OCR
Oxford Cambridge and RSA

GCE

Design and Technology

H404/01: Principles of Design Engineering

A Level

Mark Scheme for June 2023

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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

1. Make sure that you have accessed and completed the relevant training packages for on-screen marking: RM A*ssessor 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 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).

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 **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:
    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
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
SEEN	Noted but no credit given
BOD	Benefit of doubt
L1	Level 1 response
L2	Level 2 response
L3	Level 3 response
ECF	Error carried forward
^	Omission
NAQ	Not answered question
CON	Confused (replaces the question mark)
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.

Question			Answer	Mark	Guidance
1	(a)		Possible reasons may include: • Can be made in different colours (1). • Can be moulded into the stem shape (1). • Flexible to allow stem to bend (1). • Can be shrunk-wrapped onto the stem (1). • Can be made from recycled material (1). • Can be recycled at end of life (1). • Can be an electrical insulator (1). • Any other suitable response.	2	In each case: One mark for identifying a reason why a thermo softening polymer is a suitable material for the flexible stem. Specific reference to the context in the question is needed for marks to be awarded. Do not allow 'cheap' unless justified in context
1	(b)		Possible responses may include: • The bearings serve to reduce friction/unwanted heat energy to allow for smoother rotation (1). This cuts down on the amount of energy consumption (1). • Bearings prevent direct metal-to-metal contact between two elements that are in relative motion (1). This prevents wear on moving parts or provides support to moving parts (1). • Allows for increased speed of rotation (1) due to less friction within the system (1). • Any other suitable response.	2	Up to two marks for explaining why bearings are used in mechanical systems such as those used in the personal mini fan. Mix and match approach to be taken with bullet points.
1	(c)		Possible benefits to the **user** may include: • USB sockets are very common on appliances, power supplies and power banks (1), so the fan can be used in a wide range of situations (1)	4	In each case: Up to two marks for explaining a benefit to the user/manufacturer of designing the personal mini fan to be powered from a USB socket.

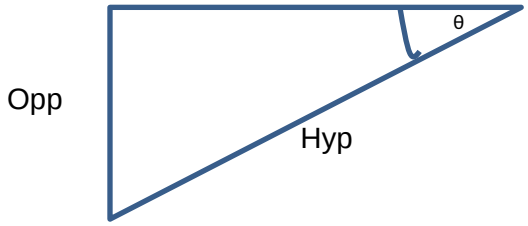
Question			Answer	Mark	Guidance
			• USB sockets are common on desktop appliances such as PCs (1), so the fan can be plugged in to keep the user cool whilst working at a desk (1). • The fan does not need to contain a battery or trailing wires (1), so it can be made smaller and more portable to fit in a pocket (1). • Relying on an external power supply means one less component to include in the fan (1), which reduces the fan cost and makes it more affordable (1). • Any other suitable response. Possible benefits to the **manufacturer** may include: • USB voltage is standard at 5V and 1A minimum (1) so the manufacturer can design the fan knowing that a specific voltage/current will be used (1). • Removing the requirement for an internal battery allows a reduction in product size and weight (1), which reduces costs in manufacturing, packaging and shipping (1). • Standardised part (1) readily available for the manufacturer (1). • Any other suitable response.		Specific reference to the context in the question is needed for marks to be awarded. Mix and match approach to be taken with bullet points. Points could focus specifically on USB technology, or be more general regarding the fan not needing to contain its own power source. Do not credit repeated points, e.g. cheaper for user, cheaper for manufacturer.
1	**(d)**	**(i)**	V = I x R followed by P = IV (instead of P = I^2R), where V = voltage [1] **Convert mA to amps :** I = 250 mA = 250 / 1000 = 0.25 amps [1]	4	Award four marks as follows: One mark for recalling and manipulation of correct formula (Ohm's Law). One mark for converting mA to amps. One mark for calculating voltage.

Question			Answer	Mark	Guidance
			V = 0.25* x 20 = 5V [1] P = 0.25* x 5* = 1.25 W [1]		One mark for calculating the power dissipated in variable resistor VR1. If correct answer is given without working out shown award full marks. Where an incorrect answer is given working out should be used to credit appropriate marks. *Allow error carried forward (ECF) where correct working out is shown. An alternative method of working would be to use Joule's Law. Award credit appropriately in this case.
1	**(d)**	**(ii)**	Possible responses may include: • The variable resistor dissipates 1.25W as heat (1). This power is wasted, it is lost to the environment and not put to any useful purpose to power the fan (1). • Any other suitable response.	2	Up to two marks for explaining why using a variable resistor is not an efficient way of controlling the speed of a DC motor. For both marks, candidates must have made it clear that the power dissipated in the variable resistor is wasted and not put to use in the fan.
1	**(d)**	**(iii)**	Q is a MOSFET (1). It is an amplifying device used to increase the current flowing through the fan (1).	2	One mark for identifying Q. One mark for explaining its function in a circuit. Allow Field Effect Transistor. Do not credit 'transistor'.

Question			Answer	Mark	Guidance
					Award credit for correct use of the words “amplifying, boosting, increasing, driving (or driver)” if the candidate demonstrates understanding.
1	(d)	(iv)	Possible reasons may include: • D is used to remove back emf from the motor (1). • D is used to protect the MOSFET (1). • D is used to remove noise interference from motor (1). • Any other suitable response.	1	One mark for identifying a reason for including diode D in the circuit. No credit for any reference to ‘prevent the current flowing backwards’. No credit for reference to protecting the motor, or protecting the circuit.
1	(d)	(v)	Possible reasons may include: • The microcontroller can add extra functionality to the product (1) so that extra features could be added such as auto power off after a period of time (1). • Standard microcontrollers are available in large quantities at low cost (1) so it may be cheaper to use a standard circuit rather than designing a bespoke solution (1). • The microcontroller delivers improved product functionality (1) which increases user appeal and marketability (1). • Use of a microcontroller will enable the motor speed to be controlled using pulse width modulation (1) providing a reduction in the consumption of power to the motor than the VR control circuit(1). • Any other suitable response.	2	Up to two marks for explaining a reason why a designer might choose to use a microcontroller to achieve motor speed control in products such as a personal mini fan. Specific reference to the context in the question is needed for marks to be awarded. Mix and match approach to be taken with bullet points. The points must refer to the designer, not the user.

Question			Answer	Mark	Guidance
			Other possible responses. • Possibility for IoT integration. • Possibility for software upgrades. • Touch button integration rather than physical buttons. • Reduce power losses therefore increase efficiency		
1	(e)		**Indicative Content:** **Responsible designing** • Design for maintenance. • Replaceable parts. • Raise price of product – improve quality/performance/functionality and increase product life – aim product at a higher level. • Offer product take-back incentives. • Consider product lease schemes. • Offer recycling incentives. **Materials** • Promote recyclability of product by using a minimum range of different materials. • Allow product to be easily broken down into component parts. • Use recyclable materials where possible. • Indicate recycling methods on the product – signage/markings. **Legislation** • WEEE directive. • RoHS. • Legislation regarding take back of products at EoL. • Manufacturer's responsibility to promote the 6Rs.	8	**Level 3 [6-8 marks]:** The candidate has a clear understanding of the role of a designer in ensuring the responsible disposal of products such as the personal mini fan at the end of their product life. They produce a thorough discussion in relation to the question by explaining a number of roles that the designer can play. The explanation of the role is clear and well-developed, at least two well supported examples are used to exemplify the points being made. **Level 2 [3-5 marks]:** The candidate has a reasonable understanding of the role of a designer in ensuring the responsible disposal of products such as the personal mini fan at the end of their product life. They produce a reasonable discussion in relation to the question by explaining a number of roles that the designer can play. The explanation of the role is sufficient although one or two opportunities are missed in the use of examples to develop the stated points further. **Level 1 [1-2 marks]** The candidate has a basic knowledge of the role of a designer in relation to responsible disposal. Any reference to this role is descriptive in nature and has little appreciation of how this role can support the

Question			Answer	Mark	Guidance
					responsible disposal of products at the end of their product life. The response contains no analysis or evaluation. **0 marks** No answer or answer not worthy of credit. Candidates can refer to other products not solely the mini fan.

Question			Answer	Mark	Guidance
2	(a)		 Length of Opp = (20 – 8) / 2 = 6 mm [1] Length of Hyp = 45mm Sin Θ = 6* / 45 = 0.133 [1] Sin^{-1} (6/45) = 7.662255661^0 [1] Θ = 7.7^0 (to 1 decimal place) [1] There are other methods of achieving this answer that would be acceptable such as Cosine/Tangent when applied with Pythagoras.	4	Award four marks as follows: One mark for calculating the length of the opposite. One mark for calculating Sin Θ. One mark for calculating the arcsine. One mark for calculating Θ to 1 decimal place. If correct answer is given without working out shown award full marks. Where an incorrect answer is given working out should be used to credit appropriate marks. *Allow error carried forward (ECF) where correct working out is shown.
2	(b)	(i)	For one mark: Extrusion (1).	1	One mark for identifying the industrial manufacturing process involved.
2	(b)	(ii)	Volume of a flute = cross section area of flute x length of sheet. Cross section area of flute = internal cross section of flute as per table = 7.0mm x 7.0mm = $49mm^2$ [1] (or 0.7cm x 0.7cm = $0.49cm^2$)	3	Award three marks as follows: One mark for calculating the cross section area of a flute. One mark for calculating the volume of a flute.

Question			Answer	Mark	Guidance
			Volume of a flute = 49mm^2 * x 500mm = 24500 mm^3 [1] = 24.5 cm^3 [1] (or 0.49cm^{2*} x 50cm = 24.5 cm^3)		One mark for converting mm into cm at some point during process. If correct answer is given without working out shown award full marks. Where an incorrect answer is given working out should be used to credit appropriate marks. Do not award credit for answers that have been rounded to the nearest whole number. *Allow error carried forward (ECF) where correct working out is shown.
2	**(b)**	**(iii)**	Total number of flutes in metre length = 134 Total volume of flutes = 134/2 [1] x (24.5cm^{3*}) = 67* x 24.5cm^{3*} = 1641.5 cm^3 [1]	2	Award two marks as follows One mark for determining that 134 needs to be halved. One mark for calculating the total volume of **all** flutes in the corrugated polymer sheet. If correct answer is given without working out shown award full marks. Where an incorrect answer is given working out should be used to credit appropriate marks. Do not award credit for answers that have been rounded to the nearest whole number. *Allow error carried forward (ECF) where correct working out is shown.

Question			Answer	Mark	Guidance
2	(b)	(iv)	Surface area of sheet = 500mm x 500mm = 250000mm^2 250000 / 1000000 = 0.25m^2 [1] Power absorbed over surface area = 2 x 0.25 = 0.5kW 0.5kW x 1000 = 500W [1] Energy absorbed (J) = power x time (seconds) [1] Seconds = 15 minutes x 60 = 900 s (seconds) [1] for coversions of units throughout question. Energy absorbed (J)= 500W x 900s [1] = 450,000J	5	Award five marks as follows: One mark for calculating the surface area. One mark for calculating the power absorbed over the surface area in W. One mark for recalling formula. One mark for converting units. (both from mm^2 to m^2 and minutes to seconds) One mark for showing the calculation required to determine that the energy absorbed by the corrugated polymer sheet over a period of 15 minutes is 450 000J.
2	(b)	(v)	Formula given: Q = mcΔT where: Q = heat energy in Joules (J) m = mass of water in kg c = specific heat capacity of water (4200J/kg^{0}C) ΔT = temperature change in ^{0}C Re-arrange the formula: ΔT = Q/mc [1] ΔT = 450,000 / (1.642 x 4200) [1] = 450,000 / 6896.4 = 65.2514355^{0}C = 65^{0}C [1]	3	Award three marks as follows: One mark for rearranging the formula. One mark for entering values into formula. One mark for calculating the temperature rise of the water to the nearest ^{0}C in the corrugated polymer sheet over a period of 15 minutes. If correct answer is given without working out shown award full marks. Where an incorrect answer is given working out should be used to credit appropriate marks.

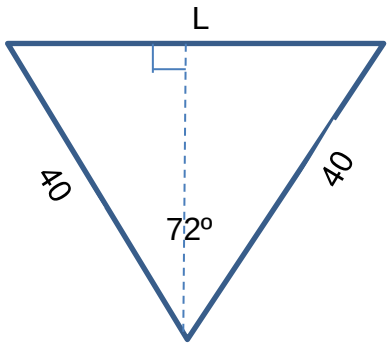
Question			Answer	Mark	Guidance
3	(a)	(i)	Possible responses may include: • Woven glass (or carbon fibre) matting used along with a polyester resin (1) to produce GRP or CFRP parts (1). • Rip-stop nylon (1) is a textile containing reinforcement threads that prevent a tear from propagating (1). • Textiles such as nylon/Kevlar (1) are used as a reinforcement in tyres where the textile is bonded inside the rubber to provide dimensional stability (1). • Kevlar (1) can be bonded to other textiles to make reinforced garments which are abrasion resistant, or bullet-proof (1). • Geotextiles such as PP or PET sheets (1) are used to keep layers of ground materials separate (1). • Any other suitable response.	2	One mark for describing a way that textiles can be used for reinforcement in design engineering. One mark for using an example of a textile in support of this process. The word reinforcement can be taken to mean improving resistance to flexing/abrasion/penetration/fire etc.
3	(a)	(ii)	Possible responses may include: There are four stages to the part's manufacture. 1) Cutting the slots happens whilst the sheet metal is still flat (1) – in batch production this would be done by a CNC cutter (1) or by manufacturing a punch tool for a hydraulic press (1).	4	Up to four marks for describing the industrial manufacturing processes which would have been used to manufacture the sheet metal part. Specific reference to the context in the question is needed for marks to be awarded. Mix and match approach to be taken with bullet points.

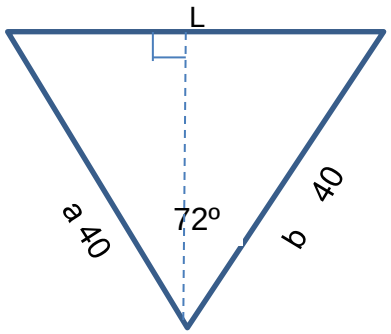
Question			Answer	Mark	Guidance
			2) Cutting out the part (1) – using CNC cutter (1), or could be done at the same time as punching holes in hydraulic press (1). Or cut with guillotine/shears (1). 3) Bending (1) – in batch production done using hydraulic press and prepared formers (1). 4) Finishing (1) – possibly powder-coated or anodised if aluminium (1). • Any other suitable response.		Candidate does not have to identify all four stages to gain full marks. Give credit if candidates identify the order of manufacture, e.g. cutting slots before bending.
3	**(b)***		**Indicative Content:** These are examples only. Candidates may choose any technological advancement and a key figure from their studies. **Invention of radio** • Key figure: Guglielmo Marconi. • Dates c1895. • Marconi did not actually invent radio, but proved that radio signals could be sent over long distances. • He increased the antenna sizes and raised the transmission power in order to create the first commercially successful radio telegraph system. • He successfully demonstrated ship-to-shore and ship-to-ship communications, which was completely unique at the time. • Marconi set up a company in his own name to install and maintain wireless equipment in ships. • The Titanic famously used Marconi's equipment to call SOS, saving some lives. • Marconi sent the first trans-Atlanic radio message. • Won the Nobel prize for physics.	8 Dates or links with other historic events may be given to clarify a timeline, but specific dates are not required in order to gain credit. Only one key historical movement (or technological advancement)	**Level 3 [6-8 marks]:** The candidate has a clear understanding of a key technical advancement or discovery and the figures associated with it. They produce a thorough discussion in relation to the question by discussing how this work has had an influence on future developments in design engineering. The explanation of the influence is clear and well-developed and a number of examples are used to exemplify the points being made. *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.* **Level 2 [3-5 marks]:** The candidate has a reasonable understanding of a key technical advancement or discovery however they may not identify figures associated with it. They produce a reasonable discussion in relation to the question by explaining how this work has had an influence on future developments in design

Question			Answer	Mark	Guidance
			• Marconi showed the world the usefulness of radio for two-way communication. This also paved the way for broadcast radio. Today, broadcast radio has developed into TV and DAB radio. Sending messages by radio has developed into wireless data transmission which includes applications such as wi-fi, Bluetooth, smart phones and mobile internet, wireless remotes, aircraft communications and satellite communications. **Invention of the Integrated Circuit** • Key figure: Jack Kilby of Texas Instruments. • Kilby and his team developed a way of integrating hundreds (later thousands and now millions) of transistors to be integrated onto a tiny chip of silicon. • The process involved a photographic method of creating p and n type semiconductors directly onto the silicon. • The photographic image could be miniaturised by optical methods. • This resulted in the miniaturisation of electronic circuits, whilst increasing their complexity and functionality, and reducing their power consumption. • The first commonly available consumer products using ICs were digital watches and pocket calculators • Previous calculators were desk sized devices, and often mechanical rather than electronic.	should be credited. Candidates who have described two or more should only be credited for the one than scores the highest mark. A best fit approach may be needed if the key movement and the key figure do not match.	engineering. The explanation of the influence is sufficient although one or two opportunities are missed in the use of examples to develop the stated points further. *There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.* **Level 1 [1-2 marks]** The candidate has a basic knowledge of a key technical advancement or discovery however they may not identify figures associated with it. Any reference to this work and descriptive in nature and has little appreciation of how this work has influenced future developments in design engineering. The response contains no analysis or evaluation. *The information has some relevance and is presented with limited structure or detail. The information is supported by limited evidence.* **0 marks** No answer or answer not worthy of credit. If a candidate does not identify a key figure marks can be awarded no higher than level 2.

Question			Answer	Mark	Guidance
			• Microchips allowed computers to be miniaturised, leading to their application in aircraft and, ultimately in space craft. • The birth of the IC is accepted as spawning the 'space age'. • ICs are now universally used in almost all electronic products. • Application specific ICs are produced very cheaply in large quantities for commonly used products. • Programmable microcontrollers are embedded into products and then programmed with custom firmware which can be updated. • Power dissipation has become a problem with modern large ICs and getting the heat away from them is a big challenge which has started to limit their growth. Any other valid suggestion.		

Question			Answer	Mark	Guidance
4	(a)		Possible reasons may include: • The electric parking brake can be integrated with other car systems (1), e.g. a hill start function (1). • More reliable brake holding function (1) adds to the safety of the car (1). • Improves safety (1) as the brake can be automatically applied when exiting car (1). • Saves room in the cabin (1) by removing the large parking brake lever (1). • Improves inclusivity (1) – no need for physical strength to pull the lever (1). • Any other suitable response.	2	Up to two marks for explaining why a manufacturer might choose to install an electric parking brake rather than a lever-operated parking brake in a car. Specific reference to the context in the question is needed for marks to be awarded. Reasons must relate to the manufacturer to gain credit.

Question			Answer	Mark	Guidance
4	(b)	(i)	 Simplest way to split triangle into two right angled triangles: Angle = 72 / 2 = 36^0 [1] Sin 36^{0*} = opp / hyp = (L / 2) / 40 Therefore: L/2 = Sin 36^{0*} x 40 [1] = 0.5877852523* x 40 = 23.511410092 [1] Therefore L = 23.511410092* x 2 = 47.022820183 = 47mm (0 decimal places) [1] **OR**	4	Award four marks as follows: One mark for halving the given angle. One mark for applying/manipulating the correct trigonometry formula. One mark for calculating L/2. One mark for calculating L to the nearest mm. If correct answer is given without working out shown award full marks. Where an incorrect answer is given working out should be used to credit appropriate marks. *Allow error carried forward (ECF) where correct working out is shown. **OR**

Question			Answer	Mark	Guidance
			 CosC = $(a^2+b^2-c^2) \div 2ab$ [1] Therefore: Cos72 = $(40^2+40^2-L^2) \div (2x40x40)$ [1] L^2 = 2211.15 [1] Therefore L = √2211.15 = 47.02286678 = 47mm (0 decimal places) [1]		Award four marks as follows: One mark for recalling the Cosine formula. One mark for correctly substituting L for side c and correct substitution of values for a, b and angle C. One mark for calculating L^2. One mark for calculating L to the nearest mm. If correct answer is given without working out shown award full marks. Where an incorrect answer is given working out should be used to credit appropriate marks. *Allow error carried forward (ECF) where correct working out is shown.
4	**(b)**	**(ii)**	Output gear = 72 / 360 = 0.2 revolutions [1] Compound gear = 0.2* x (60 / 15) = 0.8 revolutions [1] Worm wheel rotates through 0.8* x 60 = 48 revolutions [1]	3	Award three marks as follows: One mark for calculating number of revolutions for output gear. One mark for calculating number of revolutions for compound gear.

Question			Answer	Mark	Guidance
					One mark for calculating the number of revolutions of the worm wheel that are required to rotate the output gear through an angle of 72º. If correct answer is given without working out shown award full marks. Where an incorrect answer is given working out should be used to credit appropriate marks. *Allow error carried forward (ECF) where correct working out is shown.
4	**(c)**	**(i)**	Possible responses may include: • An incremental rotary encoder, also known as a quadrature encoder, produces a pulse signal when a shaft has been rotated (1). • Incremental rotary encoders measure the speed (1) and direction (1) of a rotating shaft. • Incremental rotary encoders have no end-stops (1) and can be rotated continuously (1), clicking as they do so. • Every click produces a pulse (1), which can be read by a microcontroller (1). Each click provides the user with audible feedback. • Incremental rotary encoders are versatile (1) and can be used in a range of products such as radios for volume control (1), or time input on a microwave oven (1). • Can be used to detect angular position (1).	3	Up to three marks for describing the benefits of incremental rotary encoders to design engineers. Specific reference to the context in the question is needed for marks to be awarded. Mix and match approach to be taken with bullet points.

Question			Answer	Mark	Guidance
			Any other suitable response.		
4	(c)	(ii)	When rotated clockwise, A goes high first followed by B (1). This will cause the “Is input A high?” command to respond with Yes (1). Once B then goes high, the program proceeds down the left-hand column (1). A “High beep for 0.2s” command will generate the audible user feedback (1).	4	Up to four marks for describing how the system provides audible feedback to the user when the control knob is rotated **clockwise**. For full marks, it must be clearly explained how signals A and B are read by the flowchart commands so that the program proceeds down the left-hand column of the flowchart. Therefore, a high beep will be generated.
4	(c)	(iii)	For three marks: Variable A = 1 (1) Variable B = 0 (1) Variable C = 1 (1)	3	There is no need for candidates to explain their reasoning to receive credit. Variable A will increase with every click, but if A exceeds 1, then it is reset to 0 and B is increased. If B exceeds 1 then it is reset to 0 and C is increased. The result is a binary code in the form CBA. Therefore, after five clicks, the binary code is 101. Candidates do not need to spot that the program algorithm generates a binary code. With only five iterations around the program loop, they can work out the values.

Question			Answer	Mark	Guidance
4	(c)	(iv)	Two clicks anticlockwise results in: Variable A = 1 Variable B = 1 (1 mark for A and B both 1) Variable C = 0 (1)	2	There is no need for candidates to explain their reasoning to receive credit. Anticlockwise rotation sends the program down the right hand flowchart column, which causes the variables to decrease in a binary code, by 1 per click. Candidates do not need to spot that the program algorithm generates a decrementing binary code. With only two iterations around the program loop, they can work out the values. Award one mark for variable A and B correct. Award one mark for variable C correct.

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