FOR OFFICIAL USE

National
Qualifications
SPECIMEN ONLY

Mark

S823/76/01 Engineering Science

Date — Not applicable

Duration — 2 hours 30 minutes

S8237601

Fill in these boxes and read what is printed below.

Full name of centre

Town

Forename(s)

Surname

Number of seat

Date of birth
Day Month Year

Scottish candidate number

Total marks — 110

SECTION 1 — 20 marks
Attempt ALL questions.

SECTION 2 — 90 marks
Attempt ALL questions.

Show all working and units where appropriate.

You should refer to the Higher Engineering Science Data Booklet which you have been given.

The number of significant figures expressed in a final answer should be equivalent to the least significant data value given in the question. Answers that have two more figures or one less figure than this will be accepted.

Write your answers clearly in the spaces provided in this booklet. Additional space for answers is provided at the end of this booklet. If you use this space you must clearly identify the question number you are attempting.

Use **blue** or **black** ink.

Before leaving the examination room you must give this booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

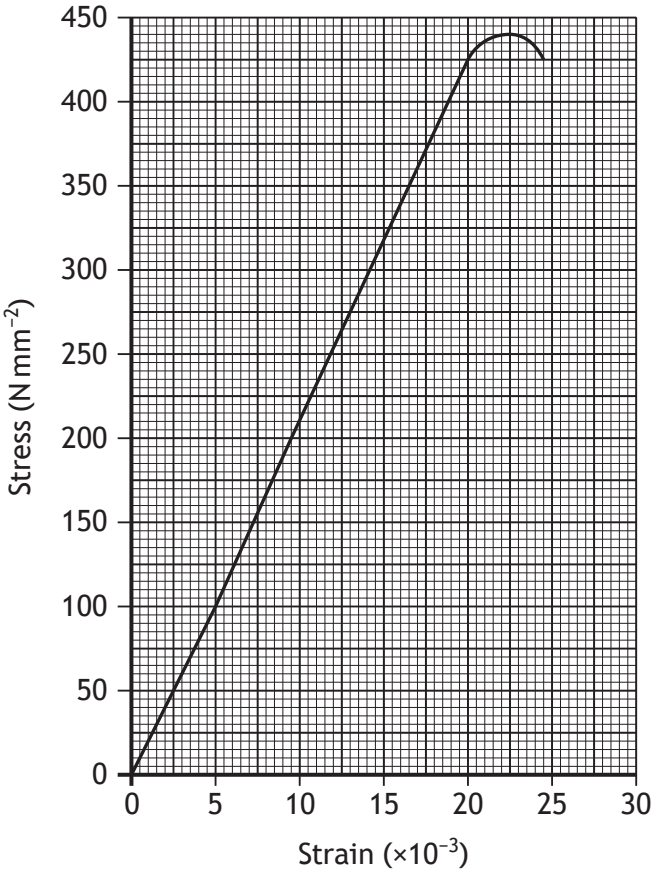
SQA ©

S8237601

SECTION 1 — 20 marks

Attempt ALL questions

1. A specimen was tested in a materials laboratory. The results are shown in the graph below.

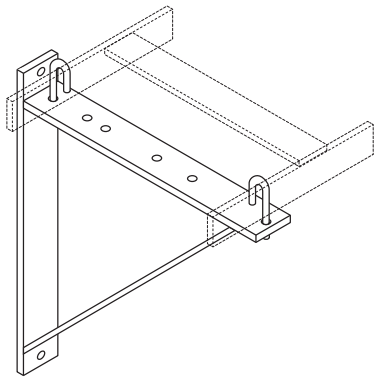


(a) Describe the effect on the specimen of applying and then removing a stress of 125 N mm^{-2}. **1**

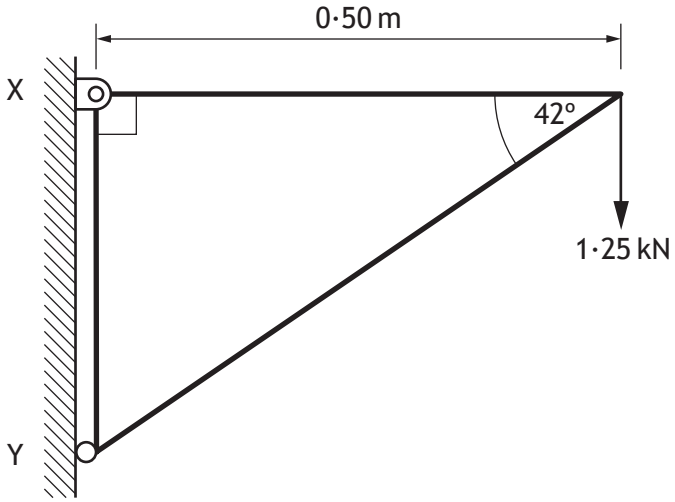
(b) Describe the effect on the specimen when applying a stress greater than 435 N mm^{-2}. **1**

(c) Annotate, on the graph above, the **yield point** and the **ultimate stress** of the material. **2**

2. A structural engineer has been asked to reduce the cost of manufacturing the cable support bracket shown below.

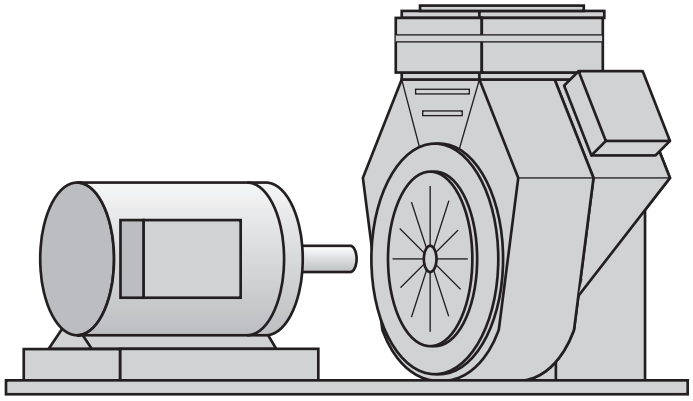


To examine the loading and fixing of the bracket, the engineer drew the loading diagram below:



Calculate the magnitude and direction of the reaction at Y. **3**

3. An electric motor drive shaft is to be connected to an air compressor using a clutch.



Describe one advantage and one disadvantage of using this coupling method.

(a) Advantage _____ **2**

_____

_____

_____

(b) Disadvantage _____ **2**

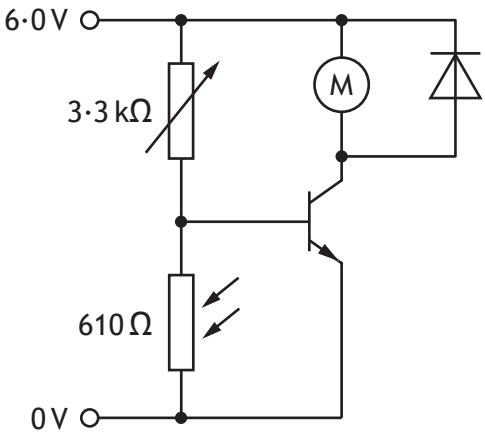
_____

_____

_____

4. A water feature in a children's play area is designed to pump jets of water when a child blocks the light to a darkness sensor.

A circuit diagram of the system is shown below.



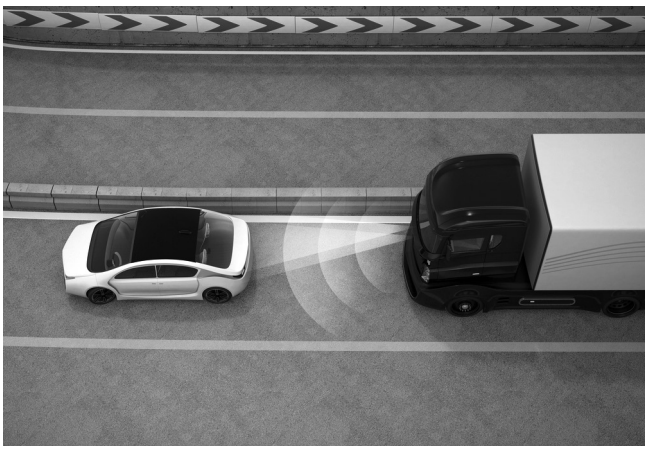
(a) Calculate the current flowing through the LDR. (V_{be} = 0·70 V) **1**

4. (continued)

(b) Calculate the current flowing through the variable resistor. **1**

(c) Calculate the base current flowing into the transistor. **1**

5. Driverless vehicles are an example of an emerging technology that may have an impact on our day-to-day lives.



(a) Describe two **economic** impacts of driverless vehicles. **2**

1 _____

_____

2 _____

_____

5. (continued)

(b) Describe two **social** impacts of driverless vehicles. **2**

1 _____

_____

2 _____

_____

6. An electronic engineer is designing the control system for a food mixer. Transistors are required to drive the mixer's outputs.

(a) Describe the difference in the way that MOSFETs and bi-polar junction transistors (BJT) control their output current. **1**

_____

_____

_____

(b) The engineer chooses a MOSFET to drive the electric motor.

Explain why a MOSFET was chosen instead of a BJT. **1**

_____

_____

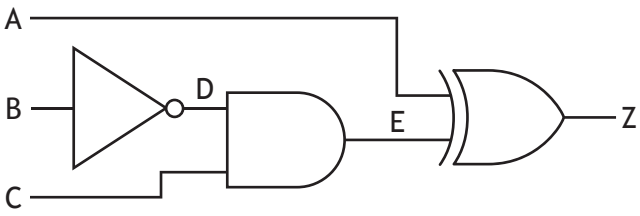
[END OF SECTION 1]

SECTION 2 — 90 marks

Attempt ALL questions

7. A control room in a chemical plant monitors many different systems.

(a) Part of a logic diagram for a control system is shown below.



(i) Complete the Boolean equation for this logic diagram. **3**

Z = _____

7. (a) (continued)

(ii) Complete the truth table for this logic diagram. **3**

A	B	C	D	E	Z
0	0	0			
0	0	1			
0	1	0			
0	1	1			
1	0	0			
1	0	1			
1	1	0			
1	1	1			

(iii) Draw the NAND equivalent for the logic diagram, shown on *page 08*. **3**

[Turn over

7. (continued)

(b) An electronic engineer is asked to design the control system for an **automatic** sprinkler for the chemical plant.

Describe one skill and one piece of knowledge the electronic engineer would use to complete this task. **2**

Skill _____

_____

Knowledge _____

_____

(c) An extension to the chemical plant building is proposed.

(i) Describe a role that an environmental engineer would take in the design of the extension. **2**

_____

_____

_____

_____

(ii) Describe a positive and a negative economic impact for the **plant** by it becoming more environmentally friendly. **2**

Positive impact

_____

_____

_____

Negative impact

_____

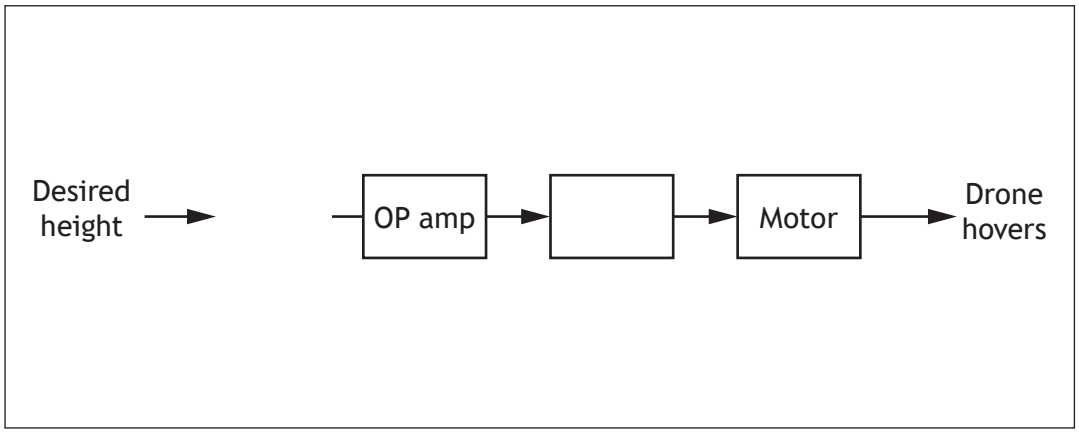
_____

_____

8. A prototype of a delivery drone is being tested.

A proportional control system changes the speed of the rotor blades to reach the user's desired height for the drone. An altimeter is used to monitor the current height of the drone.

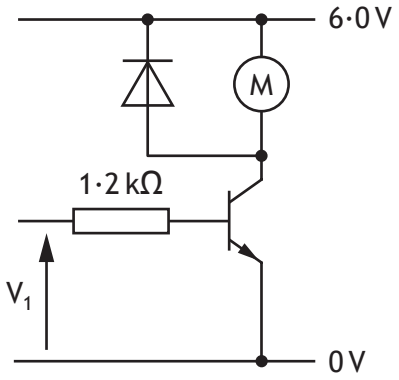
(a) Complete the control diagram for the drone. **3**



[Turn over

8. (continued)

(b) Part of an electronic engineer's design for the control system for one of the drone's motors is shown below.

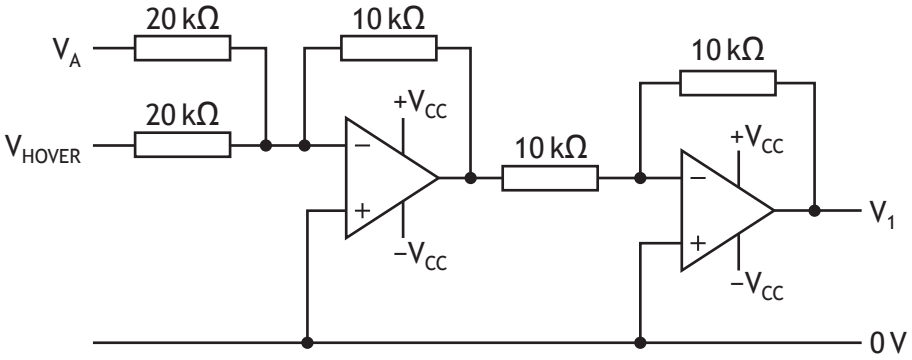


During testing it was found that the motor requires a current of 97 mA for the drone to hover. The transistor has a current gain of 210.

Calculate the value of V_1 required to make the drone hover. **3**

8. (continued)

(c) The diagram below shows another part of the control system. It combines a signal for any required changes to the motor speed (V_A) with the signal required to keep the drone hovering (V_{HOVER}).

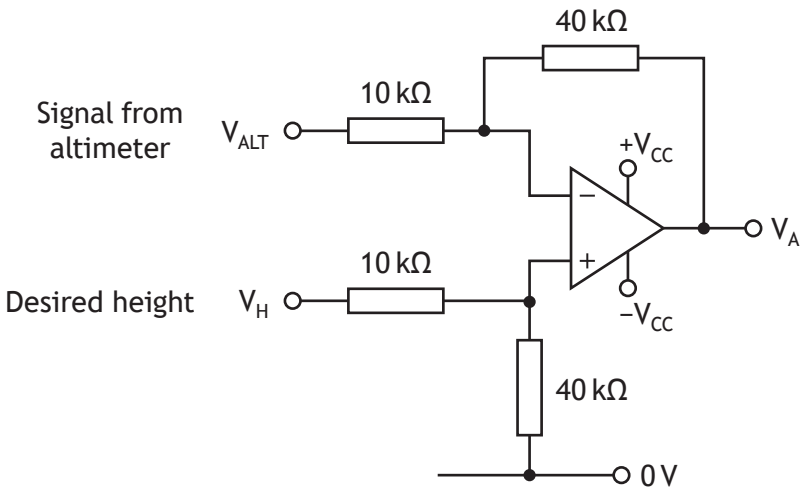


Calculate, using your answer for V_1 the value of V_{HOVER}. (Assume that V_A is 0 V at this point). **2**

[Turn over

8. (continued)

(d) The value of V_A is set using the circuit below. It compares the drone's current height with the operator's desired height.

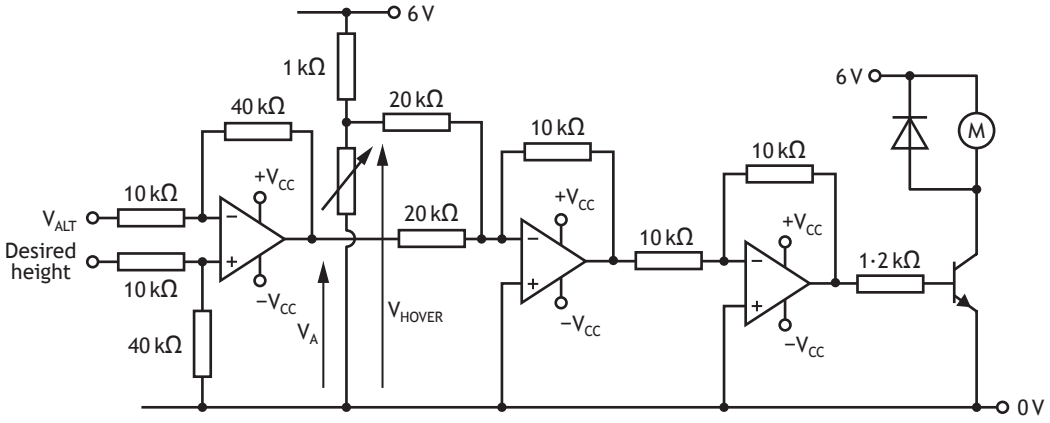


During testing V_H was changed to 3·0 V and V_A was found to be 1·6 V.

Calculate the value of V_{ALT} for this condition. **2**

8. (continued)

(e) The complete circuit diagram is shown below. V_{HOVER} is the voltage required to make the drone hover.

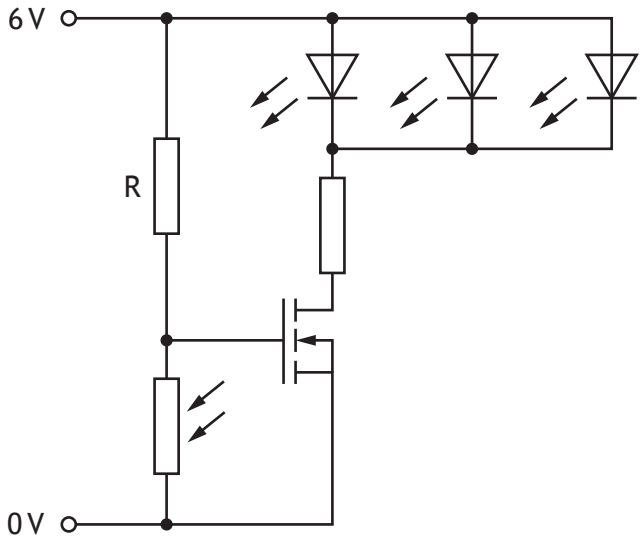


Describe, with reference to the circuit diagram above, what happens when the operator increases the desired height. **3**

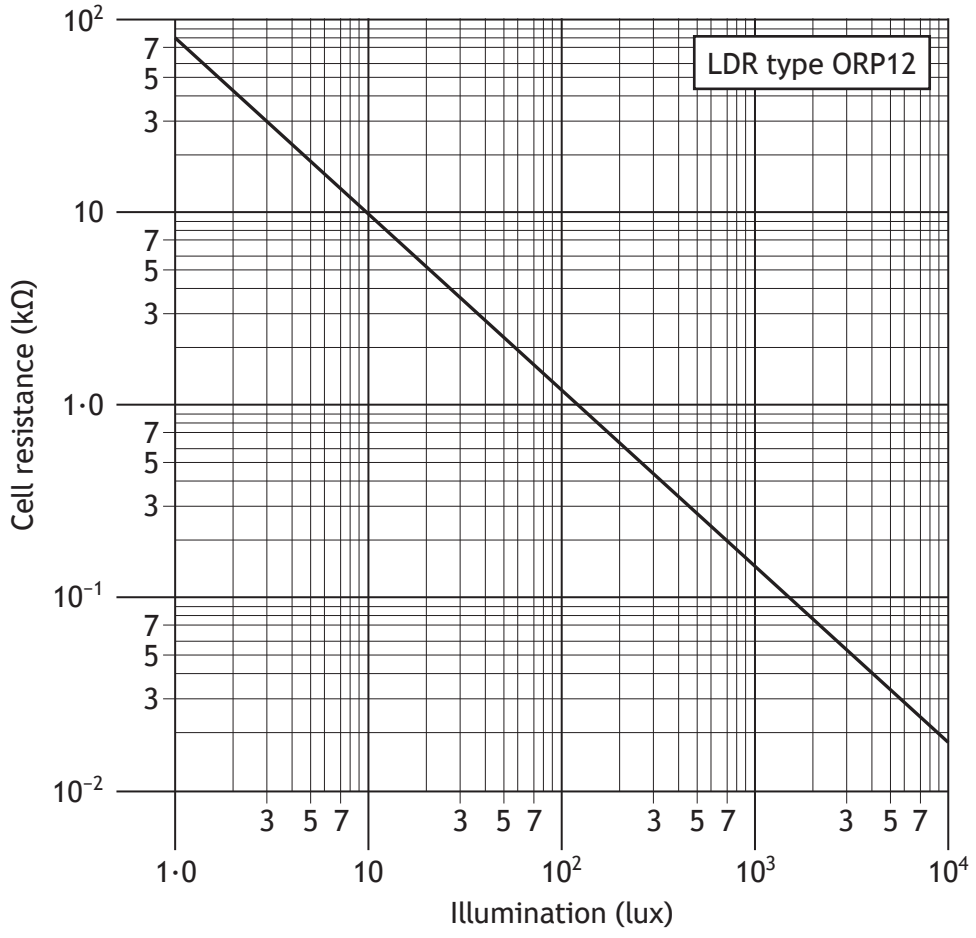
DO NOT WRITE IN THIS MARGIN

8. (continued)

(f) The diagram below shows a further sub-system which will light a series of LEDs when light levels are low



The characteristics of the LDR are shown in the graph below.



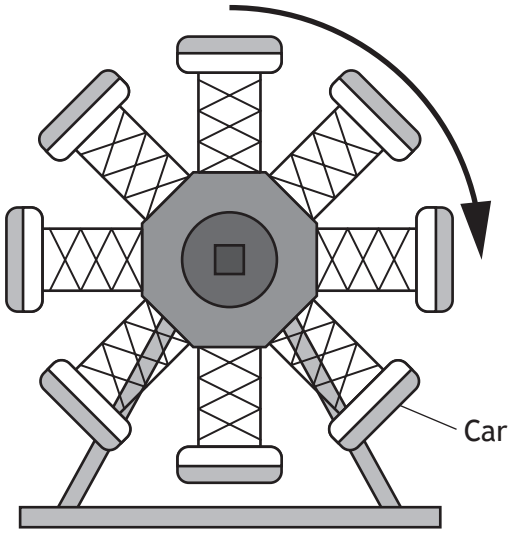
8. (f) (continued)

The LEDs must switch on when the light level drops to 200 lux. The MOSFET switches on when Vgs = 3·6 V

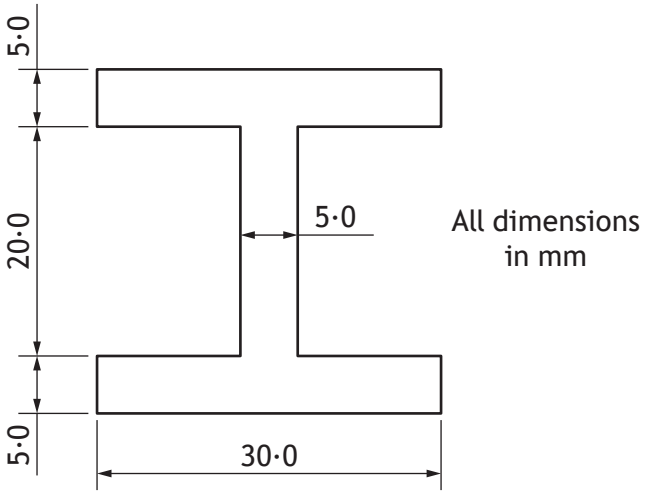
Calculate, with reference to the graph on *page 16*, the required value of R. **2**

[Turn over

9. A team of engineers are working together to design a new theme park ride.



(a) Each of the ride cars is supported by mild steel beams as shown. When the ride is operating the force on a beam was found to be 900·0 N.



(i) Calculate the working stress of the beam. **2**

9. (a) (continued)

(ii) Calculate the strain of the beam. **2**

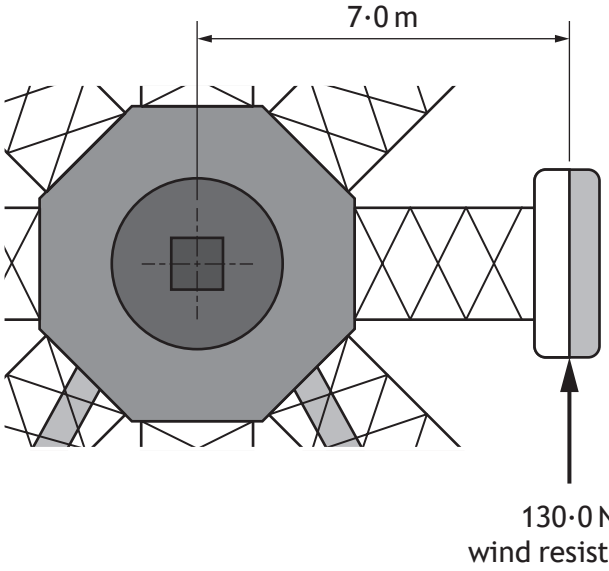
(iii) Calculate the factor of safety of the beam. **2**

(iv) Comment on the appropriateness of the factor of safety of the beam. **1**

[Turn over

9. (continued)

(b) The ride has eight cars. Each car is subjected to wind resistance of 130 N as shown in the diagram below.



(i) Calculate the torque produced by the drive shaft to overcome the total wind resistance. **2**

9. (b) (continued)

(ii) Each car on the ride completes 18 revolutions in 3 minutes.

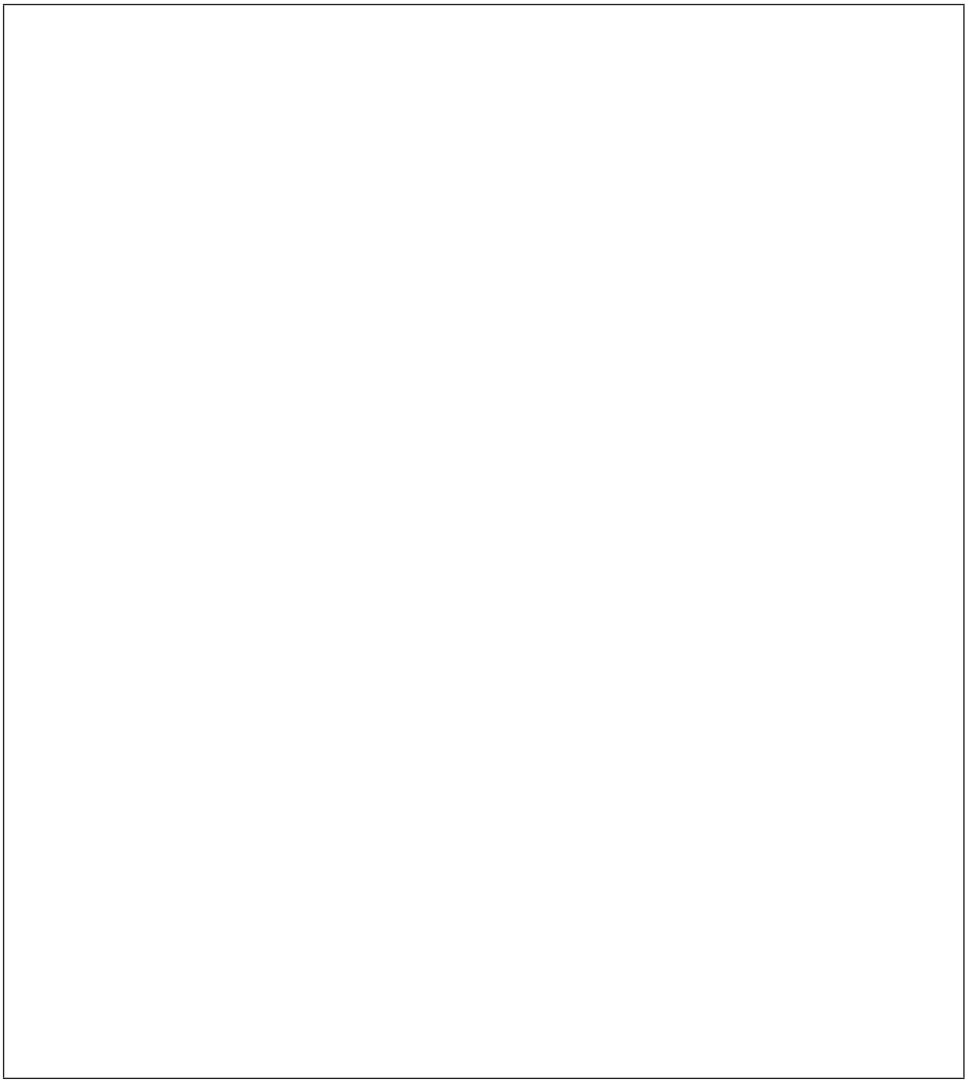
Calculate the mechanical power required by the motor. **2**

(iii) Calculate the efficiency of the motor, if it is supplied with a voltage of 240 V and draws a current of 30·0 A. **2**

9. (continued)

(c) A microcontroller is used to control the speed of the motor.

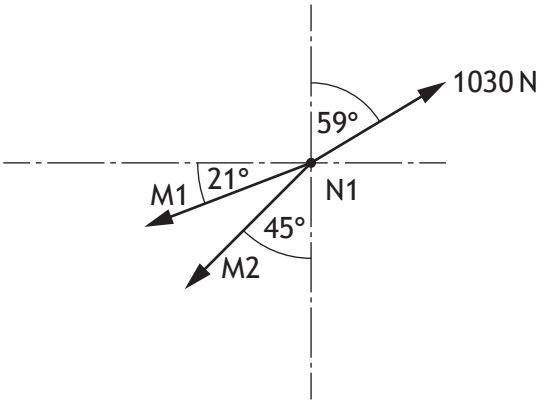
Sketch a graph to show how pulse width modulation could be used to gradually increase the speed of a motor from rest. Your graph should include at least 6 pulses. **2**



9. (continued)

MARKS DO NOT WRITE IN THIS MARGIN

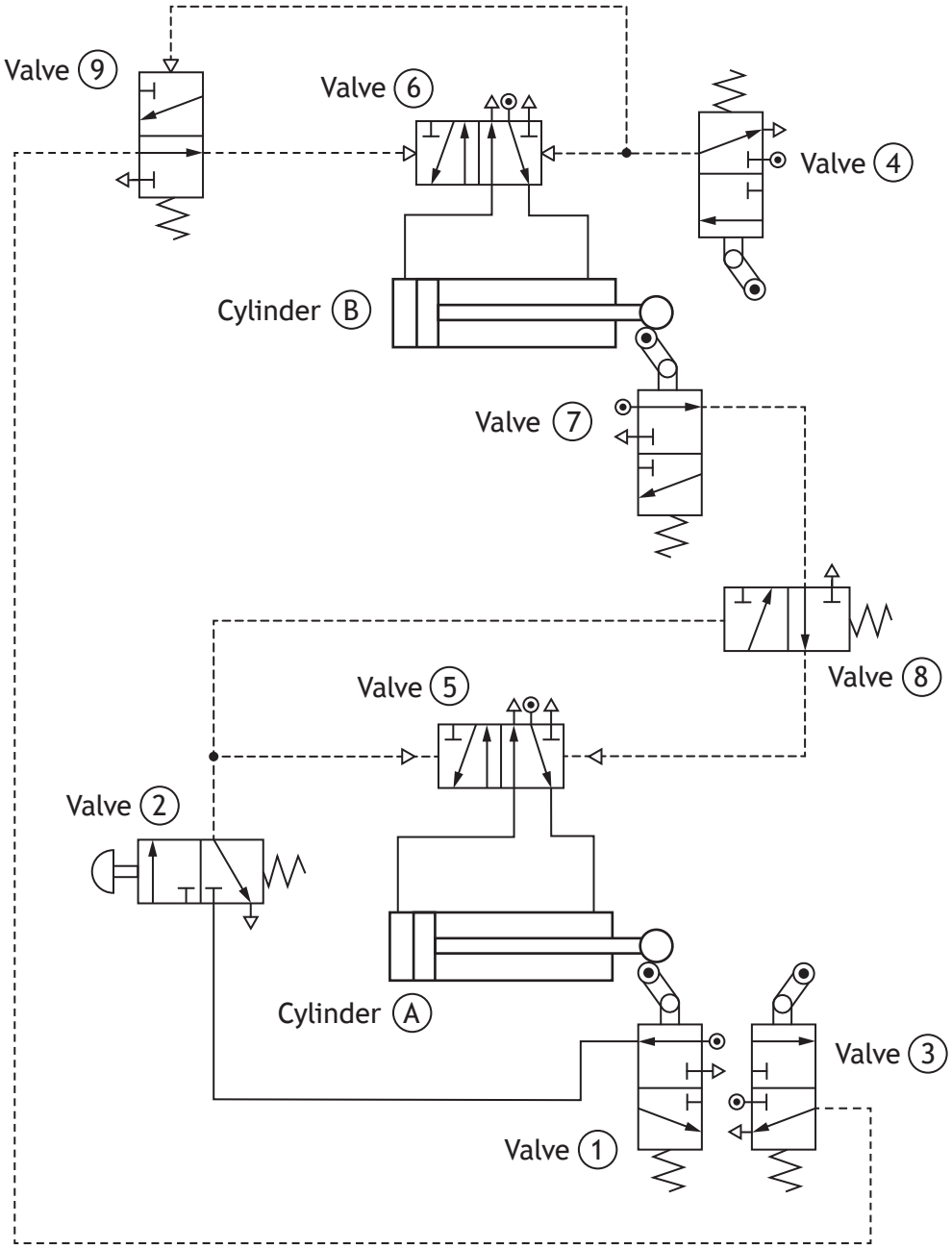
(d) As the ride spins, a force of 1030 N acts on a point of the structure as shown in the diagram below.



Calculate, using simultaneous equations, the magnitude of the forces in members M1 and M2. **5**

DO NOT WRITE IN THIS MARGIN

10. A car manufacturer uses a pneumatic system during the production of car doors.



10. (continued)

(a) (i) Describe, using appropriate terminology, the operation of the pneumatic circuit, shown on *page 24*. **6**

When the system is at rest and valve 2 is actuated…

After installation, the system is altered to meet the following criteria:

1. the system should be started using an electronic signal;
2. the instroking sequence should be delayed.

(ii) Name the components needed and explain where they should be placed in the circuit for the changes to take place. **6**

1. Component(s) _____

   Explanation _____

2. Component(s) _____

   Explanation _____

[Turn over

DO NOT WRITE IN THIS MARGIN

10. (continued)

After the doors have been assembled, an automated system is used to ensure quality checks are made.

Part of the system operates on the following sequence:

- A motor must switch on to move doors along a conveyor;
- A light sensor detects when the door has reached the inspection point;
- A pneumatic piston outstrokes for 1 second and diverts every fourth door for inspection;
- If an operator presses the sampling switch when a door is in position it will also be diverted using the piston;
- When a door is diverted a checking light flashes on and off 6 times over 3 seconds;
- This system continually repeats.

The relevant microcontroller connections are shown in the table below.

Inputs	Pins	Outputs
	7	Pneumatic piston
	6	Conveyor motor
	5	Checking light
	4	
	3	
	2	
Sampling switch	1	
Light sensor	0	

Light sensor (High signal indicates a door.)

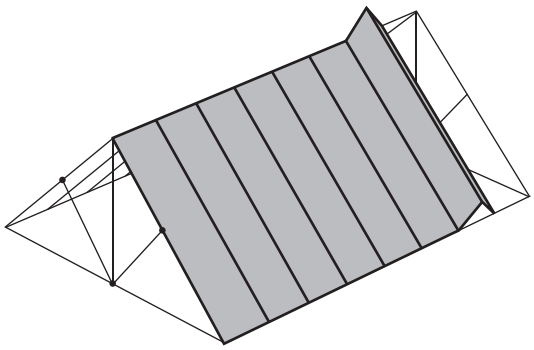
10. (continued)

(b) Draw a flowchart to show the control of the quality checks. **8**

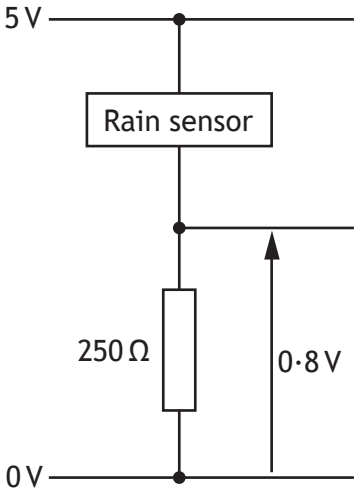
DO NOT WRITE IN THIS MARGIN

11. A sports centre is building a retractable roof over a synthetic pitch.

The diagram below shows a sketch for the proposed retractable roof.



The roof will open and close depending on the amount of rain that is falling. Part of the input sensing circuit is shown below.



11. (continued)

(a) An operational amplifier based circuit is used to change voltages to the required values ('Signal conditioning'). The output from the voltage divider has to be increased from +0·8 V to +4 V.

(i) State the name of a suitable op-amp circuit. **1**

(ii) Calculate the required gain. **1**

(iii) Sketch a suitable op-amp circuit diagram showing appropriate resistor values. **2**

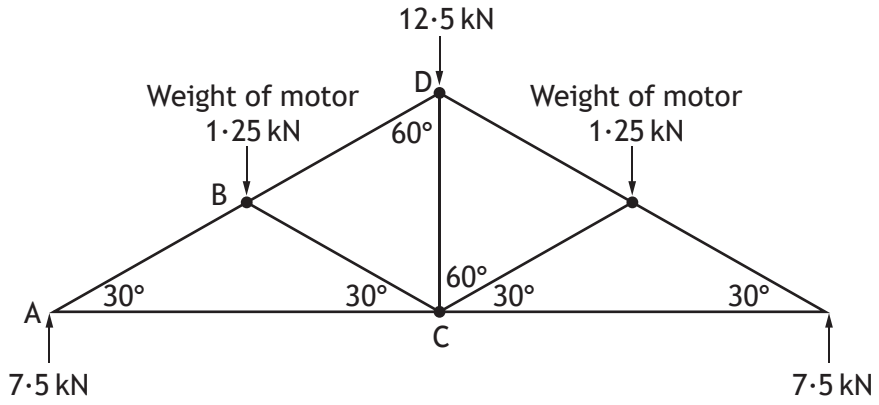
11. (continued)

A second op-amp circuit is required to condition the signal from +4 V to +2 V.

(b) Sketch a circuit diagram below, showing appropriate resistor values. **3**

11. (continued)

(c) The free body diagram for a pin-jointed frame is shown below for the end support of the roof.



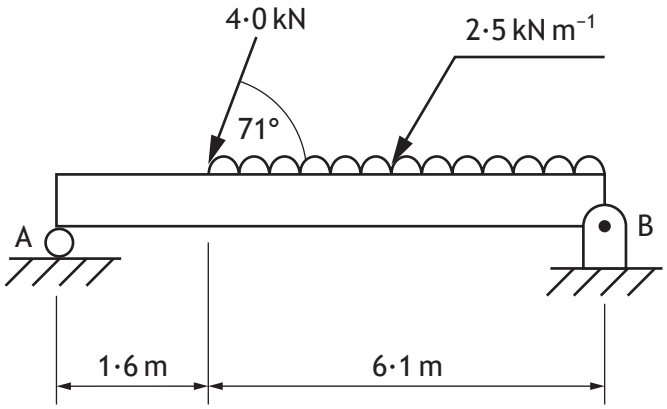
Member BC is a 1·1 kN strut.

Calculate, using **nodal analysis**, the magnitude and nature of the force in beams AB, AC, BD. **8**

Show all working and final units.

11. (continued)

(d) A beam, forming another part of the roof structure, is being tested.



Calculate the magnitude of the reaction at B. **5**

[END OF SPECIMEN QUESTION PAPER]

MARKS | DO NOT WRITE IN THIS MARGIN

ADDITIONAL SPACE FOR ANSWERS

MARKS DO NOT WRITE IN THIS MARGIN

ADDITIONAL SPACE FOR ANSWERS

Acknowledgement of Copyright

Section 1 Question 4 CaseyMartin/shutterstock.com
Section 1 Question 5 Chesky/shutterstock.com
Section 1 Question 6 Stephen VanHorn/shutterstock.com
Section 2 Question 7 Ton Snoei/shutterstock.com
Section 2 Question 8 gualtiero boffi/shutterstock.com
Section 2 Question 11 CHAIWATPHOTOS/shutterstock.com

National
Qualifications
SPECIMEN ONLY

S823/76/01 Engineering Science

Marking Instructions

These marking instructions have been provided to show how SQA would mark this specimen question paper.

SQA
©

General marking principles for Higher Engineering Science

Always apply these general principles. Use them in conjunction with the detailed marking instructions, which identify the key features required in candidates' responses.

(a) Always use positive marking. This means candidates accumulate marks for the demonstration of relevant skills, knowledge and understanding; marks are not deducted for errors or omissions.

(b) If a candidate response does not seem to be covered by either the principles or detailed marking instructions, and you are uncertain how to assess it, you must seek guidance from your team leader.

(c) Where a candidate makes an error at an early stage in a multi-stage calculation, award marks for correct follow-on working in subsequent stages. Do not award marks if the error significantly reduces the complexity of the remaining stages. Apply the same principle in questions which require several stages of non-mathematical reasoning.

(d) SQA presents all units of measurement in a consistent way, using negative indices where required (for example ms^{-1}). Candidates can respond using this format, or solidus format (m/s), or words (metres per second), or any combination of these (for example metres/second).

(e) For numerical questions, candidates should round their answers to an appropriate number of significant figures. However, award marks if their answer has up to two figures more or one figure less than the expected answer.

(f) Unless a numerical question specifically requires candidates to show evidence of their working, award full marks for a correct final answer (including unit) on its own.

(g) Award marks where a labelled diagram or sketch conveys clearly and correctly the response required by the question.

(h) Award marks regardless of spelling if the meaning is unambiguous.

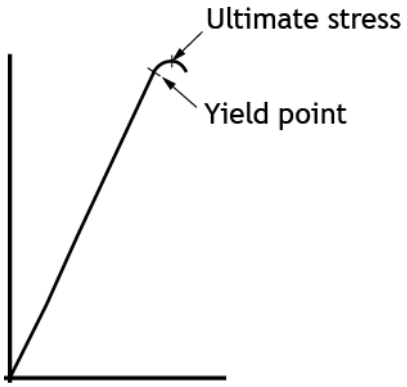
(i) Candidates can answer programming questions in any appropriate programming language. Award marks where the intention of the coding is clear, even where there are minor syntax errors.

(j) For 'Explain' questions, only award marks where the candidate goes beyond a description, for example by giving a reason, or relating cause to effect, or providing a relationship between two aspects.

(k) Where separate space is provided for rough working and a final answer, only award marks for the final answer. Ignore all rough working.

Marking instructions for each question

Section 1

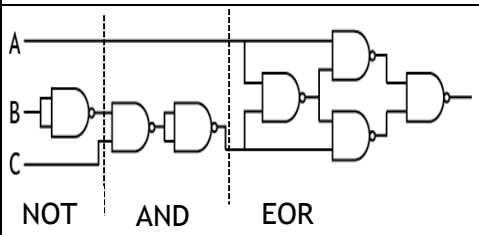
Question			Expected response	Max mark	Additional guidance
1.	(a)		The material behaves in an elastic manner – it stretches and then returns to its original length after the load is removed.	**1**	
	(b)		The material behaves in a plastic manner, it becomes permanently deformed – it stretches beyond the plastic limit until it fails/breaks.	**1**	Mark awarded for mentioning that the material will not return to its original shape.
	(c)			**2**	1 mark for each correct annotation Yield point – This should be anywhere between the top of the straight line and the ultimate stress point, if it is out with these two points, no marks.
2.			XY = 0·5 tan (42°) = 0·45 m ΣM = 0 so 0·5 × 1250 = 0·45 × R_Y so R_Y = 1388·88 N = 1·4 kN (2sf), in direction →	**3**	1 mark for calculating length 1 mark for magnitude (1·4 kN), 1 mark for direction (to the right)
3.	(a)		Advantage − allows user to connect/disconnect drive to change gears, make adjustments, control speed, etc	**2**	Connect/disconnect without explanation **(1)** We are looking for an explanation of the advantage not just a one or two word statement.
	(b)		Disadvantage − may be complex and have more parts to go wrong or require regular maintenance as it will wear, or more expensive due to more parts and replacements. Can slip, use up energy as it slips	**2**	We are looking for an explanation of the disadvantage not just a one or two word statement.

Question			Expected response	Max mark	Additional guidance
4.	(a)		I_{LDR} = 0·7/610 = 0·0011475 A = 1·2 mA (2sf)	**1**	1 mark for correct answer with unit
	(b)		I_{VR} = 5·3/3300 = 0·00161 A = 1·6 mA (2sf)	**1**	1 mark for correct answer with unit
	(c)		I_b = 1·6 − 1·2 = 0·40 mA = 0·40 mA (2sf)	**1**	1 mark for correct answer with unit FTE

Question			Expected response	Max mark	Additional guidance
5.	(a)		Taxi drivers may lose their jobs as the cars will be able to do their jobs without them. Long distance transportation would be cheaper as there would be no drivers needing breaks. Since you need to brake and accelerate less, you will use significantly less fuel, saving you money.	**2**	Any other suitable response.
	(b)		Accidents are less likely as human errors are reduced resulting in people feeling safer/less anxious on the road. Disabled people will have greater autonomy. People will not be at risk of drunk driving as the car will take them home. Car journeys will become more sociable as the "driver" can fully interact with the passengers. People without a driving licence can now get around in their own car making them more independent to go out of the house to leisure activities etc.	**2**	Any other suitable response. There must be a social impact; saying less car accidents or unemployment is not enough.

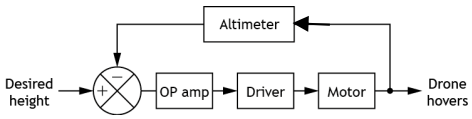
Question			Expected response	Max mark	Additional guidance
6.	(a)		MOSFETs – size of gate voltage BJTs – size of base current MOSFET is voltage controlled device with its operation controlled by gate-source voltage (V_{GS}). BJT is a current controlled device with its operation controlled by base current.	**1**	1 mark for identifying BOTH factors
	(b)		MOSFETs can handle larger currents therefore drive larger output devices. MOSFETs have lower power/energy consumption and therefore more efficient than BJTs. BJTs are preferred for low current applications, while MOSFETs are for high power functions.	**1**	Cause and effect for 1 mark

Section 2

Question			Expected response	Max mark	Additional guidance
7.	(a)	(i)	$Z = A \oplus (\overline{B}.C)$ Or $Z = \overline{A}.\overline{B}.C + A.\overline{\overline{B}.C}$ Or $Z = \overline{A}.\overline{B}.C + A.\overline{B}.\overline{C} + A.B.\overline{C} + A.B.C$	**3**	1 mark for exclusive OR 1 mark for NOT B 1 mark for B AND C Brackets are optional. 1 mark for each correct ABC 1 mark for OR 1 mark – 2 correct 2 marks – 4 correct 1 mark - OR
		(ii)	<table><tr><td>A</td><td>B</td><td>C</td><td>D</td><td>E</td><td>Z</td></tr><tr><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td></tr><tr><td>0</td><td>0</td><td>1</td><td>1</td><td>1</td><td>1</td></tr><tr><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td></tr><tr><td>1</td><td>0</td><td>0</td><td>1</td><td>0</td><td>1</td></tr><tr><td>1</td><td>0</td><td>1</td><td>1</td><td>1</td><td>0</td></tr><tr><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>1</td></tr><tr><td>1</td><td>1</td><td>1</td><td>0</td><td>0</td><td>1</td></tr></table>	**3**	1 mark for each correct column (D, E, Z) FTE should apply.
		(iii)		**3**	1 Mark for NOT 1 Mark for AND 1 Mark for EOR

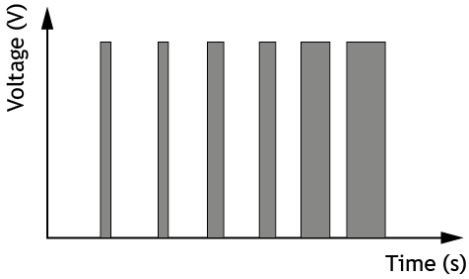
Question			Expected response	Max mark	Additional guidance
7.	(b)		A descriptive answer based on topics such as: Specialist skills: • designing electronic sub-systems eg Sensing circuits • plan programs • design interfaces • test programme function • design switching circuits • write code Specialist knowledge: • understand how microcontrollers function • op-amp electronic control systems • understand interfacing • function of a relay • programming knowledge • energy audits	**2**	Answer should not be a simple statement.

Question			Expected response	Max mark	Additional guidance
7.	(c)	(i)	Choosing of manufacturing methods that are eco-friendly to reduce the environmental impact. Choosing of materials that are eco-friendly, ie sustainable. The waste management for the construction. Introduction of low carbon technologies to reduce carbon footprint. Adapting the design to limit the impact on the environment for example soil/water/wildlife/ plants.	**2**	Must be related to the chemical plant being environmentally friendly. 1 mark for brief response 2 mark for detailed response
		(ii)	Positive Impact • reduced tax • less waste disposal costs • more sustainable • energy costs lowered • benefit from government incentives • increased sales as products are more environmentally friendly Negative Impact • initial capital costs to meet legislation • more energy efficient building methods • sustainable materials • energy efficient materials	**2**	All answers must be descriptive and not statements. Must have an economic aspect. Must be related to the chemical plant being environmentally friendly. Simply writing initial cost, as a negative impact, is not enough. The response must give indication of what areas the initial cost will cover for example insulation, water reclamation systems, heat recycling.

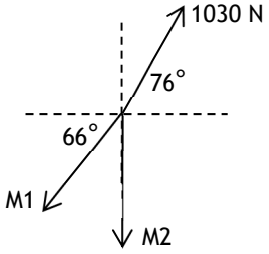
Question			Expected response	Max mark	Additional guidance
8.	(a)			**3**	1 mark for error detector symbol (must show negative error) 1 mark for driver/transistor/MOSFET 1 mark for feedback sensor with correct arrows
	(b)		I_b = 97/210 = 0·46 mA V_r = 0·46 mA × 1200 = 0·552 V V_1 = 0·552 + 0·7 = 1·252 V = 1·3 V (2sf)	**3**	1 mark for correct value of I_b 1 mark for calculating V_r 1 mark for V_1 with unit
	(c)		Input to final inverting amp is -1·3 V -1·3 V = -10 k (V_{hover}/20 k) V_{hover} = 2·6 V	**2**	 1 mark for correct substitution (-1·3 V taken from b) -1·3 V = -(20 k/10 k) × V_{hover} 1 mark for answer with unit
	(d)		1·6 = (40 k/10 k) × (3-V_{alt}) V_{alt} = 2·6 V	**2**	1 mark for substitution 1 mark for correct answer with unit

Question			Expected response	Max mark	Additional guidance
8.	(e)		As desired height is increased the output of the difference amplifier will increase positively. This produces a larger input to the transistor which generates a larger current in the motor. As the motor speeds up the drone will climb closer to the desired height. As it does the altimeter signal will increase, getting closer to the desired voltage. As it gets closer the output of the difference amp reduces and the motor speed reduces.	**3**	Any three statements that clearly reference the circuit **or** describe the action of the motor/drone.
	(f)		Rldr = 600 Ω R/600 = 2·4/3·6 R = 400 Ω	**2**	1 mark for correctly reading Rldr with unit Accept value between 600-650 Ω 1 mark for correct value of R with unit

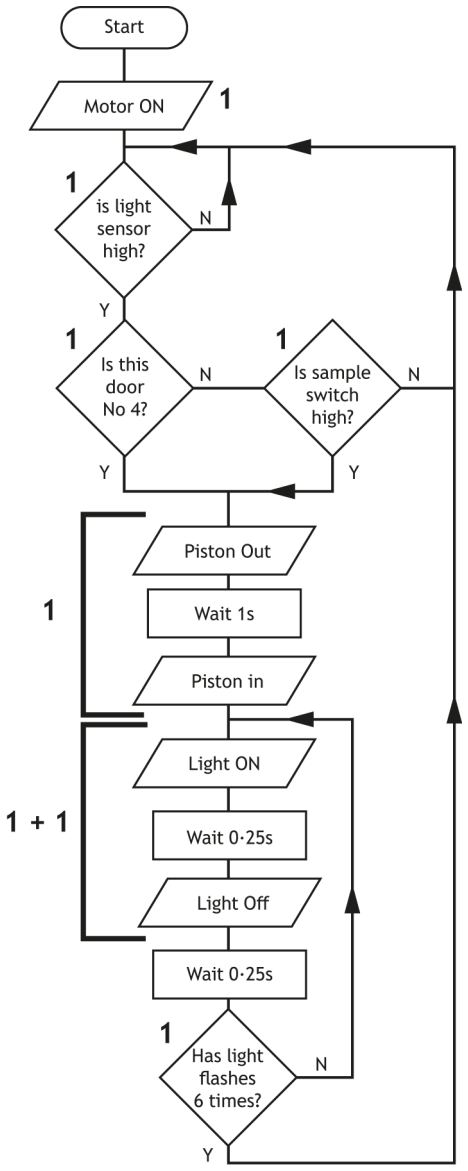
Question			Expected response	Max mark	Additional guidance
9.	(a)	(i)	Area = (30 × 5 × 2) + (20 × 5) = 300 + 100 = 400 mm^2 $\sigma = F/A = 900/400$ = 2·25 $N\,mm^{-2}$ = 2·3 $N\,mm^{-2}$ (2sf)	**2**	1 mark for correct area (units not required, not final answer) 1 mark for final answer with units
		(ii)	E = 196 $kN\,mm^{-2}$ $E = \sigma/\varepsilon$ $\Rightarrow \varepsilon = \sigma/E = 2{\cdot}25/196 \times 10^3$ = 0·0000115 = 0·000012 (2sf)	**2**	1 mark value from data booklet 1 mark final answer (no units) If a unit is given, no mark
		(iii)	F.O.S. = U.T.S/W.S. F.O.S. = 430/2·25 = 191·111 = 190 (2sf)	**2**	1 mark for UTS from data book 1 mark for final answer If unit is given, no mark
		(iv)	Could be high due to consequence of failure which would involve risk to human life. Over engineered; revise material choice, size of cross-sectional area for material to reduce costs.	**1**	1 mark for a comment which says why it is an appropriate value Candidates response should match F.O.S. value found in (iii). If F.O.S. value is low in (iii) then answer should be not appropriate due to the risk to human life.

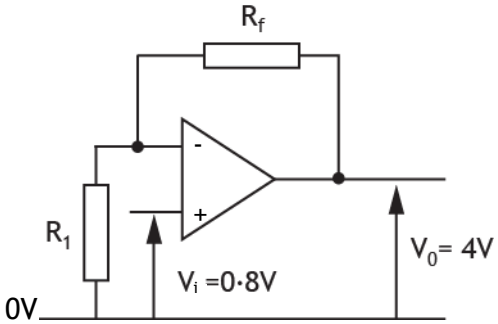
Question			Expected response	Max mark	Additional guidance
9.	(b)	(i)	T = Fr = 8 × 130 × 7 = 7280 N m = 7300 N m (2sf)	**2**	1 mark for substitution 1 mark for final answer with units
		(ii)	n = (18/3)/60 = 0·1 P = 2πnT = 2π × 0·1 × 7300 = 4580 W (4·58 kW) = 4600 W (4·6 kW) (2sf)	**2**	1 mark for correct substitution 1 mark for final answer with units
		(iii)	P = IV = 30 × 240 = 7200 W η = Pout/Pin × 100 = 4·58/7·2 × 100 = 63·6% or 0·636 = 64% or 0·64 (2sf)	**2**	1 mark for calculating P (no units required) 1 mark for final answer If unit is given for decimal answer, no mark
	(c)			**2**	1 mark for correctly labelled axes 1 mark for clearly increasing MARK/SPACE ratio as time increases Candidate must clearly show: • gaps(SPACE) getting smaller and the columns getting wider(MARK) • gaps getting smaller and the columns staying the same • gaps staying the same and the columns getting wider Must have at least 6 pulses.

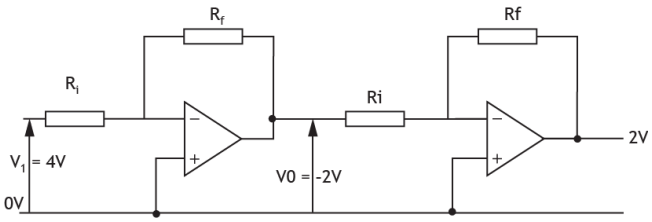
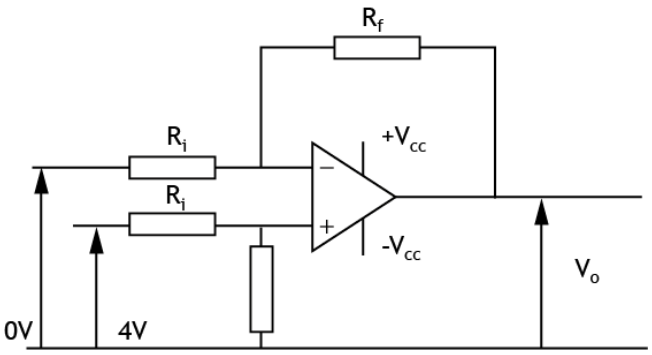
Question			Expected response	Max mark	Additional guidance
9.	(d)		<u>Verticals</u> M2 Cos45° + M1 Cos69° = 1030 Cos59° [M2 × 0·707] + [M1 × 0·358] = 530·49 <u>Horizontals</u> M2 Sin45° + M1 Sin69° = 1030 Sin59° [M2 × 0·707] + [M1 × 0·934] = 882·88 M1 × 0·358 + M2 × 0·707 = 530·49 M1 × 0·934 + M2 × 0·707 = 882·88 M2 × 0·707 = 530·49 − M1 × 0·358 M2 × 0·707 = 882·88 − M1 × 0·934 M1 530·5 − 0·358M1 = 882·9 − 0·934M1 0·934M1 − 0·358M1 = 882·9 − 530·5 0·576M1 = 352·4 M1 = 352·4 / 0·576 M1 = 611·806 **M1 = 612 N** (3sf) M2 M2 × 0·707 = 530·49 − M1 × 0·358 M2 = 530·49 − (612 × 0·358) / 0·707 M2 = 440·444 **M2 = 441 N** (3sf) **Alternative answer on next page**	**5**	1 mark for substitution 1 mark for substitution 1 mark for substitution 1 mark final answer with unit (M1) 1 mark final answer with unit (M2)

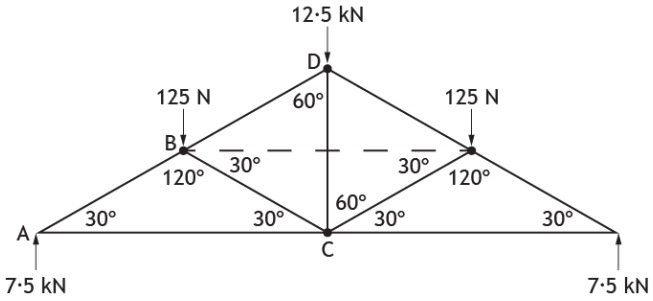
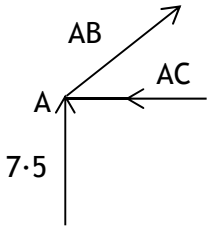
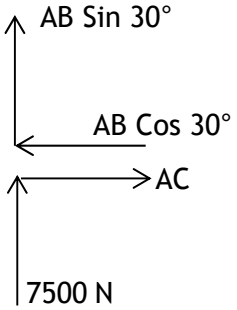
Question			Expected response	Max mark	Additional guidance
9.	(d)		**continued** Alternative method  31° + 45° = 76° 21° + 45° = 66° 45° + 45° = 90° $\sum F_H = 0$ 1030 cos 76 − M1 cos 66 = 0 M1 = 612 N $\sum F_V = 0$ 1030 sin 76 − M1 sin 66 − M2 = 0 M2 = 441 N		1 mark for all 3 angles 1 mark for substitution 1 mark final answer with unit (M1) 1 mark for substitution 1 mark final answer with unit (M2)

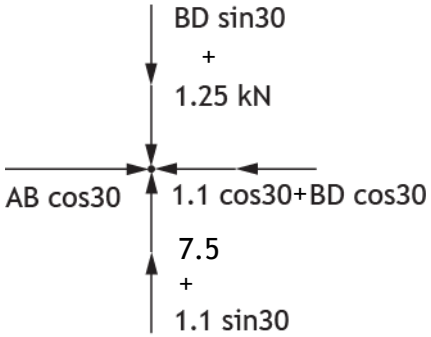
Question			Expected response	Max mark	Additional guidance
10.	(a)	(i)	• Pilot air is sent to valve 8 cutting off the pilot air sent from valve 8 to valve 5 • Valve 2 sends pilot air to valve 5 outstroking cylinder A • When cylinder A is fully outstroked, valve 3 is actuated sending pilot air through valve 9 which actuates valve 6 outstroking cylinder B • This causes cylinder B to actuate roller trip valve 4 sending pilot air back to the 5/2 valve 6 instroking cylinder B • Actuating Valve 4 cuts the air supply to valve 9 which stops cylinder B outstroking so that it now instrokes • When cylinder B has instroked, roller trip valve 7 is actuated sending pilot air to valve 8 which actuates the 5/2 valve 5 causing cylinder A to instroke resetting the system	**6**	1 mark for each statement
		(ii)	1. Solenoid actuator replacing the push button on valve 2. This will cause the system to be operated automatically as it can be connected to electronic interfaces. 2. A reservoir and restrictor between valve 4 and 6. This will create a time delay in the circuit before valve 6 starts the instroking process.	**6**	3 marks available for each point 1 mark for correct component 2 marks for explanation (location in circuit with reason) This will delay cylinder B and cylinder A from instroking. NB if candidate answers the wrong way round, give credit appropriately.

Question			Expected response	Max mark	Additional guidance
10.	(b)			8	1 mark – Motor On 4 marks – Decision box with correct Y/N directions (1 mark each decision) 1 mark Piston Out/Wait 1 s/In 1 mark Light On/Wait/Off 1 mark for light flashing in correct ratio (wait/delay 0·25 s) NB If a candidate uses the wrong symbol type then no mark, if they repeat the error for the same symbol allow FTE.

Question			Expected response	Max mark	Additional guidance
11.	(a)	(i)	Non inverting Difference	**1**	
		(ii)	$A_V = \frac{V_0}{V_1} = \frac{4}{0{\cdot}8} = 5$	**1**	
		(iii)	 $A_V = 1 + \frac{R_f}{R_1}$ $\frac{R_f}{R_1} = 5 - 1 = 4$	**2**	**1 mark** for diagram Diagram must include: 0V, and Vi/Vo or 0·8 V/4 V **1 mark** for any resistor pair in the ratio of 4:1 ie 4k(R_f) 1k(R_1) If difference amp is used resistors will have a 5:1 ratio

Question			Expected response	Max mark	Additional guidance
11.	(b)		Solution using 2 inverting op amps Any resistor values:  $V_0 = \frac{-R_f V_i}{R_i}$ $\quad \frac{R_f}{R_i} = -\frac{1}{2}$ $2v = \frac{-R_f\, 4v}{R_i}$ $0 \cdot 5 = \frac{-R_f}{R_i}$ **OR**  $V_0 = \frac{-R_f}{R_i}(V_2 - V_1)$ $2 = \frac{R_f}{R_i}(4-0) \Rightarrow \frac{R_f}{R_i} = \frac{1}{2}$	**3**	**1 mark** for diagram (either inverting or difference) Diagram must include: Vi/Vo Intermediate voltage is not required. **1 mark** for any resistor value in the ratio 1:2 **1 mark** for second op amp ratio 1:1 Any resistor values $V_0 = -V_i$ OR **1 mark** for correct substitution **1 mark** for any resistor values in ratio $\frac{1}{2}$ 1:2

Question			Expected response	Max mark	Additional guidance
11.	(c)		 AC = 13 kN (2sf) (Tie) BC = 1·1 kN (2sf) (Strut) BD = 14 kN (2sf) (Strut) AB = 15 kN (2sf) (Strut) **Node A**   $\Sigma F_v = 0$ AB Sin 30° + 7500 = 0 AB Sin 30° = −7500 $AB = \frac{-7500}{\sin 30°}$ $AB = \frac{7500}{0{\cdot}5}$ AB = 15 kN (Strut) $\Sigma F_M = 0$ AB Cos 30° = AC 15000 × 0·866 = AC 12990·38 N = AC AC = (13 kN) TIE	**8**	**1 mark** for magnitude AB **1 mark** for nature AB **1 mark** for magnitude AC **1 mark** for nature AC

Question			Expected response	Max mark	Additional guidance
	(c)		**Node B**  $\Sigma F_V = 0$ $1{\cdot}25 + 0{\cdot}5BD = 7{\cdot}5 + 0{\cdot}55$ $BD = \frac{8{\cdot}05 - 1{\cdot}25}{0{\cdot}5}$ $BD = 13{\cdot}6\,kN$ Strut $BD = 14\,kN$ (2sf) Strut --- $\Sigma F_H = 0$ $AB\ Cos\ 30 = 1{\cdot}1\ Cos\ 30 - BD\ Cos\ 30$ $BD = \frac{11{\cdot}75}{6{\cdot}866} = 13{\cdot}6kN$ Strut $BD = 14\,kN$ (2sf) Strut		**Either solution for Node B acceptable** **1 mark** for vertical BD (BD sin30) **1 mark** for correct substitution of F_v **1 mark** for magnitude of BD **1 mark** for nature of BD --- **1 mark** for horizontal BD (BD cos30) **1 mark** for correct substitution of F_H **1 mark** for magnitude of BD **1 mark** for nature of BD

Question			Expected response	Max mark	Additional guidance
11.	(d)		Uniformly distributed load: $2{\cdot}5 \times 6{\cdot}1 = 15{\cdot}25$ kN $(4 \sin 71 + 1{\cdot}6) + (15{\cdot}25 \times (3{\cdot}05 + 1{\cdot}6))$ $= B_V \times 7{\cdot}7$ $5{\cdot}38 + 70{\cdot}9/7{\cdot}7 = B_V$ $B_V = 9{\cdot}9$ kN $B_H = 4 \cos 71 = 1{\cdot}3$ kN $B = \sqrt{9{\cdot}9^2 + 1{\cdot}3^2}$ $= 9{\cdot}99$ kN	**5**	1 mark for value 15·25 kN 1 mark for substitution 1 mark for value 9·9 kN 1 mark for value 1·3 kN 1 mark for value 9·99 kN

[END OF SPECIMEN MARKING INSTRUCTIONS]

Published: September 2018

Change since last published:

Correction to marking instructions for question 8 (c).