time, the lawnmower automatically undocks from its charging station, starts its grass-cutting blade and begins to move across the lawn.
- A cable, buried around the edge of the lawn, carries an electronic signal which the lawnmower detects and uses to avoid running off the edge of the lawn.
- Proximity sensors on the lawnmower detect the presence of obstacles in the lawnmower's path so that they can be avoided.
- The lawnmower monitors its battery voltage and if the voltage falls below a set level the lawnmower returns to its charging station.

Use this function description to complete the system diagram below for the robotic lawnmower.



[4]

(e) **Fig. 4.3** shows a circuit diagram for the part of the robotic lawnmower which monitors the battery voltage.

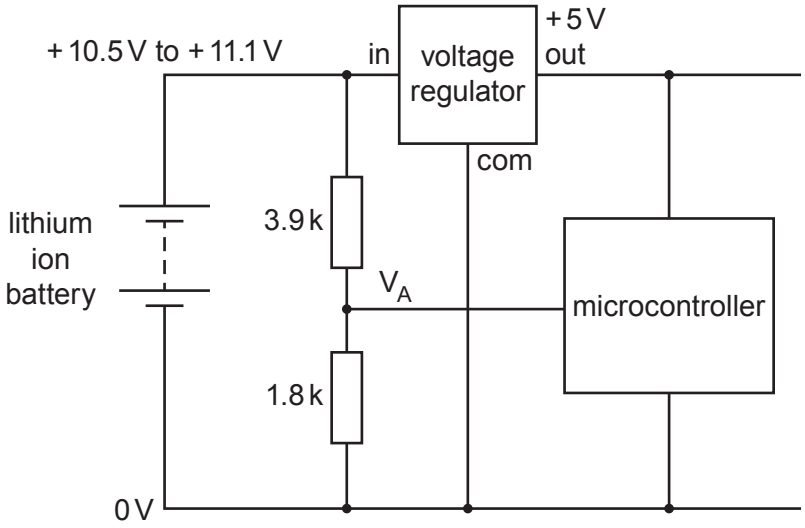


Fig. 4.3

The lithium ion battery produces a nominal voltage of 11.1 V. When the battery voltage drops to 10.5 V an alert is generated within the microcontroller code and the robotic lawnmower returns to its charging station.

(i) Calculate the voltage (V) at point V_A in **Fig. 4.3** when the battery voltage is 10.5 V. Give your answer to 2 decimal places and show your working.

Voltage V

[3]

(ii) Voltage V_A in **Fig. 4.3** is fed into an analogue to digital converter (ADC) pin on the microcontroller. The ADC produces a full-scale value of 1023 when the analogue input is 5.0 V.

Calculate the ADC value produced when the input voltage V_A is at the value you calculated in **part (e)(i)**. Give your answer as a rounded-down integer and show your working.

ADC value .....

[3]

(iii) Draw a flowchart of the robotic lawnmower subroutine to check the battery voltage and generate an alert if the battery voltage falls below 10.5 V.

[3]

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).