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Examiners' report

DESIGN AND TECHNOLOGY: DESIGN ENGINEERING

H404

For first teaching in 2017

H404/01 Summer 2022 series

Version 1

ocr.org.uk/designandtechnology

Contents

Introduction

Our examiners' reports are produced to offer constructive feedback on candidates' performance in the examinations. They provide useful guidance for future candidates.

The reports will include a general commentary on candidates' performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. A selection of candidate answers are also provided. The reports will also explain aspects which caused difficulty and why the difficulties arose, whether through a lack of knowledge, poor examination technique, or any other identifiable and explainable reason.

Where overall performance on a question/question part was considered good, with no particular areas to highlight, these questions have not been included in the report.

A full copy of the question paper and the mark scheme can be downloaded from OCR.

Advance Information for Summer 2022 assessments

To support student revision, advance information was published about the focus of exams for Summer 2022 assessments. Advance information was available for most GCSE, AS and A Level subjects, Core Maths, FSMQ, and Cambridge Nationals Information Technologies. You can find more information on our website.

Paper 1 series overview

This paper has four sets of questions that predominantly cover technical principles. Candidates are required to:

- analyse existing products or systems
- recall scientific formulae and demonstrate applied mathematical skills
- demonstrate their technical knowledge of materials, product functionality, manufacturing processes and techniques
- demonstrate their understanding of wider social, moral and environmental issues that impact on the design and manufacturing industries.

In order to do well in this series, candidates needed a sound grasp of basic electronic circuit principles, as well as a good working knowledge of a range of sensors, applications for microcontrollers, and motor control. Understanding of compound gear systems and how to use gear ratios to calculate input and output speeds of rotation was also a requirement to do well on the exam.

In order to do well in written responses, candidates needed to work to the marks available and justify the points made with specifics, for example, in questions relating to safety features, benefits of folding, use of non-ferrous alloys, and benefits of CFRP for the scooter.

Overall, the exam for this series drew a very strong set of responses and shows that many candidates had been suitably prepared for the range of contextual and mathematical questions that the paper can include.

Candidates that did well on this paper, recalled scientific formulae accurately and were able to apply mathematical skills to rearrange them. They were confident in their ability to convert units and presented the working to their maths responses neatly and in an organised, structured manner that could be followed, while paying attention to units of measurement.

A feature of strong performances was evidence of analysis in the responses to the extended writing scooter and solar panel questions, with a large number of appropriate points made and explained, targeted against the identified aspects of the questions, of 'environment' and 'inclusivity', and 'wider issues' and 'lifecycle management' respectively.

Candidates that did less well on this paper did not show a strong understanding of the fundamentals of electronic circuits, including Ohm's Law and series and parallel circuits. Maths skills tended to be weak, and responses were disorganised or missing working-out and units that could have earned valuable marks. A tendency to write vague, generic or non-specific responses to the question context was a feature of less successful responses when considering duties of employers under HASAW, and collaboration with specialists to benefit the design process. Responses to extended writing questions lacked evidence of analysis and points were often made with little justification. These candidates provided answers to these questions that did not respond to the identified aspects of 'environment' and 'inclusivity' for the scooter question.

Many candidates struggled with tessellation of a simple shape or overlooked efficiency of manufacture of the laser-cut shape. Many candidates misunderstood what the term 'inclusivity' means.

Candidates who did well on this paper generally did the following:	Candidates who did less well on this paper generally did the following:
• demonstrated a good knowledge of the chemical and mechanical properties of design engineering materials, such as alloys and composites • had a good grasp of the fundamentals of series and parallel electronic circuits • recalled formulae and could rearrange these correctly • confidently provided details of the units used and their conversion in maths questions • answered with clear points and justified points well • answered in relation to the context of the question with detailed and/or points specific to the context made • worked through maths questions in an organised and structured way • effectively analysed extended writing questions and mind mapped responses before presenting good quality descriptive writing • showed a good working knowledge of electronic circuits, sensors, microprocessors, and motor control • confidently recalled the format of a two-stage compound gear system and effectively applied their own calculations to identify appropriate number of teeth on gears and an overall gear ratio.	• demonstrated little awareness of the fundamentals of series and parallel electronic circuit design • gave vague or generic responses that did not respond to the context of the question • approached maths questions in a disorganised and/or erratic way with little evidence of working out or structure that may have helped earn marks for errors carried forward, or for appropriate working • demonstrated little awareness of units in calculations • struggled with factor of 10 unit conversion maths tasks • struggled to rearrange formulae • incorrectly measured a 2D shape presented on graph paper • overlooked numerous opportunities in extended writing responses, with answers that lacked evidence of analytical thinking skills • misunderstood the term 'inclusivity' • were unfamiliar with the term 'tessellation', or were unable to provide evidence of any tessellation • had little awareness of what the phrase 'control measures' means when related to health and safety.

Question 1 (a) (i)

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

Fig. 1.1

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

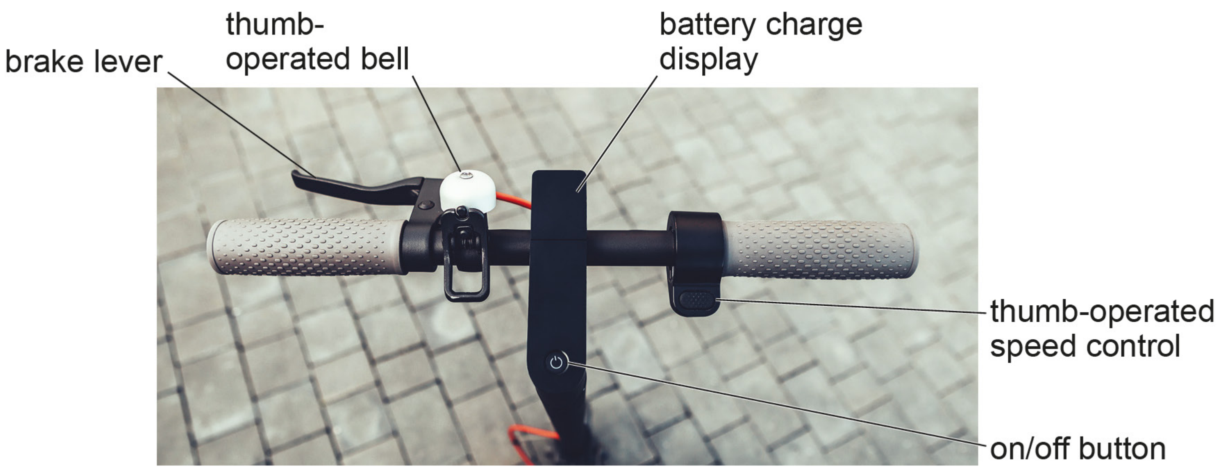

Fig. 1.2

(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]**

Candidates responded well to this question on the whole. Most candidates clearly identified key safety features, such as the brake light. The best responses made clear connections with how this provided safety to the user and others, e.g. to alert other drivers they are slowing down and to prevent being driven into from behind.

Where candidates did not achieve full marks, it was typically because they did not justify their point with clear reference to the safety of the user on the scooter.

Question 1 (a) (ii)

(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]**

This was a well-answered question by most candidates. The most common response related to the space-4e-saving nature of the scooter after folding which could support storage. The best responses included examples of reducing the size for ease of storage on public transport or in the boot of a car.

Where candidates did not achieve full marks, it was because they did not explain their point clearly with relevant justification. Some candidates repeated parts of the question saying it was foldable, alluding to this as the answer, and with weak justification as to why that was a benefit.

Question 1 (b) (i)

(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.

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....

....

.... **[2]**

Candidates typically responded well here. The best responses were made with reference to the fact that non-ferrous metals do not corrode and included explanation that this would be important due to use in rain or wet weather, to enable longevity of use of the scooter.

Some candidates demonstrated an understanding of metals but made points that were not relevant to the context of the question, for example, non-ferrous metals are non-magnetic, therefore ferrous metals will not stick to it, which has no bearing on the product.

Question 1 (b) (ii)

(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]**

This was a reasonably well-answered question. Many candidates understood that CFRP has a good strength to weight ratio. The best responses related this to improvements in speed, handling, and portability. However, there were many candidates who did not give clear rationale in their responses, for example, making comments such as durable or strong, but did not make it clear how this is better than other materials.

The less successful responses showed that many candidates did not have a good understanding of the materials' properties/characteristics, often suggesting that a CFRP frame would be less likely to break on impact than a metal frame.

Assessment for learning

When learning about material properties it would benefit candidates to consider the suitability of materials for a range of applications, by comparing and contrasting their properties.

Materials selection charts are highly effective visual learning tools and used as standard in industry to support this process. An example can be found in Section 5 of the Hodder Education endorsed textbook, and interactive material selection charts are provided for public use by Cambridge University at the following link:

http://www-materials.eng.cam.ac.uk/mpsite/interactive_charts/

Candidates can also be encouraged to make use of these resources to aid with identifying materials and requirements for the commercial manufacture of their NEA design proposal. This learning will help to provide a foundation to support responses in future similar exam questions.

Misconception

A common misconception in responses to this question was that CFRP is stronger and more durable than metals, when in fact, stainless steel, titanium, low alloy and high alloy steels are all examples of metals that could be stronger than CFRP.

Question 1 (c) (i)

(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.

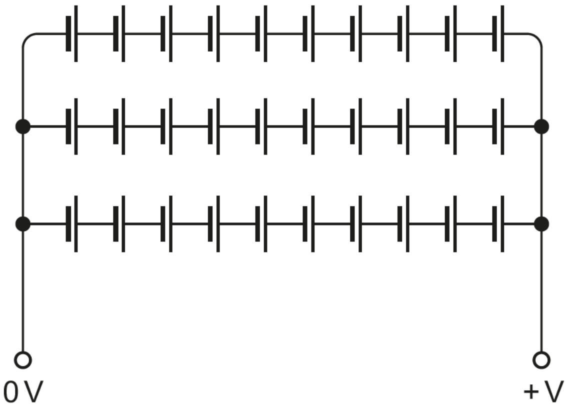


Fig. 1.3

(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

This question received a surprisingly high number of incorrect responses with many candidates not understanding the difference between parallel and series circuits. The better responses demonstrated understanding that the terminal voltage would 3.6V x 10 cells, with simple calculations to work this out. The majority of responses gave 30 cells x 3.6V which is incorrect and demonstrates a lack of understanding of how parallel circuits work.

Assessment for learning

The technical concepts behind this question are of a fundamental level in GCSE Combined Science and Physics. There is an expectation that all A Level Design and Technology: Design Engineering candidates would be able to access a question of this nature and limited complexity. It would benefit candidates to revisit electronic circuit basics at the start of the course, to consolidate prior learning in other subject areas and/or make necessary links. Circuit simulators such as Circuit Wizard are very effective learning tools and can reduce the costs and time required to fault-find when working with breadboards and other physical experiment kits.

Question 1 (c) (ii)

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

....

....

....

.... **[2]**

Due to the variable nature of responses to the previous question, many less successful responses did not understand the benefit of parallel circuits. The better responses correctly explained the benefit of the pack still working when one line of cells stops working. Weaker responses included vague suggestions that the battery would be more powerful. A number of candidates commented on the advantage of a more compact shape but overlooked that the cells could actually be arranged in any shape and series, or parallel circuit arrangements make no difference to this.

Question 1 (c) (iii)

(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]**

The responses to this question were varied. Incorrect responses focused on 18650 cells rather than the use of standard components, or commonly candidates gave responses relating to the user, not the manufacturer, such as maintenance and replacing dead batteries.

Candidates that understood the scenario typically commented on the nature of the 18650 cells being standard components, already in large scale manufacture, with associated ease of access and availability. Benefits described included cost reduction relating to the lack of need to design, develop and manufacture bespoke batteries.

Question 1 (d) (i)

(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]**

Most candidates answered this question well because they could identify the relationship between the values provided, and they could apply the appropriate calculation. However, in many cases it was difficult to find evidence that candidates understood the relationship between Watts and Joules per second.

Question 1 (d) (ii)

(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

This question received a varied set of responses. In some cases, candidates could not recall the correct formula for kinetic energy, instead referring to speed, distance, and time. The best candidates did recall the formula, and correctly rearranged it. However, many overlooked the fact that kinetic energy is constant at constant speed, and instead used 525J for kinetic energy in the formula (3 seconds x 175 joules = 525 joules), and not the correct figure of 175J.

Exemplar 1

$$K.E. = \frac{1}{2}mv^2$$

$$175 \times 3 = \frac{1}{2}(85)v^2$$

$$v^2 = \frac{210}{17}$$

$$v = 3.5147\ ms^{-1}$$

$$= 3.5\ ms^{-1}$$

Constant speed of the electric scooter ......3.5...... m/s

In this response the candidate incorrectly calculates a new kinetic energy total of 525J. In all other aspects the response is correct.

Question 1 (e)

(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]

Level 3 responses were clear and concise often discussing the impact of reduced greenhouse emissions, reduction in cars and public transport and the manufacture of the product itself, namely the production of the battery and its afterlife. In some cases, environment was used in terms of location with candidates detailing city centres, aesthetics, etc. Better candidates would usually be comfortable discussing the limited design for disabilities and possible danger of use for pedestrians.

Level 2 responses tended not to touch on the manufacture of the scooter but did identify two or three environmental and/or inclusivity matters. However, there were more limited statements that did not necessarily justify their understanding or have a large range of example/topics to show a wider understanding. Less successful responses did not consider a range of environment or inclusivity factors, instead including unrelated references to cost, style and safety.

Level 1 responses mainly missed the key points, focusing on electric scooters having little or no benefit for carbon emissions, or that inclusivity was only related to smart phone use or ownership.

Assessment for learning

A number of candidates demonstrated that they did not have a confident grasp of the concepts behind inclusivity. It would benefit candidates to be exposed to learning opportunities in a range of contexts that help them to consider the suitability of products for a number of user factors including age, gender, size, weight and disabilities.

Misconception

Less successful responses often included references to poor inclusivity being the lack of availability of access to a scooter due to popular use, or users not being able to afford the hire of a scooter.

Question 2 (a) (i)

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

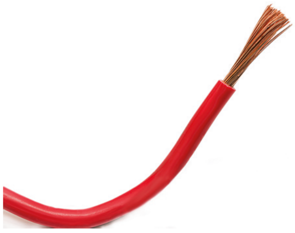


Fig. 2.1

(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

Responses to this question were mostly good with the majority of candidates recalling the formula for the area of a circle. The best responses understood the need to calculate the radius from the given diameter, as well as the need to multiply the cross-sectional area of one strand by 50 to calculate the total cross-sectional area. Less successful responses typically included incorrect recall of the formula, confusion between diameter and radius, or multiplication of the radius by 50.

Question 2 (a) (ii)

(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 .... %

Candidates that had correctly answered the previous question were able to respond strongly to this question. The best candidates were able to recall the correct formula. However, in the majority of cases where candidates performed strongly, they calculated the actual value of the cross-section as a percentage, then subtracted this from 100% to return the correct response. In some cases, candidates gave a response of 98% having overlooked the final stages of the calculation.

Typical errors arose from a misunderstanding of the formula needed, or from attempts to incorrectly use responses from the previous question.

Question 2 (a) (iii)

(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

The majority of candidates were very good at using the formula given but not many received full marks for their response.

The error that typically arose was in converting 2.50mm^2 in to m^2. However, most candidates were able to go on to calculate the resistance, with the error carried forward, providing a value that could be used for the following question.

Question 2 (a) (iv)

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

Voltage drop V

This was a generally well answered question, and the majority of candidates were able to recall Ohm's Law correctly.

Some candidates were not able to recall the formula for Ohm's Law, or the elements of the formula were mixed up.

Question 2 (b) (i)

(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.

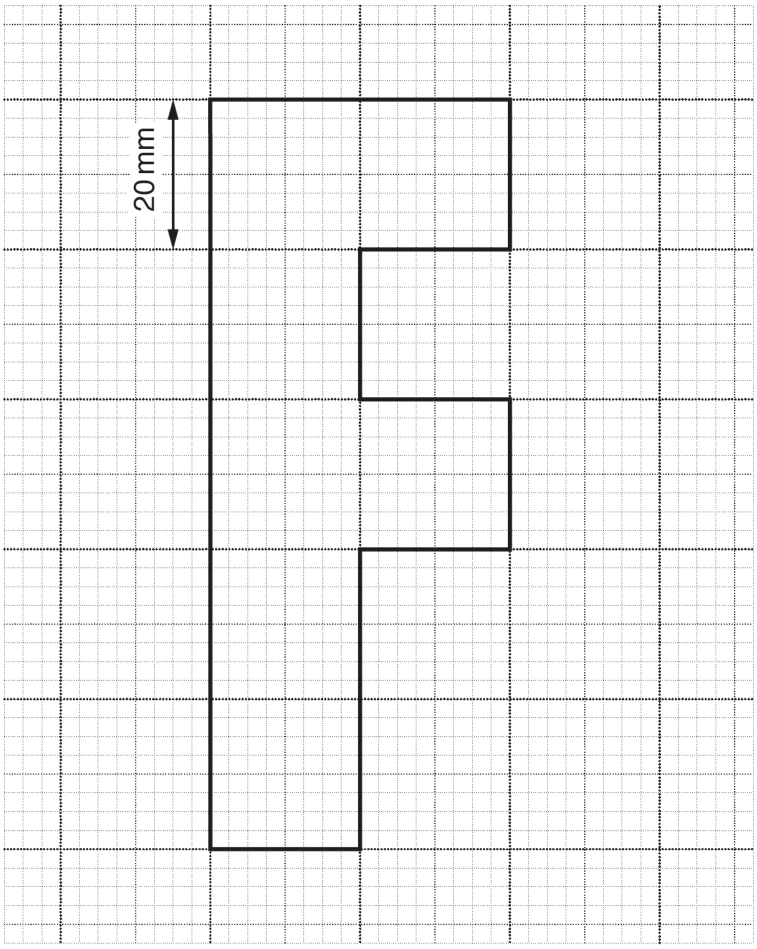


Fig. 2.2
(not to scale)

(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

This question was generally answered very well. Most candidates calculated the perimeter of the shape correctly, having identified that each larger square was 20mm x 20mm, then multiplying 20mm x 16 squares = 320mm. Some errors arose from candidates incorrectly counting the perimeter of the shape.

The final calculation of the time taken to cut the shape was completed correctly by the majority of candidates. Where an incorrect perimeter had been calculated, the error was carried forward successfully by most candidates.

Question 2 (b) (ii)

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

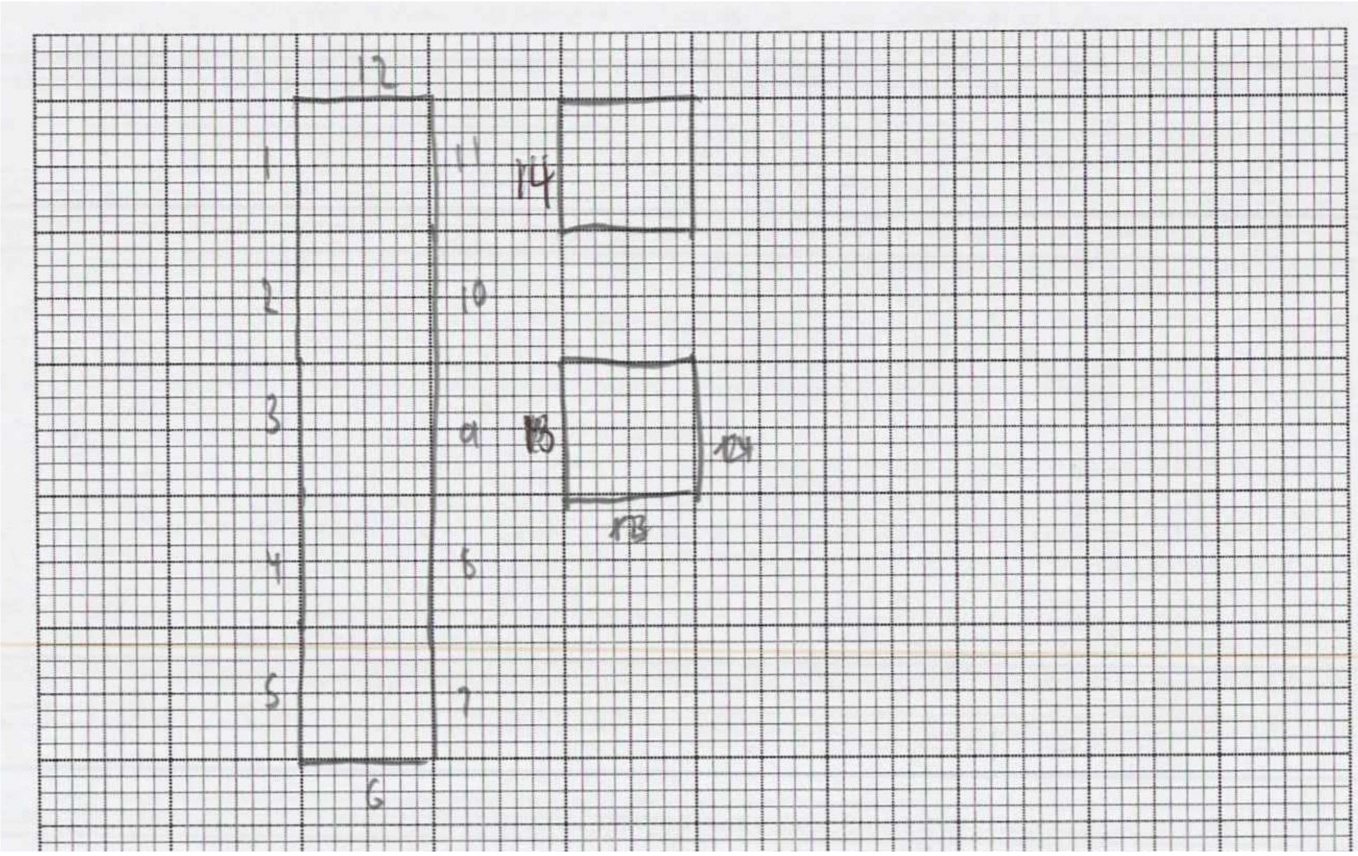
This can be achieved by tessellating (joining together) the two shapes.

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

The majority of candidates struggled to earn the mark. Many candidates were able to tessellate the shapes, but many did not arrange the shapes in the most efficient way, with one shape flipped.

Many candidates did not understand the term 'tessellate', instead, breaking up the shape into two or more parts.

Exemplar 2



In Exemplar 2, the candidate breaks-up the shape into separate components.

Assessment for learning

Tessellation in commercial and digital manufacture has featured in exam questions across the subject in recent times as a feature of design for manufacture and assembly (DFMA). It would benefit candidates to undertake learning activities that require them to experience shape tessellation, as well as exposure to genuine examples of the use of tessellation in industry to reduce waste. Starter activities, using card or laminated shapes, Lego, or even the Tetris electronic game can be low-cost and great fun for candidates.

Question 2 (b) (iii)

(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

Most candidates performed well on this question, even when the error was carried forward from the previous response. Most candidates accessed marks by establishing the perimeter of the shape in the previous response. However, some did not then consider the cutting line shared by the two shapes (where the shapes touched).

Question 3 (a) (i)

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.

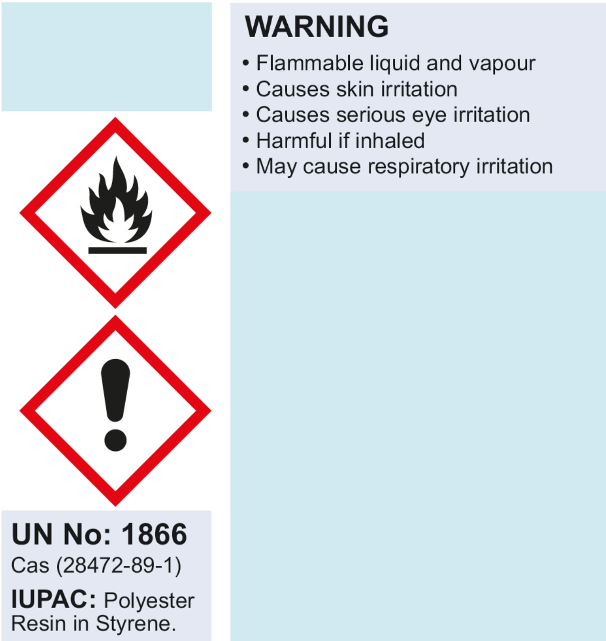


Fig. 3.1

(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]**

In general, this was a well answered question with many correct responses possible. Most common responses related to use of PPE, such as gloves or masks, as well as the need for ventilation.

The lowest scoring responses did not respond to the context of the question, and demonstrated little understanding of what 'control measures' are.

Assessment for learning

Candidates are encouraged to undertake risk assessments for all practical activities throughout their A Level NEA. This activity is invaluable in supporting their responses in an exam. In order to undertake risk assessments to an appropriate level, candidates should be exposed to examples of industry standard risk assessments, to include hazard identification, risk rating, affected parties, control measures in place and extra controls required. Examples of D&T department risk assessments and models from CLEAPSS are valuable learning resources, and will include consideration of maintenance programmes and record keeping.

Question 3 (a) (ii)

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

1 ....

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....

....

2 ....

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....

....

[4]

This was a mostly well-answered question with responses relating to provision of PPE, training, application of COSHH, etc. Many candidates missed the opportunity to access all of the marks available with responses that lacked detail or justification of the two duties. Risk assessment and record keeping were rarely-used responses.

Less successful responses did not clearly justify the responses given, and some focused their responses on the employee rather than the employer and as a result restricted their marks with responses like, 'must make sure they wear gloves'.

Question 3 (b)*

(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**.

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....

.... **[8]**

In general, candidates engaged well with the philosophical nature of this question. This was a mostly well-answered question due to the opportunity to comment on 'wider issues' as well as lifecycle management.

Level 3 responses typically showed good analysis and descriptive writing, with examples of the product lifecycle, raw materials, manufacture, transport, maintenance etc, while then discussing the idea through the wider issues of ownership of power, wildlife, impact on people, logistics and tourism.

Level 2 responses tended to touch on some of these points, but rarely the full lifecycle of the product, typically limited to more generic comments about maintenance and cost, and often combined with impact on wildlife.

Level 1 responses demonstrated a limited understanding of how this could be implemented or the impacts, with largely superficial statements provided, and little explanation of their relevance.

Question 4 (a) (i)

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.

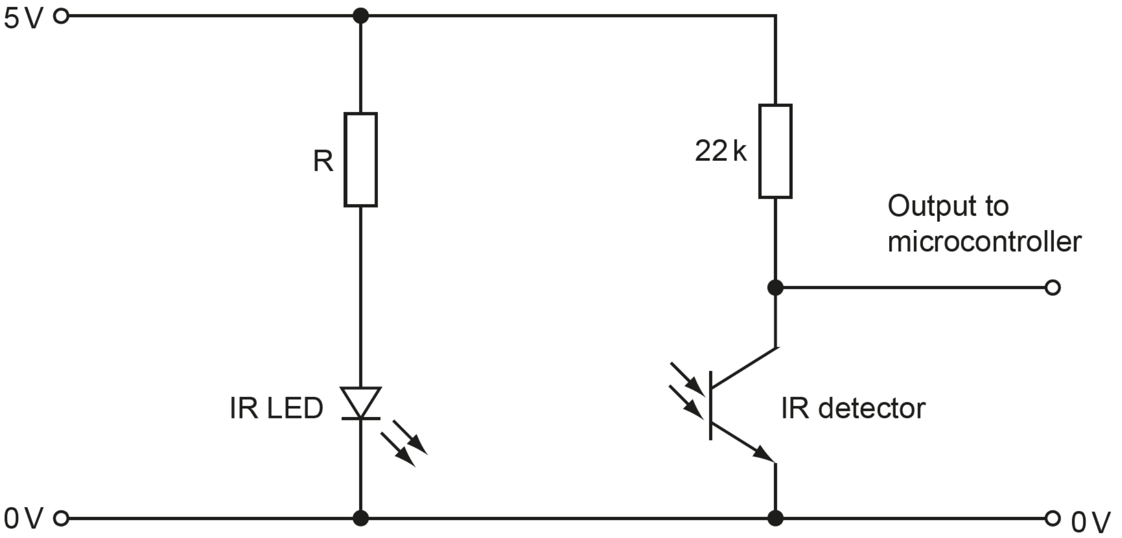

Fig. 4.2

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]**

Responses to this were often limited by the understanding of the context of the question. Many candidates did not know what the IR sensor does and how the circuit works. The better responses showed an understanding that IR can filter out visible light and therefore not be triggered or interfered by visible light. Less successful responses referenced heat, wave length and different speeds that were not relevant to the context.

Assessment for learning

An IR sensor consists of two parts, the emitter circuit and the receiver circuit. This is collectively known as a photo-coupler or an optocoupler. This sensor is also commonly used in light gate systems.

The emitter is an IR LED and the detector is an IR photodiode. The IR photodiode is sensitive to the IR light emitted by an IR LED. The photo-diode's resistance and output voltage change in proportion to the IR light received. This is the underlying working principle of the IR sensor.

It would benefit candidates to undertake practical learning challenges and experiments with a range of sensors throughout the course. Section 6 of the textbook provides details of common sensors.

Misconception

A number of candidates were under the misconception that an IR sensor circuit of this nature is used for sensing the presence of heat/thermal energy, confusing it with a passive infra-red-type sensor, rather than being a receiver of infra-red light emission from an IR LED.

Question 4 (a) (ii)

(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

Most candidates recalled Ohm's Law correctly, although this was not rewarded as it had been in a previous question. However, many candidates did not gain full marks.

Two errors were commonly evidenced by a large number of candidates:

The first was an error in considering how the voltage was divided and failing to understand how to apply the voltage drop, often using the value of 1.7V given instead of the correct use of 3.3V.

The second common error was in the conversion of mA to A.

In many cases both of the above errors were carried forward correctly to earn a mark.

Question 4 (a) (iii)

(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.

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....

.... **[4]**

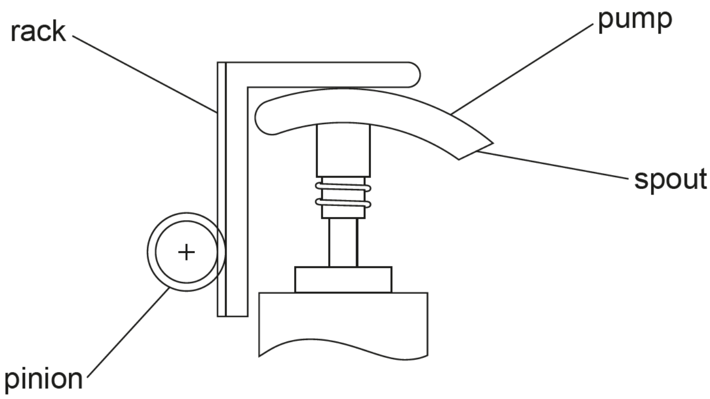
The best responses demonstrated that candidates had read the advanced information with reference to microcontrollers and the fact that the IR LED could be pulsed using a microcontroller to save energy. Some candidates had a good understanding of increasing the resistance, R, to reduce the current, but many were limited to a couple of marks.

Many candidates missed the point of the question and demonstrated a lack of understanding of the term 'drain'. In many cases less successful responses replaced the battery with a different energy supply such as a capacitor, a mains supply, or a solar panel. Some candidates suggested the use of extra sensors, such as ultrasonic proximity sensors, which would have increased drain on the battery.

Question 4 (b) (i)

(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 ....

There were a number of ways to answer this question. The better candidates understood the relationship between the distanced moved and the pitch, in order to correctly calculate the number of teeth on the pinion, or the distance moved by the pinion. In both cases, ratios were then used effectively in order to calculate the number of revolutions.

Less successful responses were often a result of calculating the ratio the wrong way around.

Question 4 (b) (ii)

(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]**

This question posed the biggest challenge of all questions in the exam with few candidates gaining full marks.

Top-level responses showed that candidates understood how to calculate the RPM and the ratio, but the difference between top and mid-level responses was to then recognise a 4:1 and 2:1 ratio with a realistic set of teeth, and resulting in a reduction in speed of rotation. They also were able to establish clear schematics with the direction of travel and motor labelled.

Candidates with mid-level responses tended to become stuck in working out the gearing, and if an error had been carried forward from the previous question, it tended to make things more challenging to establish a reasonable response. However, many candidates in this situation persevered with a level of success.

Lower-level responses often demonstrated that candidates did not know what a two-stage compound gear train is.

Assessment for learning

Section 6 of the textbook has a comprehensive section on gear systems, that includes a two-stage compound gear train. A number of candidates struggled to communicate their gear systems effectively, with some even drawing them in 3D. In order for candidates to communicate ideas efficiently and effectively under exam time allowed, they should be encouraged to use industry standard communication techniques for gears. 2D diagrammatic views, based on BS 8888 conventions, should be the norm and are easily replicated by candidates using circle templates and/or compasses.

Question 4 (b) (iii)

(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]**

This was a reasonably well-answered question with a wide array of responses relating to reversing polarity of the motor, programming a microcontroller to reverse the motor for a specific amount of time, use of a spring, etc. The less successful responses implemented complicated systems that would have involved multiple motors, gears and linkages. In order to earn both marks it was important for candidates to explain how the pump would return to its original position. Less successful responses overlooked this detailed level of description, with simplistic responses such as 'by using a spring', which overlooked placement/position and how the motor and gearing would be free to return to the start position. Strong responses included the technical mechanics of the solution described with clarity.

Question 4 (c)

(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]

The best responses clearly engaged with the stem of the question and identified specific specialists from across subject areas with whom collaboration would lead to increased efficiency of the design process. These candidates recalled specialists such as mechanical engineer and electronic engineers. Candidates often described the process of collaboration rather than giving specifics and examples. The better responses, however, focused on examples such as the electronic or mechanical advice that a specialist could give.

Many candidates answered this question with vague responses, such as designers working together. While many understood what collaboration meant, few answered in the context of the question relating to specialist knowledge. Many gave responses relating to user feedback and focus groups, with non-specific gains in efficiency.

Exemplar 3

1 A mechanical and electrical engineer can both collaberate to create the electro-mechanical system by using their specialist knowledge to design a product that suits the requirements.

2 Designers can collaberate with potential users and stakeholders to identify problems with iterations of the design to help optimise the design later on in other iterations

In the first part of Exemplar 3 the candidate identifies two specialists, although the increase in efficiency of the design process described is vague. The second response is very vague and incorrectly refers to non-specialists such as users.

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