OCR
Oxford Cambridge and RSA

# GCE

# Design and Technology

## H404/01: Principles of Design Engineering

A Level

# Mark Scheme for June 2022

OCR (Oxford Cambridge and RSA) is a leading UK awarding body, providing a wide range of qualifications to meet the needs of candidates of all ages and abilities. OCR qualifications include AS/A Levels, Diplomas, GCSEs, Cambridge Nationals, Cambridge Technicals, Functional Skills, Key Skills, Entry Level qualifications, NVQs and vocational qualifications in areas such as IT, business, languages, teaching/training, administration and secretarial skills.

It is also responsible for developing new specifications to meet national requirements and the needs of students and teachers. OCR is a not-for-profit organisation; any surplus made is invested back into the establishment to help towards the development of qualifications and support, which keep pace with the changing needs of today's society.

This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

# MARKING INSTRUCTIONS

## PREPARATION FOR MARKING
## RM ASSESSOR ASSESSOR

1. Make sure that you have accessed and completed the relevant training packages for on-screen marking: *RM Assessor assessor Online Training*; *OCR Essential Guide to Marking*.

2. Make sure that you have read and understood the mark scheme and the question paper for this unit. These are posted on the RM Cambridge Assessment Support Portal http://www.rm.com/support/ca

3. Log-in to RM Assessor Assessor and mark the **required number** of practice responses ("scripts") and the **number of required** standardisation responses.

   YOU MUST MARK 10 PRACTICE AND 10 STANDARDISATION RESPONSES BEFORE YOU CAN BE APPROVED TO MARK LIVE SCRIPTS.

## MARKING

1. Mark strictly to the mark scheme.

2. Marks awarded must relate directly to the marking criteria.

3. The schedule of dates is very important. It is essential that you meet the RM Assessor 50% and 100% (traditional 40% Batch 1 and 100% Batch 2) deadlines. If you experience problems, you must contact your Team Leader (Supervisor) without delay.

4. If you are in any doubt about applying the mark scheme, consult your Team Leader by telephone or the RM Assessor messaging system, or by email.

5. **Crossed Out Responses**
   Where a candidate has crossed out a response and provided a clear alternative then the crossed out response is not marked. Where no alternative response has been provided, examiners may give candidates the benefit of the doubt and mark the crossed out response where legible.

   **Rubric Error Responses – Optional Questions**
   Where candidates have a choice of question across a whole paper or a whole section and have provided more answers than required, then all responses are marked and the highest mark allowable within the rubric is given. Enter a mark for each question answered into RM assessor, which will select the highest mark from those awarded. *(The underlying assumption is that the candidate has penalised themselves by attempting more questions than necessary in the time allowed.)*

**Multiple Choice Question Responses**

When a multiple choice question has only a single, correct response and a candidate provides two responses (even if one of these responses is correct), then no mark should be awarded (as it is not possible to determine which was the first response selected by the candidate).

*When a question requires candidates to select more than one option/multiple options, then local marking arrangements need to ensure consistency of approach.*

**Contradictory Responses**

When a candidate provides contradictory responses, then no mark should be awarded, even if one of the answers is correct.

**Short Answer Questions** (requiring only a list by way of a response, usually worth only **one mark per response**)

Where candidates are required to provide a set number of short answer responses then only the set number of responses should be marked. The response space should be marked from left to right on each line and then line by line until the required number of responses have been considered. The remaining responses should not then be marked. Examiners will have to apply judgement as to whether a 'second response' on a line is a development of the 'first response', rather than a separate, discrete response. *(The underlying assumption is that the candidate is attempting to hedge their bets and therefore getting undue benefit rather than engaging with the question and giving the most relevant/correct responses.)*

**Short Answer Questions** (requiring a more developed response, worth **two or more marks**)

If the candidates are required to provide a description of, say, three items or factors and four items or factors are provided, then mark on a similar basis – that is downwards (as it is unlikely in this situation that a candidate will provide more than one response in each section of the response space.)

**Longer Answer Questions** (requiring a developed response)

Where candidates have provided two (or more) responses to a medium or high tariff question which only required a single (developed) response and not crossed out the first response, then only the first response should be marked. Examiners will need to apply professional judgement as to whether the second (or a subsequent) response is a 'new start' or simply a poorly expressed continuation of the first response.

6. Always check the pages (and additional objects if present) at the end of the response in case any answers have been continued there. If the candidate has continued an answer there then add a tick to confirm that the work has been seen.

7. Award No Response (NR) if:
   - there is nothing written in the answer space

   Award Zero '0' if:
   - anything is written in the answer space and is not worthy of credit (this includes text and symbols).

   Team Leaders must confirm the correct use of the NR button with their markers before live marking commences and should check this when reviewing scripts.

8. The RM Assessor Assessor **comments box** is used by your team leader to explain the marking of the practice responses. Please refer to these comments when checking your practice responses. **Do not use the comments box for any other reason.**
If you have any questions or comments for your team leader, use the phone, the RM Assessor messaging system, or e-mail.

9. Assistant Examiners will send a brief report on the performance of candidates to their Team Leader (Supervisor) via email by the end of the marking period. The report should contain notes on particular strengths displayed as well as common errors or weaknesses. Constructive criticism of the question paper/mark scheme is also appreciated.

10. For answers marked by levels of response: Not applicable in F501
    a. **To determine the level** – start at the highest level and work down until you reach the level that matches the answer
    b. **To determine the mark within the level**, consider the following:

| **Descriptor** | **Award mark** |
|---|---|
| On the borderline of this level and the one below | At bottom of level |
| Just enough achievement on balance for this level | Above bottom and either below middle or at middle of level (depending on number of marks available) |
| Meets the criteria but with some slight inconsistency | Above middle and either below top of level or at middle of level (depending on number of marks available) |
| Consistently meets the criteria for this level | At top of level |

11. **Annotations**

| Annotation | Meaning |
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| BP | Blank Page – this annotation must be used on all blank pages within an answer booklet (structured or unstructured) and on each page of an additional object where there is no candidate response. |
|  | Tick |
|  | Cross |
| BOD | Benefit of doubt |
| L1 | Level 1 |
| L2 | Level 2 |
| L3 | Level 3 |
| ECF | Error carried forward |
| NAQ | Not answered question |
| SEEN | Noted but no credit given |
| TV | Too vague |
| OFR | Own figure rule |
| REP | Repetition |

## 12. Subject Specific Marking Instructions

INTRODUCTION

Your first task as an Examiner is to become thoroughly familiar with the material on which the examination depends. This material includes:

- the specification, especially the assessment objectives
- the question paper
- the mark scheme.

You should ensure that you have copies of these materials.
You should ensure also that you are familiar with the administrative procedures related to the marking process. These are set out in the OCR booklet Instructions for Examiners. If you are examining for the first time, please read carefully Appendix 5 Introduction to Script Marking: Notes for New Examiners.

Please ask for help or guidance whenever you need it. Your first point of contact is your Team Leader.

| Question | | | Answer | Mark | Guidance |
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| 1 | (a) | (i) | Possible safety features include:<br><br>• Headlight to make the scooter visible to other road users (1), to reduce the chance of collisions (1).<br>• Wheel guard to prevent accidental contact with the wheel (1), which could destabilise the rider (1).<br>• Brake light to signal to other road users (1) that the scooter is slowing down (1).<br>• Non-slip deck to prevent rider's feet slipping (1) which could destabilise the rider and cause loss of control (1).<br>• Any other suitable response.<br><br>Other possible safety features:<br>• Brakes to control speed<br>• Bell to warn pedestrians<br>• Speed control operated by thumb<br>• Speed limiter<br>• High grip hand grips | 2 | Up to two marks for explaining how a feature improves safety on the electric scooter.<br><br><u>No marks</u> for simply identifying a feature, as these are listed in Fig. 1.1 and Fig. 1.2.<br><br>For the award of the second mark, a point must be developed or a second point made.<br><br>Specific reference to the context in the question is needed for marks to be awarded.<br><br>For the award of a mark, it must be clear that the feature identified is linked to safety.<br><br>Answers which just involve one word should not get awarded any marks as they do not show the link to safety i.e. Headlight – should be: Headlight to make the scooter visible to other road users. (1 mark) |
| | | (ii) | Possible benefits may include:<br><br>• The scooter takes up less space when folded (1) which makes storage easier (1).<br>• The scooter is easier to carry when folded (1) because the centre of gravity position makes it more balanced (1).<br>• Less space when folded (1) makes it easier to put in a car boot (1).<br>• Any other suitable response.<br><br>Other possible benefits:<br>• User can take it on public transport<br>• Can be easily stored at the user's workplace. | 2 | Up to two marks for explaining a benefit to the user of a folding scooter.<br><br>Specific reference to the context in the question is needed for marks to be awarded.<br><br>Do not award marks for points which are related to the manufacturer or retailer. |

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| | **(b)** | **(i)** | Possible responses may include:<br><br>• Non-ferrous alloys have a good strength-to-weight ratio (1) which means the scooter can be lightweight (1).<br>• They don't rust (1) which is significant as the scooter will be used outdoors (1).<br>• They do not need a finish applying (1) which simplifies manufacturing and lowers costs (1).<br>• Any other valid suggestion.<br><br>Other possible benefits:<br>Non-ferrous alloys:<br>• Are recyclable at end of life<br>• can be extruded into tubes and sections | 2 | One mark for identifying a benefit of using non-ferrous alloys for the frame of the electric scooter.<br><br>One mark for justifying why this material is suitable for the purpose given.<br><br>Specific reference to the context in the question is needed for marks to be awarded. |
| | | **(ii)** | Possible responses may include:<br><br>• CFRP is extremely lightweight and stiff (1) which will improve the handling and ride experience for the user (1).<br>• CFRP can be made into complex shapes (1) which gives more design options for the frame than simple tubes (1).<br>• CFRP has a good aesthetic (1) which can place a 'premium' label onto the product and command a higher price (1). | 2 | One mark for identifying a benefit of using composite materials for the frame of the electric scooter.<br><br>One mark for justifying why this material is suitable for the purpose given.<br><br>Specific reference to the context in the question is needed for marks to be awarded. |

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| | **(c)** | **(i)** | The cells for the battery are in series of 10.<br><br>The three rows of 10 batteries are in parallel.<br><br>The voltage per battery is 3.6 V<br><br>10 (1) x 3.6 V<br><br>= 36 V (1) | 2 | Award two marks as follows:<br><br>One mark for identification of 10 cells in a series.<br><br>One mark for calculating the output terminal voltage from the battery pack in volts to 0 decimal places<br><br>Do not award marks if given answer is 108 V as the batteries are in 3 parallel rows each containing a series of 10.<br><br>Where an incorrect answer is given working out should be used to credit appropriate marks.<br><br>An answer of 108 V with no working gains no marks.<br><br>If correct answer is given without working out shown award full marks. |
| | | **(ii)** | Possible advantages may include:<br><br>• The capacity of the battery is increased (1) so that the range of the scooter is increased (1). | 2 | Up to two marks for explaining one advantage of building the battery pack with three parallel groups of cells. |

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| | | | • The battery will not need charging as often (1) which improves the user experience (1).<br>• The current sourcing ability is increased (1) – because the effective internal resistance of the battery is reduced (1).<br>• If one of the parallel battery groups fail (1) the battery pack still supplies enough voltage to operate the scooter (1).<br>• Any other valid suggestion.<br><br>Other possible advantages:<br>• Capacity is increased without raising the voltage<br>• A greater number of smaller cells can be used – giving more options for their physical layout. | | Specific reference to the context in the question is needed for marks to be awarded.<br><br>Award the second mark if the candidate specifies “by a factor of 3 (by 3 times)” |
| | | **(iii)** | Possible benefits may include:<br><br>• They are manufactured in bulk by a specialist supplier (1) who will be able to sell the cells at lower cost (1).<br>• The scooter manufacturer can purchase the cells from a 3rd party supplier (1) - so they do not need to invest in specialist technology (1).<br>• Several cell manufacturers will exist, so there is a healthy competition (1) which will keep prices lower (1).<br>• Any other valid suggestion.<br><br>Other possible benefits:<br>• Reliability of supply from a reputable supplier.<br>• JIT manufacturing issues.<br>• Accuracy, repeatability, quality, reliability issues.<br>• Guarantees of battery quality, safety.<br>• Purchasing of the latest battery technology. | 2 | One mark for stating a benefit to a scooter manufacturer of using standard 18650 cells in a battery pack rather than designing a bespoke battery pack.<br><br>One mark for justifying why this would be a benefit in the context given.<br><br>Arguments can be generic ones for using any standard parts in a design.<br><br>No marks for ‘cheaper’ or ‘faster’ unless thoroughly justified. |

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| | **(d)** | **(i)** | 250 J of dissipated energy = 250 W (1)<br><br>Therefore, 250 x 70% = 250 x 70/100<br>= 250 x 7/10 = 25 x 7<br>= 175J (1)<br><br>There are a number of ways this can be calculated all of which are acceptable e.g.<br><br>• 250 x 0.7 = 175 J<br><br>• (250 x 70)/100 = 175 J | 2 | One mark if the candidate indicates understanding of the fact that 250W means 250 joules of energy dissipated per second, even if their calculation is wrong.<br><br>One mark for determining by calculation that the gain in kinetic energy of the electric scooter and rider in the first second is 175 J. |
| | | **(ii)** | Formula for Kinetic Energy is:<br><br>$KE = {}^1/_2mv^2$ (1) (where KE = Kinetic Energy, m = mass and v = speed)<br><br>KE = *175 J (taken from Q 1d(i)) for 1 second)<br><br>Speed (v) = $\sqrt{(KE/({}^1/_2m)} = \sqrt{(2KE/m)}$ (1)<br>= $\sqrt{(2 \times 175)/85)}$<br>= $\sqrt{(350*/85)} = \sqrt{(70*/17)} = 2.02919862478$<br>= 2.0 m/s (1) | 3 | Award three marks as follows:<br><br>One mark for recalling formula for Kinetic Energy.<br><br>One mark for rearranging recalled formula.<br><br>One mark for calculating the speed to 1 decimal place.<br><br>If correct answer is given without working out shown award full marks.<br><br>Where an incorrect answer is given working out should be used to credit appropriate marks.<br><br>*Allow error carried forward (ECF) where correct working out is shown. |

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| | **(e)** | | **Indicative Content:**<br><br>**Environmental factors**<br>• Electric scooter use in cities could reduce car use, so massively reducing pollution.<br>• Rechargeable using carbon zero electricity<br>• Use of solar PV or wind turbine for carbon zero charging<br>• Reduction of traffic jams – improving pedestrian safety and reducing road rage/impatience.<br>• Life cycle analysis of electric scooter<br>• Use of low environmental impact materials for manufacture<br>• Battery technology – use of harmful chemicals<br>• RoHS directive<br>• WEEE directive<br>• Need for quiet, pedestrian only areas?<br>• Encouraging riders to be out of cars, enjoying the environment<br>• Dangerous riders<br>• Would get better exercise riding a bike.<br>• Any other valid suggestion.<br><br>**Inclusivity factors**<br>• Making the scooter accessible for wide range of users<br>• Current scooter design demands a high level of physical fitness to ride<br>• Demands a high level skill to ride<br>• Dangers of inexperienced riders<br>• Demand fast reactions and cognition<br>• Risks for older riders, due to slower reactions and lower physical fitness<br>• Current scooters totally exclude wheelchair users or people with limited mobility<br>• Creating a safe ride experience for riders with prosthetic limbs | 8 | **Level 3 [6-8 marks]**<br>The candidate has a clear understanding of the wider issues of scooters being available for short-term rent in city centres. They produce a thorough discussion in relation to the question by explaining both environmental and inclusivity factors. The explanation of the issues is clear and well-developed and a number of examples are used to exemplify the points being made.<br><br>**Level 2 [3-5 marks]**<br>The candidate has a reasonable understanding of the wider issues of scooters being available for short-term rent in city centres. They produce a reasonable discussion in relation to the question by explaining environmental and/or inclusivity factors. The explanation of issues is sufficient although one or two opportunities are missed in developing the stated issues further.<br><br>**Level 1 [1-2 marks]**<br>The candidate has a basic knowledge of the issues of scooters being available for short-term rent in city centres. Any reference to this issue is descriptive in nature and has little appreciation of the factors involved. The response contains no analysis or evaluation.<br><br>**0 marks**<br>No answer or answer not worthy of credit. |

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| | | | • Age range – minimum age?<br>• Making the scooter adjustable for a range of rider heights<br>• Rider weight – maximum safe weight?<br>• Need to wear helmet – might conflict with religious/cultural expectations | | |

| Question | | | Answer | Mark | Guidance |
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| 2 | (a) | (i) | Candidates could calculate the cross-sectional area one strand in the following ways:<br><br>A = $A = \pi r^2$ (1)<br><br>= $\pi$ x $(\frac{0.25}{2})^2$<br>= $\pi$ x (0.125*) $^2$<br>= 0.04908738521 (1)<br><br>Total cross-sectional area of wire =<br><br>50 x 0.04908738521* = 2.45436926062 = 2.45mm$^2$ (1)<br><br>**OR:**<br><br>A = πd$^2$/4<br><br>A = π((0.25)$^2$/4)<br>= π x (0.0625*/4)<br>= π x 0.015625*<br>= 0.04908738521<br><br>50 x 0.04908738521* =<br>2.45436926062 = 2.45mm$^2$ | 3 | Award three marks as follows:<br><br>One mark for identifying formula to be used.<br><br>One mark for inputting values and calculating cross-sectional area of 1 strand.<br><br>One mark for calculating cross-sectional area to 2 decimal places.<br><br>If correct answer is given without working out shown award full marks.<br><br>Where an incorrect answer is given working out should be used to credit appropriate marks.<br><br>*Allow error carried forward (ECF) where correct working out is shown. |
| | | (ii) | % error =<br>((expected value – actual value)/expected value) x 100 (1)<br><br>% error = ((2.50 – 2.45*)/2.50) x 100<br>= (0.05*/2.50) x 100<br>= 0.02* x 100 = 2 % (1) | 2 | Award two marks as follows:<br><br>One mark for identifying formula to be used.<br><br>One mark for calculating the percentage error between the cross-sectional area calculated in **part (a)(i)** and the expected area of 2.50 mm$^2$.<br><br>If correct answer is given without working out shown award full marks. |

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| | | | There are a number of ways this can be calculated all of which are acceptable e.g.<br><br>(2.45 / 2.5) * 100 = 98%<br><br>100% - 98% = 2% | | Where an incorrect answer is given working out should be used to credit appropriate marks.<br><br>*Allow error carried forward (ECF) where correct working out is shown. |
| | | **(iii)** | Convert cross-sectional area in $m^2$<br><br>2.5/(1000x1000)<br><br>=<br>2.5 x $e^{-6}$ $m^2$ (can be written as 2.5 x $10^{-6}$) $m^2$ (1)<br><br>$R = \frac{\rho L}{A}$<br><br>R = ((1.72 x $10^{-8}$) x 3) / (2.5 x $10^{-6}$)*<br><br>= (5.16 x $10^{-8}$) / 0.0000025*<br>= 0.02064 Ω (1) | 2 | Award two marks as follows:<br><br>One mark for converting $mm^2$ to $m^2$.<br><br>One mark for calculating the resistance in Ω of a 3 m length of the electrical stranded wired shown in **Fig. 2.1**.<br><br>If correct answer is given without working out shown award full marks.<br><br>Where an incorrect answer is given working out should be used to credit appropriate marks.<br><br>*Allow error carried forward (ECF) where correct working out is shown. |
| | | **(iv)** | V = IR (1)<br><br>V = 25 x 0.02064*<br>= 0.516 V (1) | 2 | Award two marks as follows:<br><br>One mark for identifying formula to be used.<br><br>One mark for calculating the voltage drop along the 3 m length of wire when it carries 25 A.<br><br>If correct answer is given without working out shown award full marks.<br><br>*Allow error carried forward (ECF) where correct working out is shown. |

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| | **(b)** | **(i)** | Perimeter of shape =<br><br>16 x 20 = 320 mm (1)<br><br>Formula for speed =<br><br>Speed = distance / time (1)<br><br>= 320* / 16 = 20 s (1) | 3 | Award three marks as follows:<br><br>One mark for calculating the perimeter distance.<br><br>One mark for recalling the formula for speed.<br><br>One mark for calculating the time taken in seconds to cut out the shape.<br><br>If correct answer is given without working out shown award full marks.<br><br>Where an incorrect answer is given working out should be used to credit appropriate marks.<br><br>*Allow error carried forward (ECF) where correct working out is shown. |

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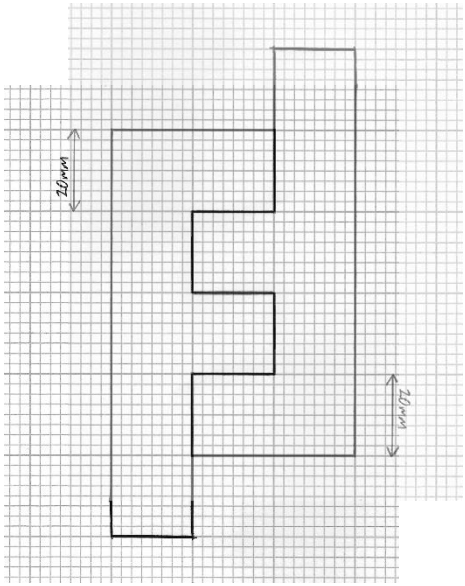
| | | **(ii)** | The most efficient way of tessellating the two shapes is:<br>  <br> | 1 | One mark for drawing the most efficient way to tessellate the two shapes. |

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| | | **(iii)** | Perimeter of tessellated shape = 18* x 20mm = 360mm (1)<br><br>Cutting line between shapes = 7 x 20mm = 140mm<br><br>Total cutting length combined cutting length = 360*mm + 140mm = 500mm (1)<br><br>There are a number of ways this can be calculated all of which are acceptable e.g.<br><br>Perimeter of original shape before tessellation = 320**<br><br>Length of additional shape to be cut after tessellation = 9 x 20 = 180 mm<br><br>Total cutting path = 320** + 180 = 500 mm | 2 | Award two marks as follows:<br><br>One mark for calculating the length of the cutting line between the two shapes.<br><br>One mark for calculating the total cutting length of the tessellated shape.<br><br>If correct answer is given without working out shown award full marks.<br><br>Where an incorrect answer is given working out should be used to credit appropriate marks.<br><br>*Allow error carried forward (ECF) from b(ii) where correct working out is shown.<br><br>**If this other method is used for the calculation, there could be an ECF from b (i) |

| Question | | | Answer | Mark | Guidance |
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| 3 | (a) | (i) | Possible control measures may include:<br>• No naked flames (1).<br>• Wear protective gloves (1).<br>• Wear safety goggles (1).<br>• Provide adequate ventilation (1).<br>• Any other valid suggestion.<br><br>Other examples:<br>• No smoking when using<br>• Wash hands after using<br>• Use LEV<br>• Use in a fume booth<br>• Use outdoors<br>• Wear a respirator mask<br>• Read COSHH data sheet | 2 | In each case:<br><br>One mark for identifying a control measure which should be in place to address the hazards indicated on the label in **Fig 3.1.**<br><br>Specific reference to the context in the question is needed for marks to be awarded. |
| 3 | (a) | (ii) | Possible duties may include:<br><br>• Make sure the workplace is safe (1) by carrying out risk assessments (1).<br>• Ensuring machinery and equipment is safe (1) and setting out safe procedures for using them (1).<br>• Ensuring items and substances are stored safely (1) and providing training for using them safely (1).<br>• Providing adequate welfare facilities such as toilets (1) and including first aid arrangements (1).<br>• Promoting employees' personal health and safety (1) by providing information, training and supervision (1).<br>• Making sure equipment is suitable for the intended use (1) and arranging for annual inspection and maintenance (1).<br>Other possible benefits:<br>• Providing necessary PPE. | 4 | In each case:<br><br>Up to two marks for describing **two** duties of **employers** as set out in the Health and Safety at Work Act (HASAW).<br><br>The answer may be in a generic context. |

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| | | | • Ensuring that mandatory safety signs are provided and maintained. | | |
| **3** | **(b)*** | | **Indicative Content:**<br><br>**Product Lifecycle Management**<br>• Large resources and materials needed to construct the huge number of PV panels needed.<br>• Initial setup costs – can the world afford to do this?<br>• Ongoing maintenance<br>• Cleaning of panels – removing sand<br>• Lack of local water for cleaning the panels<br>• Damage caused by sand storms<br>• How to transport the electricity around the world – cost of electricity cables<br>• Reliable energy source - strong overhead sunlight, very few cloudy days<br>• Expected lifetime of panels<br>• Emerging technology<br>• Replacement schedules<br>• End of panel life considerations<br>• Recyclability of materials<br>• Circular economy<br>• Any other valid suggestion.<br><br>**Wider Issues**<br>• Who owns the PV panels?<br>• Who owns the electricity generated?<br>• Who invests in installing the panels?<br>• Who manufactures the panels?<br>• Does this put too much political power in the hands of a few countries?<br>• Huge potential financial boost for LEDC<br>• Could cause an imbalance of worldwide financial<br>• Large heat absorption causing local air temperature rises which can affect climate and wildlife<br>• Covering the desert floor will change the ecology of the desert | 8 | **Level 3 [6-8 marks]**<br>The candidate has a clear understanding of the issues behind the statement. They produce a thorough discussion in relation to the question by evaluating the statement in depth. The explanation of product lifecycle management and wider issues is clear and well-developed and a number of examples are used to exemplify the points being made.<br><br>*There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated with the use of examples.*<br><br>**Level 2 [3-5 marks]**<br>The candidate has a reasonable understanding of the issues behind the statement. They produce a reasonable discussion in relation to the question by evaluating the statement to a reasonable depth. The explanation of product lifecycle management and/or wider issues is sufficient although one or two opportunities are missed in developing the stated issues further.<br><br>*There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.*<br><br>**Level 1 [1-2 marks]**<br>The candidate has a basic knowledge of what the statement is driving at. Any reference to any issue is descriptive in nature and has little appreciation of the wider context. The response contains no analysis or evaluation. |

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| | | | • Local wildlife issues<br>• Local social issues<br>• Ethical issues<br>• Very clean, carbon zero electricity generated<br>• Any other valid suggestion. | | *The information has some relevance and is presented with limited structure or detail. The information is supported by limited evidence.*<br><br>**0 marks**<br>No answer or answer not worthy of credit. |

| Question | | | Answer | Mark | Guidance |
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| 4 | (a) | (i) | Possible advantages may include:<br><br>• IR systems can filter out visible light (1) so they are more immune to noise/interference from light sources (1)<br>• IR is invisible (1) so the light source does not cause annoyance at night (1).<br>• IR is invisible (1 making it more aesthetically pleasing (1).<br>• IR emitters and detectors are readily available (1) so they are low cost (1).<br>• Any other valid suggestion.<br><br>Other valid points:<br>• IR detectors are very sensitive so they can detect weak signals<br>• IR systems can be modulated (pulsed) to make the system highly immune to background IR sources | 2 | Up to two marks for explaining an advantage of using infra-red light rather than visible light in sensing systems such as this.<br><br>Specific reference to the context in the question is needed for marks to be awarded.<br><br>Do not credit 'cheap', 'easy to use' etc. unless fully justified. |
| | | (ii) | Voltage across R = 5 v – 1.7 v = 3.3* v (1)<br><br>Convert mA to A = 10/1000 = 0.01* (1)<br><br>R = v / I = 3.3* / 0.01* = 330 Ω (1) | 3 | Award three marks as follows:<br><br>One mark for calculating voltage across R.<br><br>One mark for converting MA to A.<br><br>One mark for calculating resistance of resistor R, to the nearest whole number.<br><br>If correct answer is given without working out shown award full marks.<br><br>Where an incorrect answer is given working out should be used to credit appropriate marks.<br><br>*Allow error carried forward (ECF) where correct working out is shown. |

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| | | **(iii)** | Possible responses may include:<br><br>• The IR LED could be pulsed briefly (1) twice a second (1) which would be frequent enough to detect a user placing their hand under the spout (1).<br>• The resistor R could be increased (1) to reduce the current (1) which would reduce the sensitivity of the sensor (1).<br>• The IR LED could be connected to an output pin on the microcontroller (1) and code could be written to pulse the LED (1) with an on/off ratio of 1:9 (1) which would reduce the average current to 1mA (1).<br>• Any other valid suggestion. | 4 | Up to four marks for describing options available to the design engineer to minimize this problem.<br><br>Mix and match approach with bullet points possible.<br><br>Specific reference to the context in the question is needed for marks to be awarded. |
| | **(b)** | **(i)** | Number of teeth in 18 mm rack =<br><br>Distance moved / pitch (1)<br>= 18 / 2 = 9* teeth (1)<br><br>Revolutions of pinion required =<br><br>Teeth moved on rack / teeth on pinion (1)<br>= 9* / 12 = 0.75 revolutions (1) | 4 | Award four marks as follows:<br><br>One mark for identifying correct formula to be used.<br><br>One mark for calculating number of teeth.<br><br>One mark for identifying correct formula to be used.<br><br>One mark for calculating the number of revolutions of the pinion required to move the rack down 18 mm.<br><br>If correct answer is given without working out shown award full marks.<br><br>Where an incorrect answer is given working out should be used to credit appropriate marks.<br><br>*Allow error carried forward (ECF) where correct working out is shown. |

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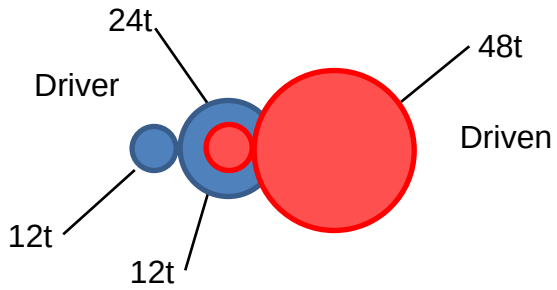
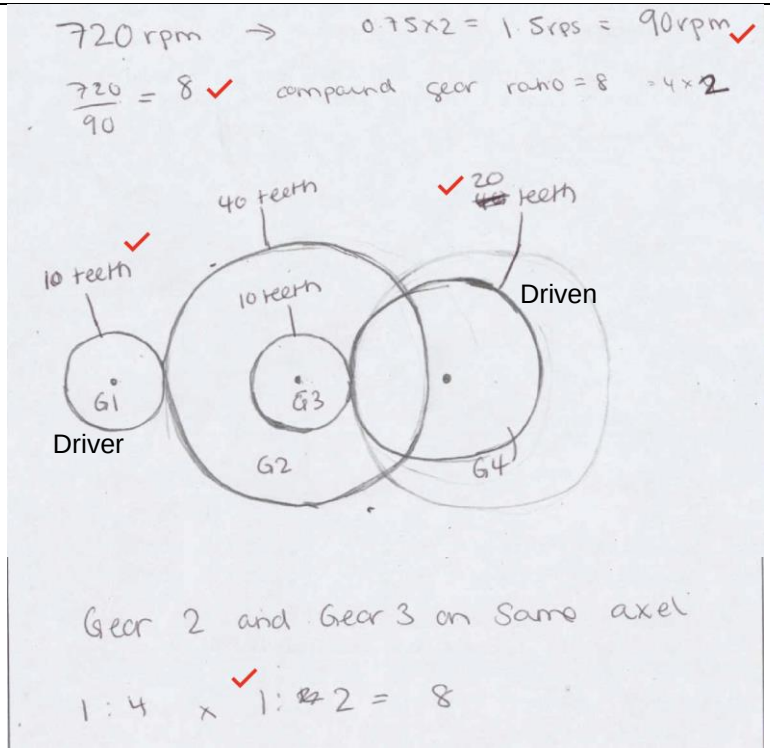
| | | **(ii)** | Calculate the required rotational speed of the pinion:<br><br>Rotational speed = 0.75* / 0.5 = 1.5* rev/s<br>In rpm: rotational speed = 1.5* x 60 = 90* rpm (1)<br><br>Gear ratio required = 720 / 90* = 8 (1)<br><br>Understanding that a two-stage compound gear system can be achieved with one stage having a gear ratio of 2, and the other stage having a gear ratio of 4 (1).<br><br>e.g:<br>  <br><br><br>Suitable ratio of gear teeth for 1st stage (1)<br>Suitable ratio of gear teeth for 2nd stage (1)<br><br>Accept any other suitable gear ratio combination that results in the correct overall gear ratio of 8.<br><br>There are a number of ways this can be calculated all of which are acceptable e.g. | 5 | Award five marks as follows:<br><br>One mark for calculating the rotational speed of the pinion.<br><br>One mark for calculating the gear ratio required.<br><br>One mark for demonstrating understanding that a two-stage compound gear system can be achieved with one stage having a gear ratio of 2, and the other stage having a<br>gear ratio of 4.<br><br>One mark for indicating a suitable ratio of teeth for 1st stage.<br><br>One mark for indicating a suitable ratio of teeth for 2nd stage.<br><br>Award a maximum of 4 marks if the compound gear train increases the speed of rotation rather than decreases it.<br><br>Award a maximum of 4 marks if the driven and driver gears are not labelled.<br><br>Accept any other suitable gear ratio combination that results in the correct overall gear ratio of 8.<br><br>*Allow error carried forward (ECF). |


720 rpm → 0.75x2 = 1.5rps = 90rpm
720/90 = 8 compound gear ratio = 8 = 4x2
40 teeth
20 teeth
10 teeth
10 teeth
Driven
G1
G3
Driver
G2
G4
Gear 2 and Gear 3 on same axel
1 : 4 x 1 : 2 = 8

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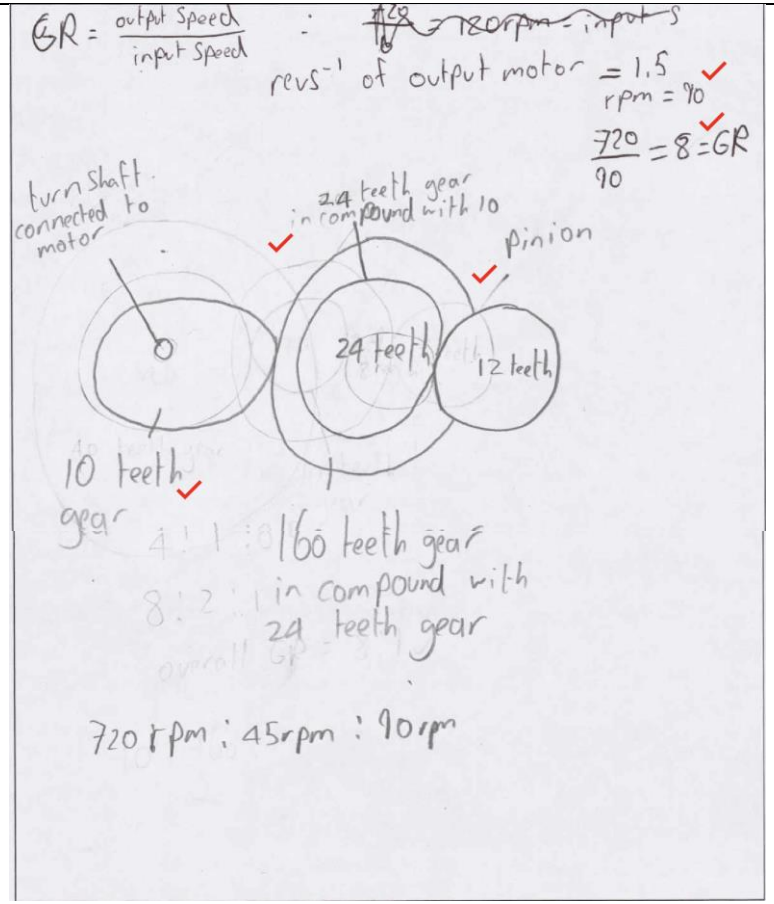
| | | |  | | |
| | | **(iii)** | Possible responses may include:<br><br>• A spring could be used on the rack (1) to pull the rack back after the motor is switched off (1).<br>• The motor could be reversed (1) under the control of the microcontroller (1).<br>• Experiments could be carried out (1) to see if the existing return spring on the pump is strong enough to push the rack back up (1). | 2 | Up to two marks for describing how the pump could return to its original start position to complete the pump action in this mechanical system.<br><br>Specific reference to the context in the question is needed for marks to be awarded.<br><br>Allow responses that involve a spring beneath the spout component as candidates may not have recognised the spring feature in the diagram. |

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| | | | • Any other valid suggestion. | | |
| | **(c)** | | Possible ways may include:<br><br>• An electronics specialist could work on the circuit and the PCB layout (1) and optimise the component values (1).<br>• A coding specialist could write the microcontroller code (1) to improve the experience of the user interface (1).<br>• Injection moulding specialists (1) can advise on the design of the design of the casing (1)<br>• Mechanical engineers (1) can advise on the gearing system, and bearings and other mechanical issues (1)<br>• Any other valid suggestion. | 4 | In each case:<br><br>Collaboration must be with a specialist i.e. not a user, or other non-specialist stakeholder.<br><br>Up to two marks for describing a way in which collaboration could be used to increase the efficiency of the designing process for the automatic hand gel dispenser.<br><br>The points must be specific to the hand gel dispenser project for credit to be given. Do not award marks for generic comments.<br><br>Ensure that the points made are referring to the design process. |

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