OCR
Oxford Cambridge and RSA

Thursday 9 June 2022 – Afternoon

A Level in Design and Technology: Design Engineering

H404/01 Principles of Design Engineering

Time allowed: 1 hour 30 minutes

9086369502

You can use:
- a ruler (cm/mm)
- a scientific calculator
- 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. 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 **20** pages.

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

© OCR 2022 [603/1131/9]
DC (KN/JG) 313064/2
OCR is an exempt Charity

Answer **all** the questions.

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

Fig. 1.1

Fig. 1.2 shows the handlebar controls of a similar electric scooter.

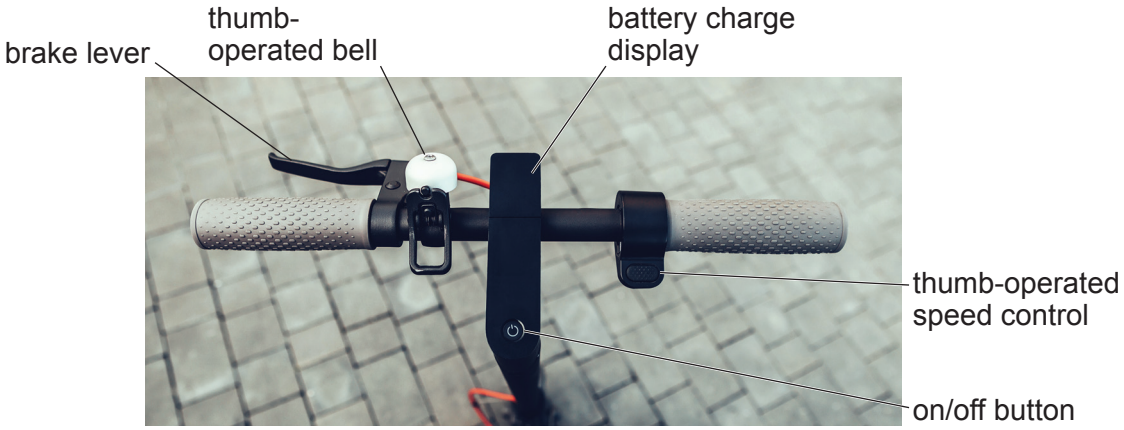


Fig. 1.2

© OCR 2022

(a) (i) Electric scooters are designed with a range of safety features.

Explain how **one** of the features indicated on the electric scooters in **Fig. 1.1** or **Fig. 1.2** improves safety.

.....

.....

.....

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

(ii) The electric scooter in **Fig. 1.1** can be folded at the folding point shown.

Explain **one** benefit to the user of making the electric scooter foldable.

.....

.....

.....

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

(b) (i) On most electric scooters, the frame is made from a non-ferrous aluminium alloy.

Identify **one** benefit of using non-ferrous alloys for the frame of an electric scooter.

Justify your answer.

.....

.....

.....

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

(ii) In some higher-end models, frame parts are manufactured from a composite material such as carbon fibre reinforced plastic (CFRP).

Identify **one** benefit of using composite materials for the frame of an electric scooter.

Justify your answer.

.....

.....

.....

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

© OCR 2022

(c) One model of electric scooter has a rechargeable battery pack which is made from 30 individual '18650' lithium-ion cells. The 18650 cell is a standardised component.

Fig. 1.3 shows how the cells are connected to form the complete battery pack.

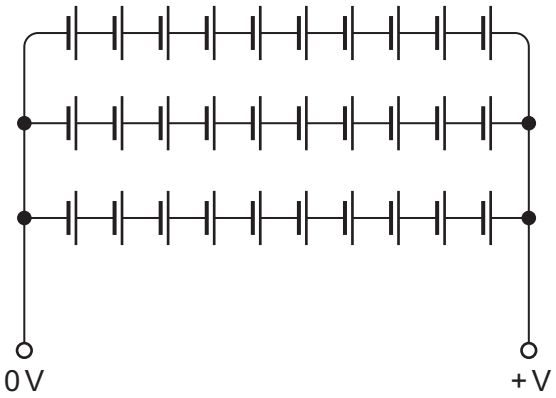


Fig. 1.3

(i) Each cell produces a voltage of 3.6 V.

Calculate the output terminal voltage from the battery pack in volts to **0** decimal places. Show your working. **[2]**

Output terminal voltage V

(ii) Explain **one** advantage of building the battery pack with three parallel groups of cells.

.....

.....

.....

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

© OCR 2022

(iii) State **one** benefit to a scooter manufacturer of using standard 18650 cells in a battery pack rather than designing a bespoke battery pack.

Justify your answer.

.....

.....

.....

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

© OCR 2022

(d) (i) The motor in an electric scooter is rated at 250 W.

The efficiency of the motor is 70%.

The rider accelerates the electric scooter at full power from a standstill on level ground.

Determine by calculation that the gain in kinetic energy of the electric scooter and rider in the first second is 175 J.

You **must** ignore the effects of friction and air resistance. **[2]**

(ii) The total mass of the electric scooter and rider is 85 kg.

The electric scooter reaches a constant speed after 3 seconds.

Use the information in **part (d)(i)** to calculate the constant speed of the electric scooter when it reaches 3 seconds. Give your answer in m/s to **1** decimal place and show your working.

You **must** assume that the power output from the motor remains constant. **[3]**

Constant speed of the electric scooter ..... m/s

© OCR 2022

(e) Some cities are making electric scooters available as a form of shared public transport. Users can hire a scooter using an app on their smartphone.

Discuss the wider issues of electric scooters being available for short-term hire in city centres.

In your answer you **must** make reference to **environmental** and **inclusivity** factors.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

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

© OCR 2022

2 **(a)** **Fig. 2.1** shows the structure of a stranded electrical wire.

Fig. 2.1

(i) The stranded electrical wire in **Fig. 2.1** is made from 50 strands of copper. The diameter of each strand is 0.25 mm.

Calculate the total cross-sectional area of copper in the wire. Give your answer in mm^2 to **2** decimal places and show your working. **[3]**

Total cross-sectional area of copper in the wire ..... mm^2

(ii) The manufacturer states that the cross-sectional area of copper in the wire is 2.50 mm^2.

Calculate the percentage error between the cross-sectional area calculated in **part (a)(i)** and the expected area of 2.50 mm^2. Show your working. **[2]**

Percentage error ..... %

© OCR 2022

(iii) The resistance of a wire can be calculated using the formula:

$$R = \frac{\rho L}{A}$$

where:
R is the resistance (Ω)
ρ is the resistivity of the wire material (Ωm)
L is the length of wire (m)
A is the cross-sectional area (m^2)

The resistivity of copper is 1.72×10^{-8} Ωm.

Using the value 2.50 mm^2 for the cross-sectional area, calculate the resistance in Ω of a 3 m length of the electrical stranded wired shown in **Fig. 2.1**.

You **must not** round off your answer. Show your working. **[2]**

Resistance ..... Ω

(iv) Use your answer from **part (a)(iii)** to calculate the voltage drop along the 3 m length of wire when it carries 25 A. Show your working. **[2]**

Voltage drop V

© OCR 2022

(b) **Fig. 2.2** shows a shape that is to be cut from a sheet of acrylic using a laser cutter.

The shape is drawn on a 20 mm grid.

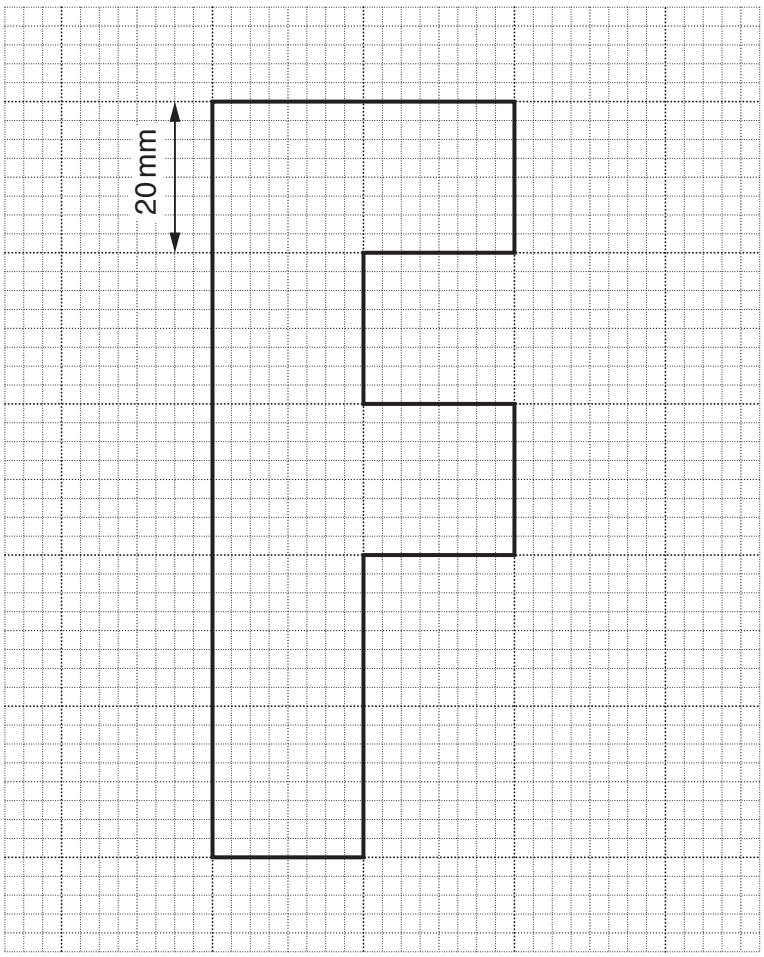


Fig. 2.2
(not to scale)

(i) The laser cutting speed is 16 mm / s.

Calculate the time taken in seconds to cut out the shape. Show your working. **[3]**

Time taken ..... s

© OCR 2022

(ii) Two of the shapes shown in **Fig. 2.2** are to be laser cut in the shortest possible time.

This can be achieved by tessellating (joining together) the two shapes.

Draw a diagram to show the **most efficient** way of tessellating the two shapes to achieve the shortest laser cutting time. **[1]**

(iii) Calculate the total cutting length of the combined tessellated shape. Give your answer in mm and show your working. **[2]**

Total cutting length ..... mm

© OCR 2022

3 **(a)** A student wishes to use polyester resin in the Design and Technology workshop.

Fig. 3.1 shows part of the hazard warning label on the side of the resin bottle.

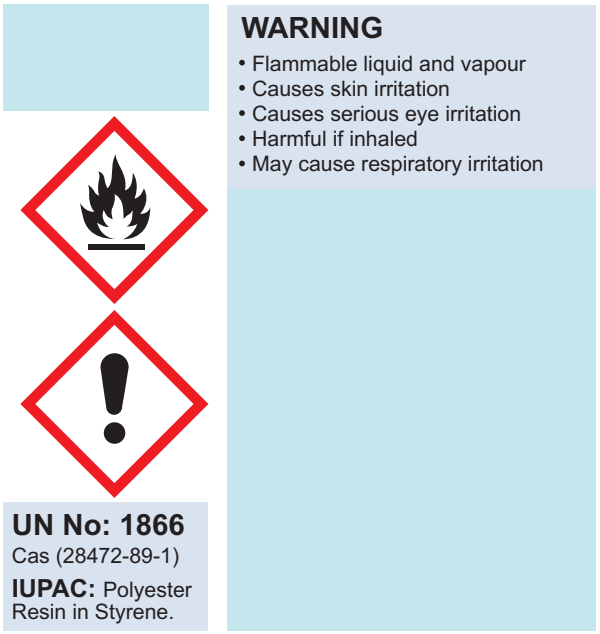


Fig. 3.1

(i) State **two** control measures which should be in place to address the hazards indicated on the label in **Fig. 3.1**.

1 .....

.....

2 .....

.....

[2]

(ii) Describe **two** duties of **employers** as set out in the Health and Safety at Work Act (HASAW).

1 .....

.....

.....

.....

2 .....

.....

.....

.....

[4]

© OCR 2022

(b)* The following statement has appeared on various online platforms:

'If we covered the Sahara Desert with solar photovoltaic (PV) panels, we could generate enough electricity to meet the world's energy demands four times over.'

Evaluate this statement, focusing on **product lifecycle management** and any **wider issues**.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

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

© OCR 2022

4 **Fig. 4.1** shows a pump-action hand gel bottle in use.

Fig. 4.1

A design engineer is developing an automatic hand gel dispenser to work with bottles of the type shown in **Fig. 4.1**.

The device will automatically dispense gel when a user places their hand under the bottle spout.

The device will be battery powered and controlled by a microcontroller.

(a) An infra-red (IR) sensor will be used to detect the presence of the user's hand. The sensor consists of an IR light emitting diode (LED) and an IR detector.

Fig. 4.2 shows how these components are wired into a circuit.

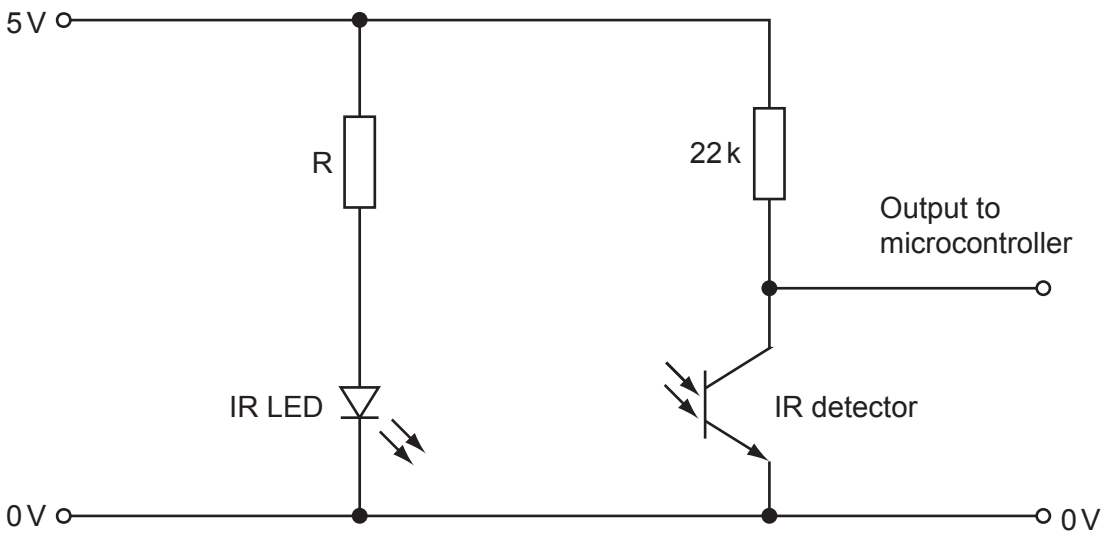


Fig. 4.2

© OCR 2022

The IR LED illuminates an area near the sensor. When an object is placed in this area, IR light is reflected back onto the IR detector.

(i) Explain **one** advantage of using infra-red light rather than visible light in sensing systems such as this.

.....

.....

.....

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

(ii) The IR LED has a forward voltage drop of 1.7 V. A current of 10 mA is required through the IR LED.

Use **Fig. 4.2** to calculate the resistance of resistor R, to the nearest whole number. Give your answer in Ω and show your working. **[3]**

Resistance ..... Ω

(iii) A continuous current of 10 mA flowing through the IR LED could cause significant drain on the battery.

Describe options available to the design engineer to minimize this problem.

.....

.....

.....

.....

.....

.....

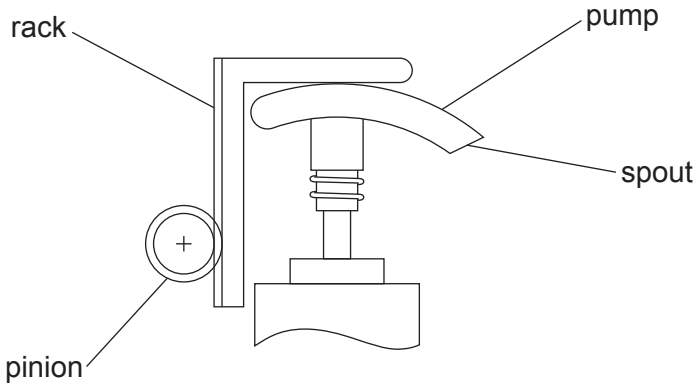
.....

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

© OCR 2022

(b) A mechanical system is needed to operate the pump on the gel bottle. A DC motor is being used to drive the system. The design engineer decides to use a rack and pinion to provide a rotary to linear conversion of motion.

Fig. 4.3 shows a diagram of the rack and pinion system in use.



Pinion	12 teeth
Pitch of teeth on rack	2 mm

Fig. 4.3

(i) To dispense gel, the pump on the bottle needs to move down 18 mm.

Use **Fig. 4.3** to calculate the number of revolutions of the pinion to move the rack down 18 mm. Show your working. **[4]**

Number of revolutions .....

© OCR 2022

(ii) The DC motor output speed is 720 rpm.

Experiments have determined that the pump must complete the 18 mm downward motion in a time of 0.5 seconds.

A compound gear train is needed between the motor and the rack and pinion.

Use sketches and/or notes to show a **two-stage** compound gear train, using spur gears, to achieve the required motion.

You **must** use your answer to **part (b)(i)** and other calculations to support your choice of gear. You **must** indicate the number of teeth on each gear. **[5]**

© OCR 2022

(iii) After being compressed and dispensing gel, the pump must return to its original start position to complete the pump action.

Describe how this could be achieved in this mechanical system.

.....

.....

.....

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

(c) Collaboration can be beneficial to gain specialist knowledge from across subject areas when working on the automatic hand gel dispenser.

Describe **two** specific ways in which collaboration could be used to increase the efficiency of the designing process for the automatic hand gel dispenser.

1 .....

.....

.....

.....

2 .....

.....

.....

.....

[4]

END OF QUESTION PAPER

© OCR 2022

BLANK PAGE

PLEASE DO NOT WRITE ON THIS PAGE

© OCR 2022

PLEASE DO NOT WRITE ON THIS PAGE

OCR
Oxford Cambridge and RSA

Copyright Information

OCR is committed to seeking permission to reproduce all third-party content that it uses in its assessment materials. OCR has attempted to identify and contact all copyright holders whose work is used in this paper. To avoid the issue of disclosure of answer-related information to candidates, all copyright acknowledgements are reproduced in the OCR Copyright Acknowledgements Booklet. This is produced for each series of examinations and is freely available to download from our public website (www.ocr.org.uk) after the live examination series.

If OCR has unwittingly failed to correctly acknowledge or clear any third-party content in this assessment material, OCR will be happy to correct its mistake at the earliest possible opportunity.

For queries or further information please contact The OCR Copyright Team, The Triangle Building, Shaftesbury Road, Cambridge CB2 8EA.

OCR is part of Cambridge University Press & Assessment, which is itself a department of the University of Cambridge.

© OCR 2022