Oxford Cambridge and RSA

GCE

Design and Technology

H404/01: Principles of Design Engineering

Advanced GCE

Mark Scheme for November 2020

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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.

Annotations

Annotation	Meaning
	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
	Confused (replaces the question mark)
	Benefit of doubt
	AO1 – Knowledge and understanding
	AO2 – Apply knowledge and understanding
	AO3 - Analyse
	AO4 - Evaluation
	Omission
	Not answered question
	Noted but no credit given
	Too vague
	Own figure rule

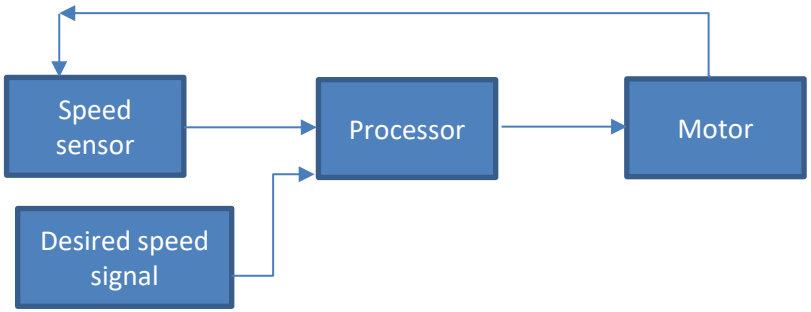
REP	Repetition

Question			Answer	Mark	Guidance
1	a	i	**Smart object** – a physical object with embedded electronic sensors/microcontrollers/actuators which is equipped for two-way communication (1). **Network** – a series of devices (e.g. smart objects) connected together in such a way that they can communicate with each other and exchange data (1). **Communication protocol** – an agreed method of communication between the devices in a network which allows for successful data exchange and routing (1).	3	In each case: One mark for definition of term. Answers should convey that two-way communication is happening between devices. No marks for points that only consider the control of devices. As long as understanding is shown award marks.
		ii	Possible responses may include: • The microcontroller can add enhanced functionality to a kettle, e.g. a smart kettle (1) which will increase the attraction to potential buyers (1). • The microcontroller control circuit may be a commonly available standard subsystem (1) which makes it simple for a designer to integrate rather than designing a bespoke control system (1). • Kettle can be networked (1), so can be controlled remotely or exchange information e.g. about energy usage (1). • Any other valid suggestion. Other possible responses may include: • Increased reliability, which prolongs the kettle's life. • Can accurately sense water temperature which means reliable boiling and potential energy saving. • Firmware can be upgraded, so development features can be added later.	4	In each case: If candidates mention enhanced functionality to the kettle but do not justify with a benefit to the manufacturer award one mark. Up to two marks for describing two benefits to a designer or manufacturer of embedding a microcontroller into a kettle. Mix and match approach to be taken.

Question			Answer	Mark	Guidance
					It must be clear how the points benefit the **designer or manufacturer.** No marks for points that appear to only benefit the user.
1	**b**	**i**	Possible responses may include: • The input worm scan drive the output gear but not vice-versa (1) which means that the blind cannot fall under its own weight when the motor is not running (1). • The input worm screw can drive the output wheel but not vice-versa (1) which means that the blind cannot fall under its own weight when the motor is not running (1). • A large gear ratio provides slow rotation and steady controlled movement of the blind (1), enabling the user to stop the blind at a desired position (1). • Any other valid suggestion. Other possible responses may include: • A large gear ratio can be achieved in one stage, which allows for a compact gearbox size. • A large gear ratio means that smaller, lower torque motors can be used. • The mechanism is quiet in operation, which is beneficial in a home environment.	**2**	Up to two marks for explaining one functional feature of a worm drive system that makes it useful in the roller-blind mechanical drive system. Mix and match approach. Specific reference to the context in the question is needed for marks to be awarded. Do **not** accept 'the drive is transferred through 90 degrees' unless it is clearly justified why this is useful in a roller blind system.
		ii	Circumference = πd (or 2πr) (1) Circumference = π x 35 = 110 mm (to nearest mm) (1)	**2**	Award two marks as follows: One mark for recalling formula. One mark for applying formula to calculate the circumference of the roller to the nearest mm.

Question			Answer	Mark	Guidance
					If the correct answer is given award full marks.
		iii	Revolutions of roller to raise blind 165 mm = distance/circumference = 165/110* = 1.5 revs (1) Rotational speed of roller = 1.5*/2 = 0.75 revs s^{-1} (1) The gear ratio of the worm drive system is 40 Motor rotational speed = 0.75* x 40 = 30 rev s^{-1} (1) Convert to rpm: Motor rotational speed = 30* x 60 = 1800 rpm (1)	**4**	Award four marks as follows: One mark for calculating the number of revolutions of the roller needed to raise the bind. One mark for calculating the rotational speed of the roller. One mark for calculating the motor rotational speed.in revolutions per second. One mark for converting revolutions per second to revolutions per minute. 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
					*Allow error carried forward (ECF) where correct working out is shown. Do not award a mark for stating that the gear ratio is 40. The mark for this comes from using this figure to calculate the motor rotational speed.
		iv	Possible responses may include: • As the blind rises the roller diameter increases (1) due to the thickness of the blind fabric (1). • As the blind rises there is less weight hanging off the roller (1) meaning there is less load on the motor (1). • As the blind rises the roller diameter increases (1), which increases the circumference of the roller (1). • Any other valid suggestion. Other possible responses may include: • The motor must overcome the initial inertia of the system (1), meaning the speed will significantly increase over the first couple of seconds of operation (1). • Any other valid suggestion.	**4**	In each case: Up two marks for explaining why the speed of the blind increases throughout the raising cycle. Mix and match approach. Specific reference to the context in the question is needed for marks to be awarded.
		v	Sensor: • Slotted opto-sensor and a slotted disk on the blind roller (1). • Reed switch and a magnet on the blind roller (1). • Microswitch and a cam on the blind roller (1). • Rotary encoder on the blind roller (1).	**4**	Award four marks as follows: One mark for identifying a suitable sensor for detecting the roller speed.

Question			Answer	Mark	Guidance
			• Continuous potentiometer on the blind roller (1). • Hall effect sensor on the blind roller (1). • Any other valid suggestion. System diagram (or similar) (1):  Explanation: • The speed signal from the sensor is compared to the desired speed by the processor (1). • The motor speed is adjusted until it matches the desired speed (1). • Any other valid suggestion.		One mark for a system diagram showing the sensor, a process subsystem, the motor as the system output and closed loop feedback. Award one mark for a circuit diagram showing the sensor, a microprocessor, and the motor. Up to two marks for explaining the principle of operation of the closed loop system. Candidates are likely to use a combination of sketches and/or notes although the candidate may outline the closed loop system in place of drawing a system diagram. The interaction between the sensor and the mechanical system must be clear for the sensor mark. Credit should be given wherever the candidate has supplied the required information in their response.
		vi	**Indicative Content:**	**6**	**Level 3 [5-6 marks]**

Question			Answer	Mark	Guidance
			• Problem of a power source. Batteries could be used, but a means of recharging or replacing them needs to be found. Rechargeable battery pack could be made removable. Possible inclusion of low battery warning. • Problem of recharging batteries. Possible use of renewable energy source, e.g. solar panels, which could work as the blind is next to a window. • Problem of communication with the device, e.g. to make blind raise or lower. Investigate wireless protocols such as WiFi, Bluetooth etc. • Wireless communication is prone to interference, and limited range. Two-way communication allows for information feedback or 'handshaking'. System could send alerts to central hub, e.g. low battery, blind jammed. • Problem of integrating the battery into the housing of the blind. Use of existing battery form factors may be necessary. A balance of battery energy capacity against size of enclosure will need to be struck by the designer. • Any other valid suggestion.	For MB3 to be awarded there will be both challenges and solutions listed. If candidate does not provide an analytical/evaluative response, then only L1 can be awarded.	The candidate has a clear understanding of challenges when designing wireless devices. They produce a thorough discussion in relation to the question by explaining a number of challenges that designers could face as well as identifying potential solutions that could be investigated further. The explanation is clear and well-developed and there is a clear appreciation of both challenge and solution in the iterative designing process. **Level 2 [3-4 marks]** The candidate has a reasonable understanding of challenges when designing wireless devices. They produce a sound discussion in relation to the question by explaining a number of challenges that designers could face as well as identifying potential solutions that could be investigated further. The explanation is sufficient although one or two opportunities are missed in drawing out solutions from the challenges presented. **Level 1 [1-2 marks]** The candidate has a basic knowledge of wireless devices. Any reference to a

Question			Answer	Mark	Guidance
					technical challenge when developing wireless devices is largely descriptive in nature. There is little appreciation of solutions and the response contains no analysis or evaluation. **0 marks** No response or no response worthy of credit.

2	**a**		Converting 4m to 4000 mm (1) Similar triangles methodology: 100 / 4000 = 5 / L (1) Finding L: L = (4000 x 5) / 100 = 200 mm (1)	**3**	Award three marks as follows: One mark for converting 4 m to mm. One mark for applying similar triangles methodology. One mark for re-arranging formula to find L. 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. This problem can also be solved using trigonometry.
	b	**i**	Subtracting 2x radii off the length: W = 180 – 30 – 30 (1) Calculating answer: W = 120 mm (1)	**2**	Award two marks as follows: One mark for understanding that you need to take 2 x radii of the length. One mark for calculating the Width W. 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.

		ii	The radius of the outer curved surface: 30 + (3 x 5) = 45 mm (1) The total arc length of the curved sections: Total arc length = πd/2 = 141.371669412 (1) The height of the vertical sides: Height = 90 – 45* = 45 mm (1) 4Total outside length PQ: (2 x 45*) + 120* + 141.371669412* = 351.4 mm (1) Accept rounded answer e.g. 350mm to 2sf, 351mm to 3sf.	**4**	Award four marks as follows: One mark for calculating the radius of the outer curved surface. One mark for calculating the total arc length of the curved sections. One mark for calculating the height of the vertical sides. One mark for calculating the outside length PQ. 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. Height of vertical sides can also be calculated (75 – 30) = 45mm from Fig. 2.2.
		iii	Possible responses may include: • The former needs to separate from the part after forming (1). • This requires the former to have tapered sides with a draft angle (1). • Any other valid suggestion.	**2**	Up to two marks for explaining why well-designed formers are not usually manufactured with vertical sides. One mark can be awarded for stating that the part cannot easily separate from the former if the sides are vertical.

					One mark can be awarded for stating that the former has tapered sides or draft angle. Specific reference to the context in the question is needed for marks to be awarded.
		iv	Possible materials may include: • Polystyrene modelling foam (1). • Any timber (e.g. pine) (1). • Plywood (1). • Plaster of Paris (1). • Any other valid suggestion. Functional performance: • The polystyrene foam has a small cell structure (1) which allows it to be sanded to the shape shown without crumbling (1). • The wide grain in the pine allows for it to be easily sanded to shape (1) whilst being resilient enough to resist splitting (1). • Any other valid suggestion. Environmental considerations: • Polystyrene foam is unlikely to be recycled after use (1) but the former could be used to manufacture several parts, so the negative environmental impact is reduced (1). • Pine can be sourced from sustainable forests (1) or the pine for the former could be reused from an obsolete or unwanted product (1). • Any other valid suggestion.	**5**	One mark for naming a material suitable for manufacturing the former. Up to two marks for explaining the selection of materials in terms of functional performance. Up to two marks for explaining the selection of materials in terms of environmental considerations. Specific reference to the context in the question is needed for marks to be awarded. A specific named material must be given, e.g. no credit for ‘wood’. An obscure material can be awarded one mark if justification is given in the explanation that follows. Justification for an obscure material may be given in the explanation which follows.

					The functional explanation must go beyond ‘it is strong’ or ‘it can be sanded’ for the award of marks. The environmental considerations may be positive or negative in nature. The strongest answers will realise that there is a negative environmental impact when using most materials.

3	a		Possible responses may include: • Incremental innovation can be used to gradually improve versions of an already successful product (1) which requires very little investment from a manufacturer as each change can be quite small (1). • The small changes can be released as part of a planned product lifetime strategy (1) which can help sustain sales of an already established product within the market (1). • As new technology emerges, its use can enhance the function of a product (1), which can increase its attraction to buyers (1). • Any other valid suggestion. Other responses may include: • Incremental innovation also applies to manufacturing systems, so manufacturing techniques can evolve to reduce costs and improve manufacturing speed. • Small changes may be demanded by customers, to fit fashions or to ensure product compatibility with other technology systems.	**4**	In each case: Up to two marks for explaining two ways in which an incremental strategy can be beneficial to a product manufacturer.
	b*		**Indicative Content:** **Registered designs** • Gives the designer ownership rights for the appearance of a product. • Protects distinctive product shape, pattern or decoration. • Protects distinctive visual features e.g. lines, contours, colours, materials. • The design must be new and original. • Must have a unique character, not resemble an existing design. • Must be registered with the Intellectual Property Office (IPO). • Must be renewed every 5 years. **Registered trademarks** • Used by a company or individual to identify their brand. • Used to distinguish their product from others' brands.	**8** For MB3 to be awarded a number of ways will be given. If candidate does not provide an analytical/evaluative response, then only	**Level 3 [6-8 marks]** The candidate has a clear understanding of IP legislation. They produce a thorough discussion in relation to the question by explaining some of the ways in which the IP of designers can be protected. The explanation is clear and well-developed and specific areas of legislation 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.*

			• Trademarks can be in the form of a word, name, song, or symbol. • Trademarks can be registered as a logo, slogan, domain name, shape or sound. • To register a trademark it must be unique and distinctive. • Trademarks must be fair and accurate. • Trademarks must be morally acceptable. • Must be registered with the Intellectual Property Office (IPO). • Must be renewed every 10 years. **Copyright** • A set of exclusive rights given to creators of original ideas, information or other intellectual works. • Copyright material can only be copied, used or recreated with the owner's permission. • Copyright protection is automatic and no registration is needed. • The work is often marked with the © symbol, used alongside the creator's name and the date. • Work is still protected even without the © symbol. • Copyright does not protect the ideas for a piece of work. • Copyright lasts for 70 years for most types of written work. • Photographs are copyrighted for 25 years. **Design rights** • Protect the creator of a design (unless a 3rd party commissions the work). • Design rights protect the configuration or shape of a product. • They can be used to prevent copying of an original design without permission. • Design rights do not protect the 2D aspects of the design, e.g. patterns. • Design rights can be bought, sold or licensed. • They stay in force for 10 years after first marketing of the product (or 15 years after creating the design). • For the first 5 years, others are prevented from copying the design. • For the remaining time the design is subject to a licence of right.	L1 can be awarded.	**Level 2 [3-5 marks]** The candidate has a reasonable understanding of IP legislation. They produce a sound discussion in relation to the question by explaining some of the ways in which the IP of designers can be protected. The explanation of ways is sufficient although one or two opportunities are missed in referring to different areas of legislation. *There is a line of reasoning presented with some structure. The information presented for the most part relevant and supported by some evidence.* **Level 1 [1-2 marks]** The candidate has a basic knowledge of IP legislation. Any reference to this issue is descriptive in nature and has little appreciation of the ways in which the IP of designers can be protected. 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.

			• Design rights only apply in the UK. **Patents** • Granted by the government, they offer strong protection. • Difficult to obtain, involving long, expensive, technical processes. • Inventors must publicise all details of the invention. • Patent lawyers are often employed to write a strong patent. • Protect against copying the technical and functional aspects of a design. • Can cover how a device works and what materials are used. • Protect designs and inventions for 20 years. • The invention must be new. • It must have an inventive step that is not obvious to someone with technical knowledge. • The invention must be capable of being made. Any other valid suggestion.		

4	**a**	**i**	Reading on-time (or off-time) from graph: On time = 0.1 ms Off time = 0.3 ms (1) Adding on + off times to determine the period: 0.1 + 0.3 = 0.4 ms (1)	**2**	Award two marks as follows: One mark for reading on-time (or off-time) from graph. One mark for adding on and off times to determine the period. Award 1 mark for the answer 0.1ms or 0.3ms. 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.
		ii	Recall of formula: Frequency = 1/period (1) Calculating frequency in kHz: Frequency = 1 / 0.4* = 2.5 kHz (1)	**2**	Award two marks as follows: One mark for recalling formula. One mark calculating frequency in kHz. *Allow error carried forward (ECF) where correct working out is shown.
	b	**i**	R = 1.25 x $\frac{0.003}{0.005 \times 50 \times 10^{-6}}$ (1) (1) = 15000 Ω (1) Conversion to kΩ: R = 15 kΩ (1)	**4**	Award four marks as follows: One mark for two conversions of mm measurements to m and inserting in formula.

					One mark for conversion of of µm measurement to m and inserting in formula. One mark for calculating the resistance result in Ω. One mark for conversion to kΩ. 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.
		ii	Calculating voltage (pd) across probes: V = 3 – 2 = 1V (1) Ratio of voltages to the ratio of the resistances: V_{probes} / V_R = 1 / 2 1 / 2 = $R_{probes*}$ / R (1) Calculating R: R = (2 x $R_{probes*}$) / 1 = 30 kΩ (1)	**3**	Award three marks as follows: One mark for calculating voltage (pd) across probes. One mark for equating the ratio of voltages to the ratio of the resistances. One mark for calculating the minimum value of Resistor R. Other valid methods may be used, including the use of the potential divider formula V_{out} = V_{in} x R2/(R1+R2) or V=IR 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. Correct answer with no working gains full marks. *Allow error carried forward (ECF) where correct working out is shown.
		iii	0 V (1)	**1**	Award mark as indicated.
	c		**Problem 1:** After executing the 'A.0>2V?' command the program becomes stuck in a loop if the result is 'No' (1). **Solution 1:** The 'No' output from 'A.0>2V?' should loop back to 'Read ADC A.0' (1). **Problem 2:** After switching on the LED (High B.0), there is no later command to turn it off again (1). **Solution 2:** Insert a 'Low B.0' command in the 'Yes' loop after Y=1600? (1). **Problem 3:** The loop containing the Y counter does not last for 1.5s, so the sound will not last for 1.5s (1). **Solution 3:** The loop duration is 0.4ms, so the loop must be executed 1.5/0.0004 = 3750 times, so change the decision command to 'Y=3750?' (1).	**6**	When evaluating the flowchart against the functional specification candidate should be able to identify three problems and suggest solutions in each case. The solutions must be specific and detailed to gain the marks. They be presented as per the mark scheme or more likely in narrative prose. Candidates may draw their answers from **Fig. 4.4.** Specific reference to the context in the question is needed for marks to be awarded.
	d	**i**	Possible materials may include: • Thermochromic pigment (1). • Photochromic pigment (1). • Electroluminescent material (1).	**1**	The answer requires a smart material NOT a modern material. A smart material has a property which reacts in response to a stimulus.

			• Piezoelectric material (1). • Shape memory alloy (1). • Shape memory polymer (1). • Motion control grease (1). • Electro translucent glass (privacy glass) (1). • Electrochromic material (1). • Any other valid suggestion. Other possible responses may include: Nitinol		As there is a blurred boundary for some materials, it may be necessary to look at the candidate's response to part 4)d)ii) to see if they have correctly identified the property and the stimulus. Do NOT allow 'conductive ink' or 'smart ink'. Specific reference to the context in the question is needed for marks to be awarded.
	d	**ii**	Possible responses may include: • Thermochromic pigment is used in battery testers (1). Thermochromic pigment is coloured at low temperature but loses its colour above a transition temperature (1). In the battery tester, a thin conductive strip heats up when current is passed through it and this heats the thermochromic material (1). The conductive strip is tapered, so for low currents it only heats the thermochromic piment at one end, revealing Red ink behind, whilst at higher currents it heats the entire length of strip (1), revealing red, yellow and green ink. • Thermochromic pigment is used in baby feeding products, such as bowls, cups and spoons (1). These products are made of polymers mixed with thermochromic pigments that change colour with heat (1), allowing the user to check the temperature (1), without contaminating the food by touching it (1). • Electrochromic windows are used in airliners (1). Suspended particle device (SPD) glass films provide active shading (1). The films are applied between the double glazing (1). When off (no voltage) the particles are scattered creating opacity, as voltage is increased by the user pressing a button, the particles align and light can pass through the window (1). • Electrochromic glass, known as privacy glass is used in shower and bathrooms (1). They switch from transparent to opaque when a voltage is	**4**	Up to four marks for describing how the properties of the smart materials identified in **part (d)(i)** (in relation to a specific product) provide functionality. Award one mark for identification of a specific product. A specific product must be identified or described for full marks. The functional description must be sufficiently detailed and accurate to award full marks. Award a maximum of two marks if the description does not correspond to the material identified in part d)i).

			applied to them (1). When the voltage is applied, the liquid crystals inside the glass align and allow light to pass through (1). When the voltage is nor present the liquid crystal molecules are positioned randomly and block out any light, becoming opaque (private) (1). • Any other valid suggestion.		Specific reference to the context in the question is needed for marks to be awarded.

OCR (Oxford Cambridge and RSA Examinations)
The Triangle Building
Shaftesbury Road
Cambridge
CB2 8EA

OCR Customer Contact Centre

Education and Learning
Telephone: 01223 553998
Facsimile: 01223 552627
Email: general.qualifications@ocr.org.uk

www.ocr.org.uk