FOR OFFICIAL USE

N5

National
Qualifications
SPECIMEN ONLY

Mark

S823/75/01 Engineering Science

Date — Not applicable

Duration — 1 hour 50 minutes

* S 8 2 3 7 5 0 1 *

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 National 4/5 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.

* S 8 2 3 7 5 0 1 0 1 *

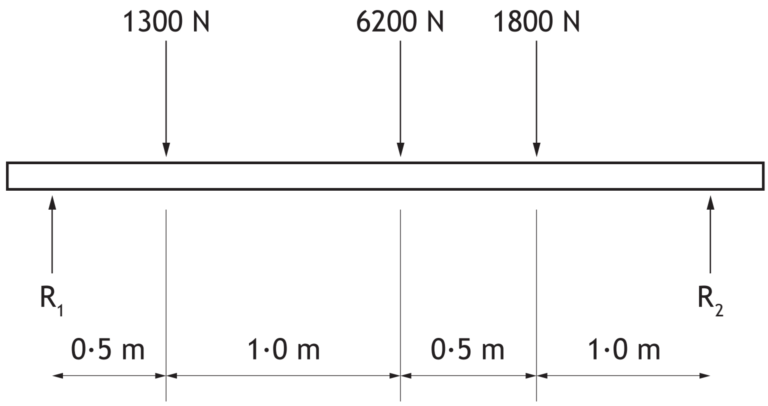
MARKS | DO NOT WRITE IN THIS MARGIN

SECTION 1 — 20 marks

Attempt ALL questions

1. Describe the difference between **open** and **closed** loop control. **2**

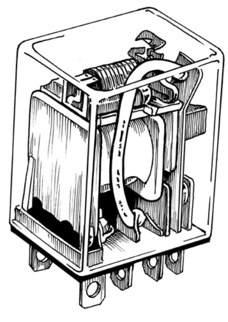
2. The diagram shown below could be used to analyse a structure.



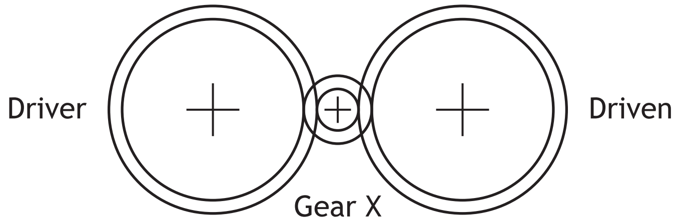
State the name of this type of diagram. **1**

3. Relays like the one shown in this diagram are often used in electronic control circuits.

Describe the general purpose of a relay. **2**



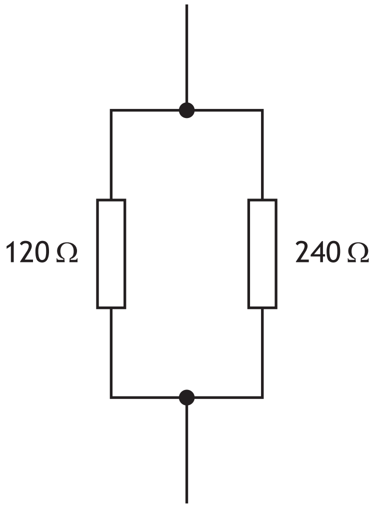
4. The diagram below represents a simple gear train.



(a) State the name of Gear X. **1**

(b) Describe the purpose of Gear X in this simple gear train. **1**

5. Part of the circuitry in a mobile phone is shown in the diagram below.



Calculate the combined resistance of the two parallel resistors. **2**

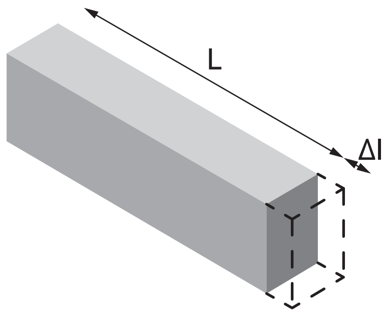
6. Describe three possible environmental impacts of constructing a new bridge over a river. **3**

7. A beam in a structure fails when a large force is applied.

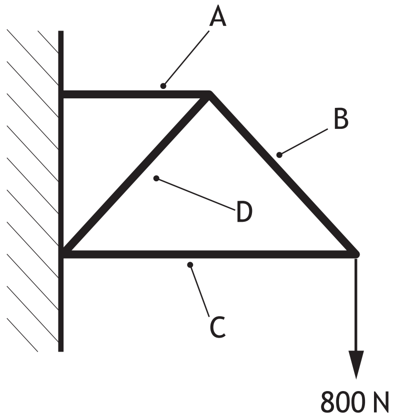
Describe **two** changes to its replacement that would reduce the risk of failure. **2**

8. A metal bar (see diagram to the right) is 310 mm long and stretches 2·2 mm when a tensile force is applied.

Calculate the strain in the bar. **2**



9. A simplified diagram of a frame structure is shown below.

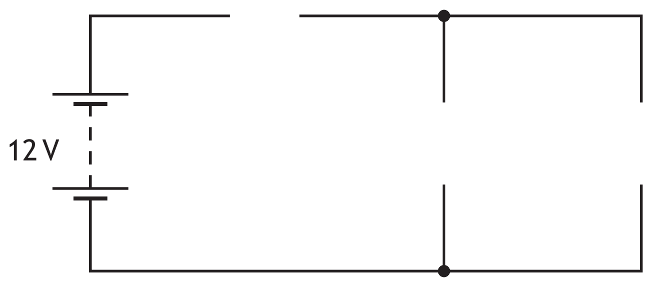


Identify a member of the structure (A–D) that is in:

(a) tension ______________________ **1**

(b) compression ______________________ **1**

10. Complete the circuit diagram below to show a motor operated when one switch or another switch is pressed. **2**



[Turn over

SECTION 2 — 90 marks

Attempt ALL questions

11. A prototype solar panel is being tested.

(a) Describe the role of the following engineers in the **development** of the panel.

(i) Type of engineer — **Electronic Engineer** **1**

Role — ______________________________

____

(ii) Type of engineer — **Structural Engineer** **1**

Role — ______________________________

____

During testing, the panel absorbs 15 MJ of energy and is found to be 73% (0·73) efficient.

(b) Calculate the **output** electrical energy produced. **3**

11. (continued)

(c) Explain **how** solar panels can contribute to tackling climate change. **2**

____

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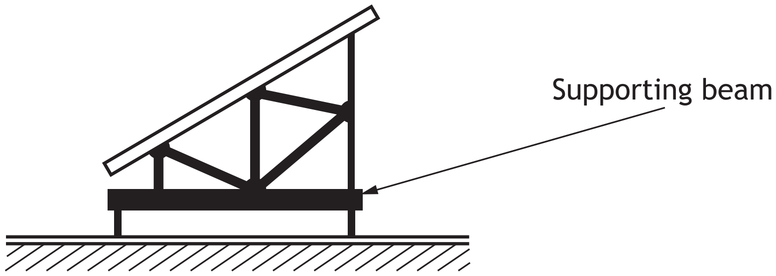
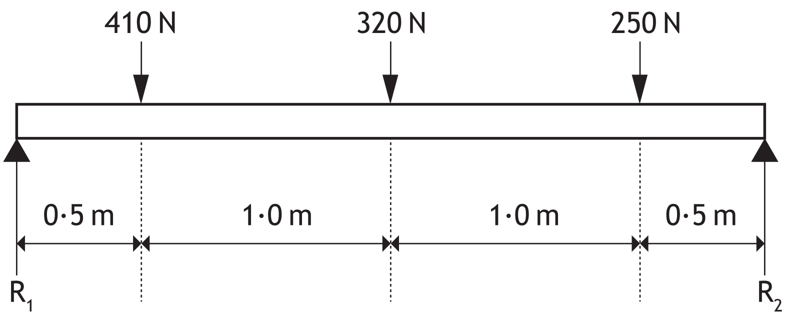
____

____

The solar panels are fitted to a frame supported by a beam, as shown in the diagram below.

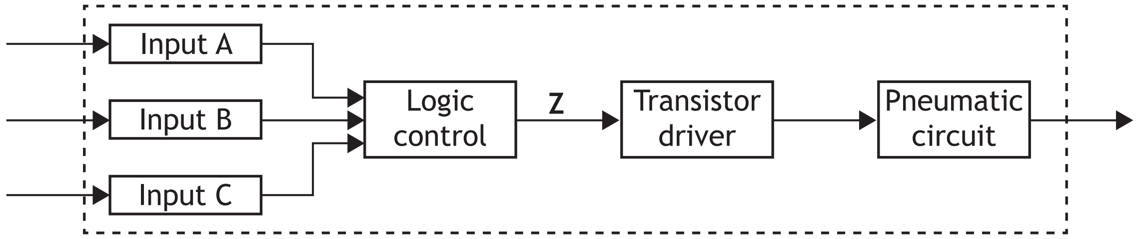


The forces acting on the beam are shown in the diagram below.



(d) Calculate the size of reaction force R_2 by taking moments about R_1. **3**

12. The diagram below shows the sub-systems of a pneumatic press used in a factory.

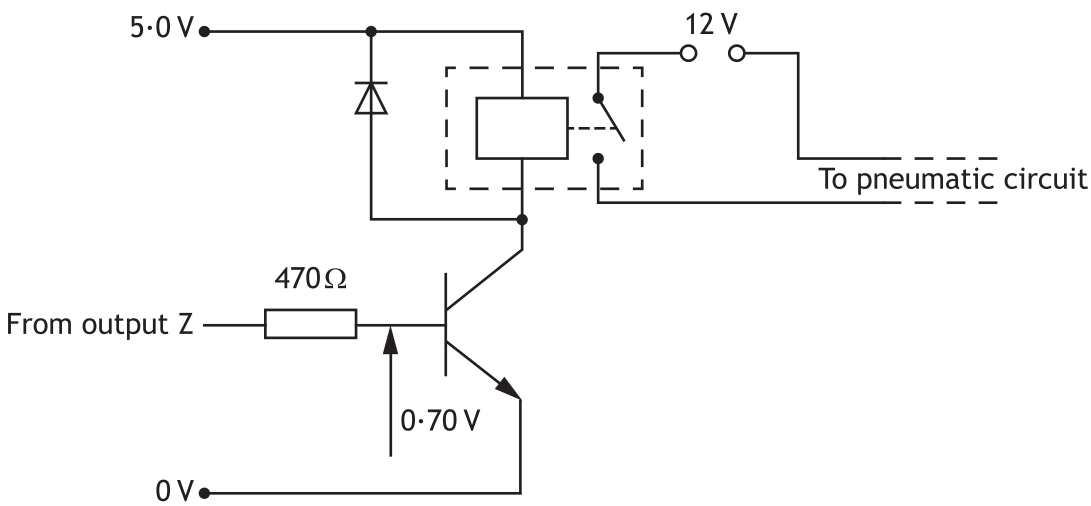


The logic control activates the transistor driver when the following conditions are met:

$$Z = \overline{A} \bullet B \bullet \overline{C}$$

(a) Complete the logic diagram for the given Boolean equation. **3**

The output of the logic diagram is used to switch on the transistor driver circuit shown below.



12. (continued)

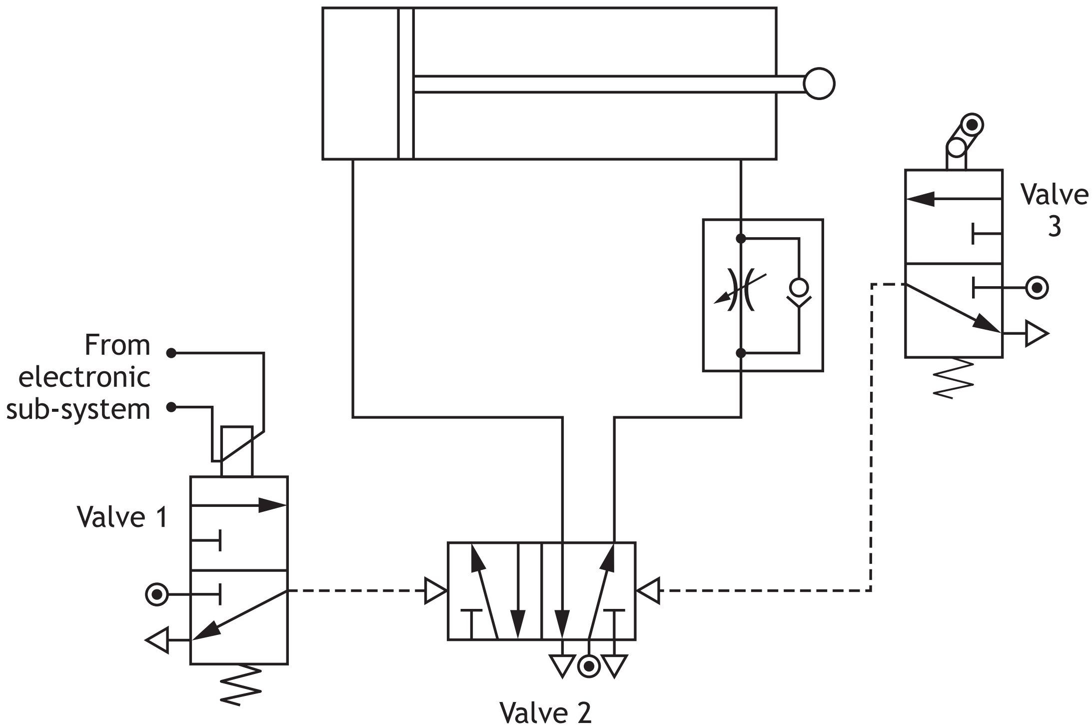
(b) Calculate the base current when output Z is high (5·0 V). **4**

(c) An engineer simulates the electronic system on a computer before building a prototype on breadboard. Explain why the system is simulated before a prototype is built. **2**

[Turn over

12. (continued)

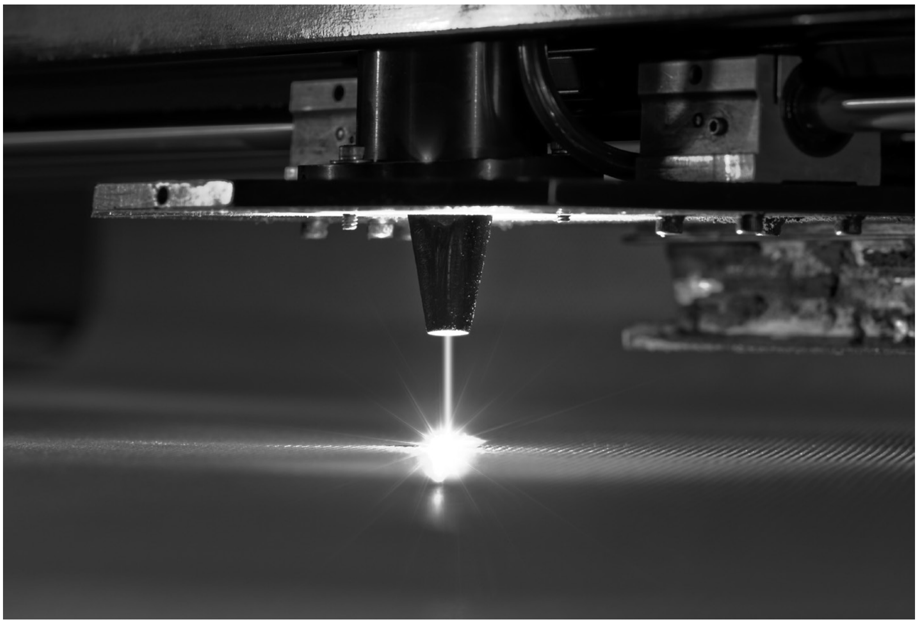
The electronic sub-system controls the pneumatic circuit shown in the diagram below.



(d) Describe, using appropriate terminology, the operation of the pneumatic circuit. **3**

When Valve 1 is actuated by the electronic sub-system, ____________________

13. A laser cutting machine is used to cut sheet steel, as shown in the photograph below.



The laser is positioned by motors A and B which are operated by a microcontroller.

Input and output connections to the microcontroller are shown in the table below.

Input connection	Pin	Output connection
	7	Motor A forward (move right)
	6	Motor A reverse (move left)
	5	Motor B forward (move forward)
	4	Motor B reverse (move back)
	3	Laser (on when high, off when low)
	2	
	1	
	0	

The cutter is required to perform the following sequence of operations:

1: Switch on the laser

2: Move right for 0·5 seconds

3: Move forward for 0·5 seconds

4: Repeat steps 2 and 3 four times

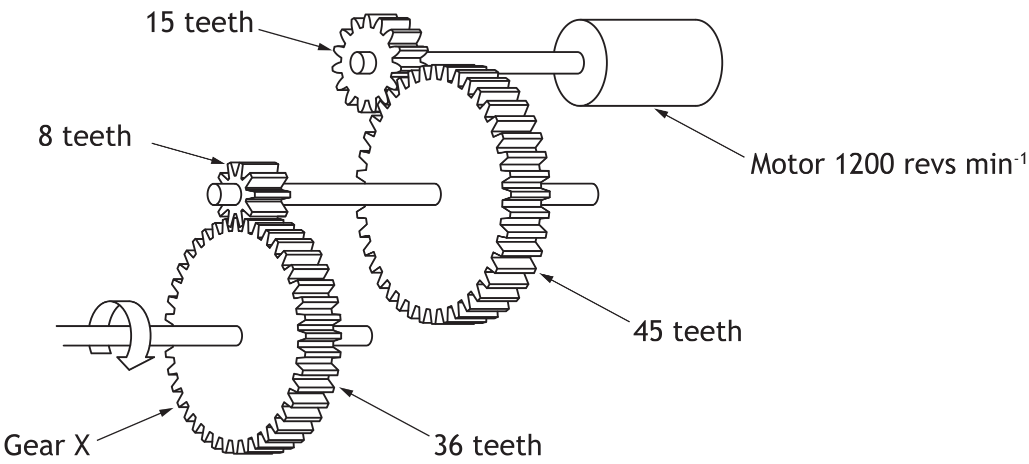
5: Switch off laser and motors

13. (continued)

(a) Complete, with reference to the data booklet and input/output connections, the flowchart for the control sequence. Include **all** pin numbers. **7**

13. (continued)

Motors A and B are each connected to a drive system for the laser cutting machine, as shown in the diagram below.



(b) (i) State the name of this type of drive system. **1**

____

(ii) Calculate the output speed of Gear X. **4**

[Turn over

14. An electric guitar is shown in the photograph below.

Tuning a guitar string produces an 80 N tensile load in the string.

The table below gives the properties of three alloys that could be used to make a guitar string.

Alloy	Maximum load	Brittle/ductile
A	120 N	Brittle
B	90 N	Ductile
C	65 N	Ductile

(a) (i) State which alloy (A–C) would be most appropriate for the guitar string. ________ **1**

(ii) Explain, with reference to the table, your choice of alloy. **1**

____

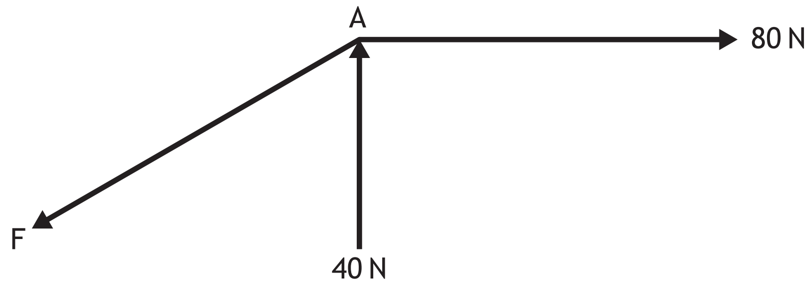
____

The guitar string has a cross-sectional area of 0·2 mm^2.

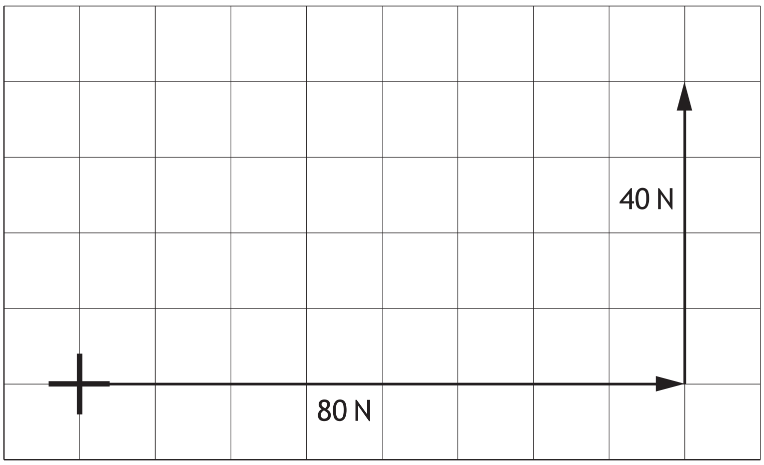
(b) Calculate the stress in the guitar string. **2**

14. (continued)

During the design of the guitar, the designer needs to calculate the force F required to keep point A in equilibrium.



(c) Determine the size of force F using the scale drawing of the triangle of forces shown in the diagram below. **1**

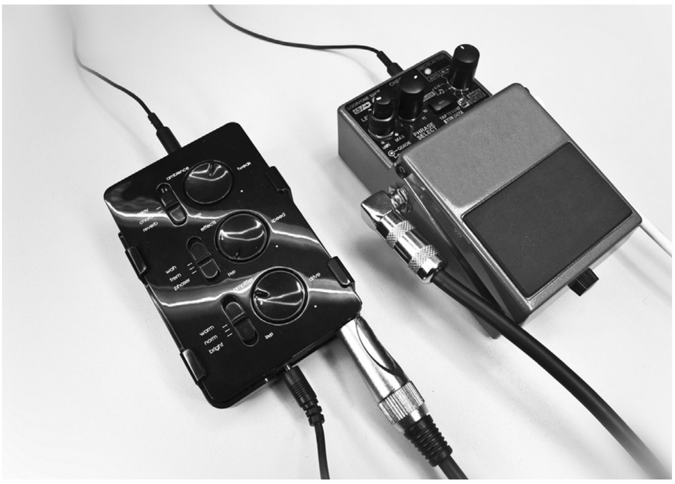


F = ______ N

[Turn over

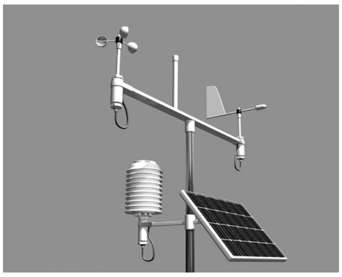
14. (continued)

An “effects pedal”, as shown in the photograph below, can be attached to the guitar to change the sound produced. The effects pedal uses complex electronic circuitry.

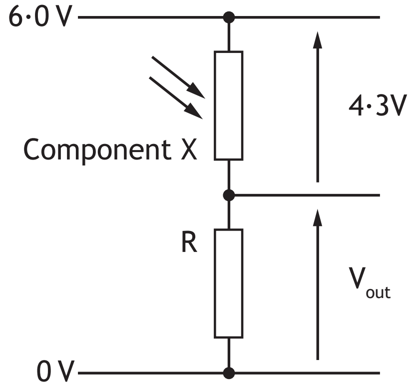


(d) Explain why a microcontroller might be used in place of a hard wired circuit in the effects pedal. 2

15. A weather monitoring station, as shown in the photograph to the right, is used to collect data.



Light levels are measured using the sensing sub-system shown in the diagram below.



(a) State the **full** name of Component X. **1**

Component X and the fixed resistor R are connected in series.

(b) State the name given to this arrangement. **1**

(c) Calculate the value of V_{out}. **1**

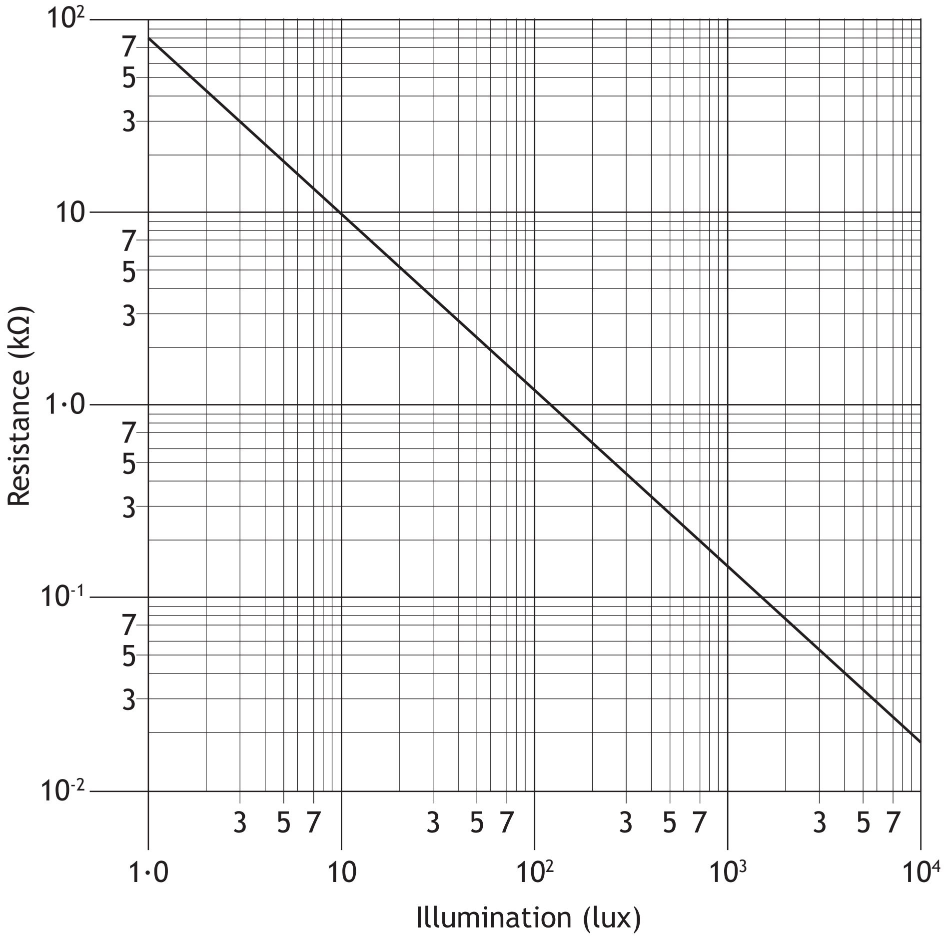
Component X is found to have a resistance of 1·5 kΩ.

(d) (i) Calculate the resistance of R. **3**

MARKS | DO NOT WRITE IN THIS MARGIN

15. (d) (continued)

The graph below shows the resistance of Component X at different light levels.



(ii) State, by referring to the graph, the light level when the resistance of component X is 10 kΩ. **1**

____

(e) Explain the effect on V_{out} of increasing **and** decreasing light level. **3**

____

____

____

____

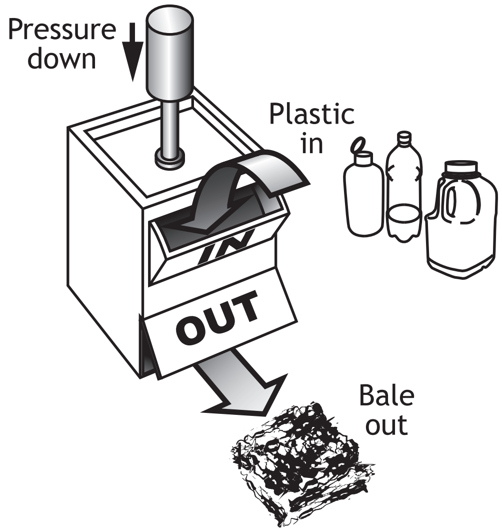
____

* S 8 2 3 7 5 0 1 1 8 *

MARKS | DO NOT WRITE IN THIS MARGIN

16. A prototype system to compress plastic bottles is operated by pneumatics.

For safety reasons, two buttons must be pressed before the plastic is compressed by a pneumatic cylinder. After a set period of time, the piston must instroke automatically (see diagram below).



A proposed design for the system is shown in the diagram below but it has been found to have two faults.

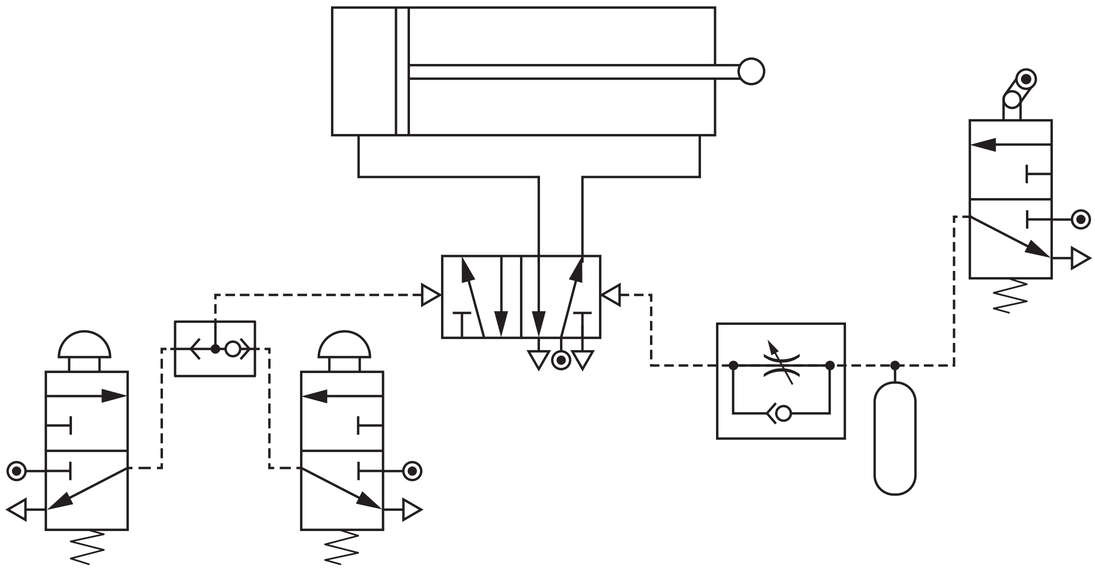
(a) Describe the **two** faults in the circuit design. **2**

____

____

____

____



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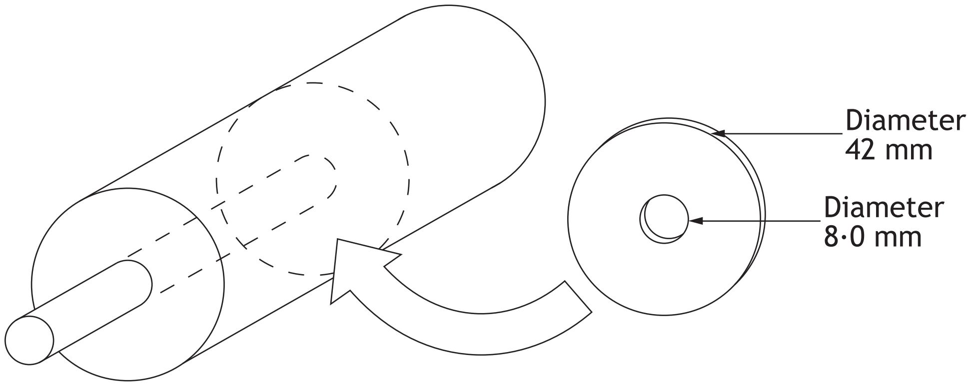
MARKS DO NOT WRITE IN THIS MARGIN

16. (continued)

The diagram below shows the pneumatic cylinder used. Air is supplied to the cylinder at 2·0 Nmm^{-2} .

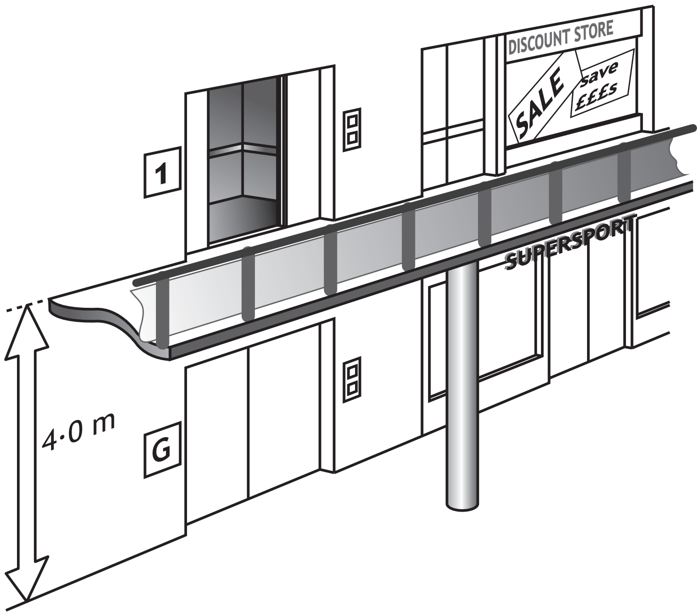


(b) Calculate the instroking force of the cylinder. **4**

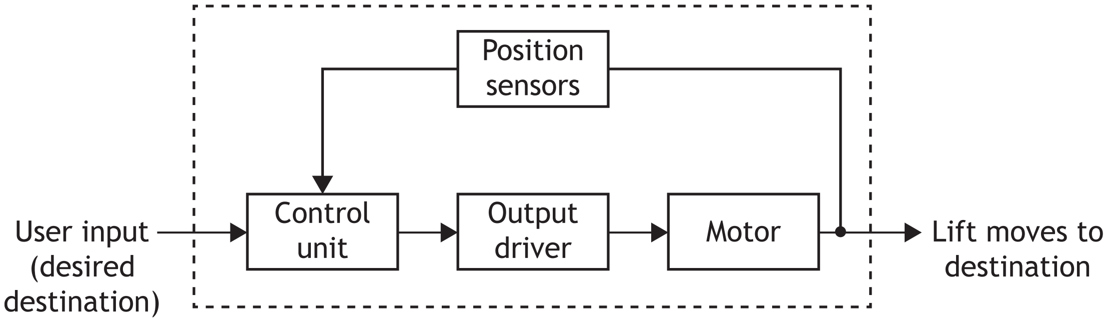
The reservoir and the uni-directional restrictor perform the delay function of the system.

(c) Describe how the length of the delay could be **increased**. **1**

17. A shopping centre decides to introduce a lift to give all its customers access to shops on the first floor (see diagram below).



A simplified diagram for part of the system is shown below.



(a) Describe the control of the lift **with reference to the diagram** and using appropriate terminology. **4**

17. (continued) MARKS | DO NOT WRITE IN THIS MARGIN

When the lift is full of people it has a total mass of 1250 kg.

(b) (i) Calculate the potential energy gained when the lift has moved up 4·0 m to the first floor. **2**

The lift is powered by an electric motor that is supplied with 240 V and 22 A.

(ii) Calculate how long it would take the lift to reach the first floor when full. Assume no energy loss. **3**

(iii) In reality, the lift took longer to reach the first floor. Explain why the lift was less than 100% efficient. **2**

(c) (i) Describe one **positive economic** effect of introducing the lift to the shopping centre. **1**

(ii) Describe one **negative economic** effect of introducing the lift to the shopping centre. **1**

18. A rollercoaster is shown below. **MARKS** DO NOT WRITE IN THIS MARGIN

John Leung/Shutterstock.com

(a) Describe two tasks a mechanical engineer would undertake during the **design** of the rollercoaster.

1 ____ **1**

____

2 ____ **1**

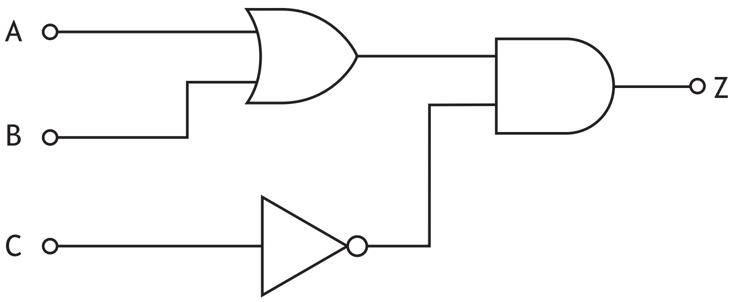
____

An electronic engineer used computer simulation during the design of the rollercoaster.

(b) State one feature of the **rollercoaster** design that the electronic engineer would simulate. **1**

____

The logic diagram for part of the electronic control system used in the rollercoaster is shown below.



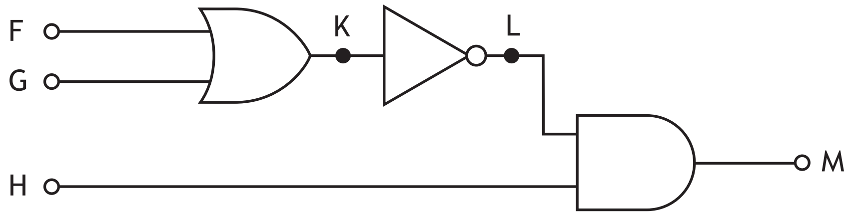
(c) Complete the Boolean equation for the logic diagram. **3**

Z = ____

18. (continued)

MARKS | DO NOT WRITE IN THIS MARGIN

The logic diagram for a second part of the electronic control system is shown below.



(d) Complete the truth table below for the logic diagram. **3**

F	G	H	K	L	M
0	0	0			
0	0	1			
0	1	0			
0	1	1			
1	0	0			
1	0	1			
1	1	0			
1	1	1			

(e) An **emerging technology** can be defined as something new that has great potential but is not yet fully tried commercially in a product or system.

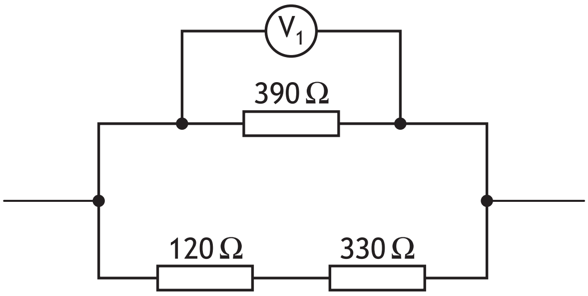
One of the most exciting emerging technologies today is nanosensors. These tiny sensors have many uses; for example, they could be embedded in construction materials.

Explain the possible impacts of an emerging technology with which you are familiar. **2**

(f) Explain one positive **social** impact of having a theme park built in a small community. **2**

19. A drone used to film sporting events is shown below.

Part of the electronic circuit used in the drone is shown below.



(a) Calculate the total resistance for the circuit shown. **3**

Show all working and final unit.

19. (continued)

(b) Calculate the current through the $390\,\Omega$ resistor when the voltage V_1 is $12\,V$. **3**

Show all working and final unit.

[END OF SPECIMEN QUESTION PAPER]

ADDITIONAL SPACE FOR ANSWERS

ADDITIONAL SPACE FOR ANSWERS

N5 National Qualifications SPECIMEN ONLY

S823/75/01 **Engineering Science**

Marking Instructions

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

General marking principles for National 5 Engineering Science

This information is provided to help you understand the general principles you must apply when marking candidate responses to questions in this paper. These principles must be read in conjunction with the specific marking instructions for each question. The marking schemes are written to assist in determining the 'minimal acceptable answer' rather than listing every possible correct and incorrect answer.

(a) Marks for each candidate response must always be assigned in line with these general marking principles and the specific marking instructions for the relevant question.

(b) Marking should always be positive. This means that, for each candidate response, marks are accumulated for the demonstration of relevant skills, knowledge and understanding: they are not deducted from a maximum on the basis of errors or omissions.

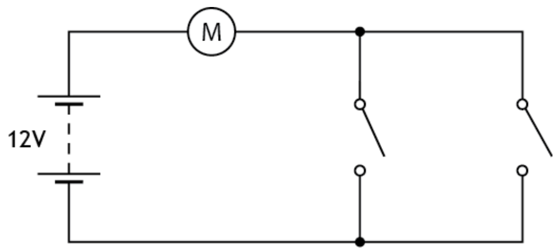
(c) Where a candidate makes an error at an early stage in a multi-stage calculation, credit should normally be given for correct follow-on working in subsequent stages, unless the error significantly reduces the complexity of the remaining stages. The same principle should be applied in questions which require several stages of non-mathematical reasoning.

(d) All units of measurement will be presented in a consistent way, using negative indices where required (eg ms^{-1}). Candidates may respond using this format, or solidus format (m/s) or words (metres per second), or any combination of these (eg metres/second).

Marking instructions for each question

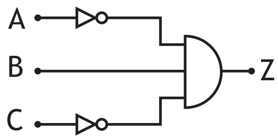
Section 1

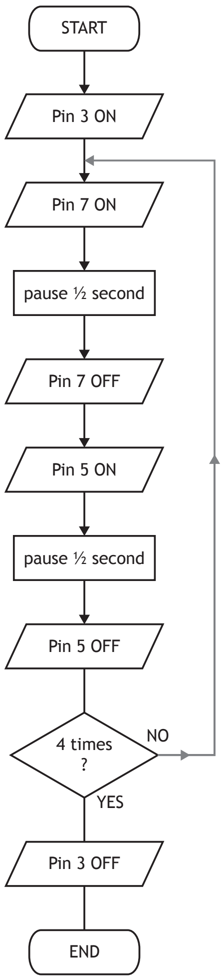
Question			Expected response	Max mark	Additional guidance
1			Open loop systems have no feedback (1). Closed loop systems have feedback (1).	2	
2			Free body diagram	1	
3			It acts as a link allowing a low powered electronic control circuit to switch/ control a high powered electrical circuit	2	1 mark for the idea of a link between low and high power circuits (or idea of isolating low from high). 1 mark for the idea that it acts as a switch (or control).
4	a		Idler gear	1	
4	b		It makes the driver and driven turn the same way.	1	Do not accept: that it has no effect on the speed of the gears.

Question			Expected response	Max mark	Additional guidance
5			$R_t = \frac{R1 \times R2}{R1 + R2}$ (1 mark for substitution) $= \frac{120 \times 240}{120 + 240}$ $= 80\,\Omega$ (1 mark for correct answer from candidate's working)	2	
6			Any three valid examples, such as: Landscaping may destroy animal habitat. Construction may impact river ecosystem. Bridge might reduce distance travelled, so reducing fuel consumption. (1 mark for each reasonable description)	3	
7			Choose a stronger material (1). Increase x-section area to reduce stress (1).	2	Or any other valid response.
8			$\varepsilon = \frac{\Delta l}{L}$ $= 2{\cdot}2/310$ (1 mark for substitution) $= 0{\cdot}0071$ (1 mark for correct answer from candidate's working) $= 0{\cdot}007$	2	
9	a		A or B	1	
9	b		C or D	1	
10				2	1 mark for motor and switch symbol. 1 mark for correct positions of three components. Ignore any additional symbols.

Section 2

Question			Expected response	Max mark	Additional guidance
11	**a**	**i**	Electronic Engineer: Designing the electronic control systems and circuitry	1	(1 mark for each valid example, which could relate to any aspects of design or production, but must clearly be electronic and engineering roles).
11	**a**	**ii**	Structural Engineer: Designing the supporting structure	1	(1 mark for each valid example, which could relate to any aspects of design or production, but must clearly be structural and engineering roles).
11	**b**		E_{out} = E_{in} x efficiency (1 for manipulating given formula) E_{out} = 0·73 x 15 MJ (1 for substituting values) = 10·95 MJ (1 for correct answer from candidate's working) = 11 MJ (2 sf)	3	
11	**c**		They reduce the need for power produced using fossil fuels (1) which means reduced carbon dioxide output (1).	2	Reduced pollution not acceptable; answer must relate to climate change, so must refer to carbon dioxide output.
11	**d**		∑Anticlockwise moments = ∑Clockwise moments (410 x 0·5) + (320 x 1·5) + (250 x 2·5) = R2 x 3 (1 for substitution) R2 $= \frac{1310}{3}$ (1 for manipulation) = 436·7 N (1 for correct answer from candidate's working) = 437 N = 440 N	3	

Question			Expected response	Max mark	Additional guidance
12	**a**		1 mark for correct logic symbols 1 mark for correct AND connection 1 mark for correct NOT connection 	3	
12	**b**		V = IR, I = V/R (1 mark for manipulating equation) $I = \frac{(5{\cdot}0 - 0{\cdot}7)}{470}$ (1 mark for calculating voltage) (1 mark for substitution) = 9·1 mA (1 mark for correct answer from candidate's working)	4	
12	**c**		eg real, expensive components will not be damaged if there is a problem or mistake.	2	1 mark for cause 1 mark for effect
12	**d**		1 mark for correct outstroking condition 1 mark for correct instroking condition 1 mark for speed outstroking controlled	3	

Question			Expected response	Max mark	Additional guidance
13	a			7	1 mark for all symbols used correctly 1 mark for feedback loop with arrows 1 mark for decision including yes/no 1 mark for both pause commands 1 mark for PIN 3 ON and OFF 1 mark for PIN 7 ON and OFF 1 mark for PIN 5 ON and OFF
13	b	i	Compound gear	1	
13	b	ii	*First pair of gears* 15 x 1200 = 45 x Output speed (1 mark for substitution) Output speed = 400 revs min^{-1} (1 mark for answer from candidate's working) *Second pair of gears* 400 x 8 = 40 x Output speed (1 mark for substitution) Output speed = 89 revs min^{-1} (1 mark for answer from candidate's working)	4	Do not accept rpm

Question			Expected response	Max mark	Additional guidance
14	a	i	B	1	
14	a	ii	It is strong enough to support the load and will bend as appropriate.	1	Explanation must refer to both relevant points (load support and bending).
14	b		Stress = Force/Area = 80 N/0·2 (1 mark for substitution) = 400 N mm^{-2} (1 mark for correct answer from candidate's working)	2	
14	c		~89 N (1 mark for answer)	1	Accept answers between 85 and 95. (A drawn arrow is not required for the mark to be awarded.) Answer must be taken from drawing and not calculated.
14	d		Any valid point with explanation, such as: • reduced size • quicker assembly • reduced cost, etc … due to fewer components	2	
15	a		Light dependent resistor	1	LDR not acceptable
15	b		Voltage divider	1	
15	c		V_{out} = 6·0 — 4·3 = 1·7 V (1 mark for correct answer from candidate's working)	1	

Question			Expected response	Max mark	Additional guidance
15	d	i	V1/V2 = R1/R2 4·3/1·7 = 1500 / R (1 mark for substitution) R = (1·7/4·3) x 1500 (1 mark for rearranging formula) = 593 Ω (1 mark for correct answer from candidate's working) = 590 (2 sf)	3	Allow FTE from 15(c)
15	d	ii	10 Lux	1	
15	e		1 mark for each valid statement (as below) up to 3 marks: • as light level increases the LDR's resistance decreases • as the LDR's resistance decreases V_{out} increases • as light level decreases the LDR's resistance increases • as the LDR's resistance increases V_{out} decreases.	3	
16	a		The shuttle valve produces an OR function rather than the desired AND (1). The reservoir is positioned in front of the uni-directional restrictor rather than after it (1).	2	
16	b		Outstroking area = 3·14 x 21^2 = 1384·74 mm^2 (1 mark for calculating area) Instroking area = 1384·74 — (3·14 x $4{\cdot}0^2$) = 1334·5 mm^2 (1 mark for instroking area) Force = Pressure x Area = 2·0 x 1334·5 (1 mark for substitution) = 2669 N (1 mark for correct answer from candidate's working) = 2700 N	4	

Question			Expected response	Max mark	Additional guidance
16	c		1 mark for a valid method, eg: • increase restriction on uni-direction restrictor • increase volume of reservoir	1	
17	a		Up to 4 marks for four valid statements, such as: • The user's desired destination is fed into the control unit. • The control unit compares the current position with the desired destination. • The control unit sends the appropriate signal to activate the output driver. • The position sensors provide feedback.	4	
17	b	i	E_p = mgh = 1250 x 9·8 x 4·0 (1 mark for substitution) = 49 000 J (1 mark for correct answer from candidate's working)	2	
17	b	ii	E_e = ItV 49 000 = 22 x t x 240 (1 mark for substitution) t = 49 000 / (22 x 240) (1 mark for rearranging formula) = 9·3 seconds (1 mark for correct answer from candidate's working)	3	Allow FTE from 17(b)(i)
17	b	iii	Some energy would be transferred (1) in the form of heat/sound due to friction (1).	2	1 mark for cause (friction) 1 mark for effect (energy 'lost' to heat/sound)
17	c	i	It would allow increased access to shops on the first floor, so more spending in these shops.	1	
17	c	ii	It would be expensive to design/install.	1	

Question			Expected response	Max mark	Additional guidance
18	(a)		Calculating drive systems VR/torque Selecting suitable gear sizes Creating brake system	2	1 mark per correct descriptive response Statements must be mechanical engineer based and relate to the design stage.
	(b)		To simulate control circuits, safety systems, lighting, braking systems, program/flowchart and test their operation. (1 mark for any relevant answer)	1	Statement based response
	(c)		$(A + B) \cdot \overline{C} = Z$	3	(1 mark OR with bracket, 1 mark AND, 1 mark NOT) Other correct Boolean equations are acceptable
	(d)		K, L, M: 0, 1, 0 0, 1, 1 1, 0, 0 1, 0, 0 1, 0, 0 1, 0, 0 1, 0, 0 1, 0, 0	3	1 mark for each correct column Allow follow through error for column L and M; L = NOT K M = H AND L
	(e)		Self-driving cars will reduce congestion and speed up journey times because they can safely travel much closer together. Less power required to run devices Quicker diagnostics	2	Explanation response only 1 mark cause 1 mark effect No mark without specific emerging technology named. Maximum of 1 mark if given example, nanosensors, is used.
	(f)		The new theme park will need workers which means more jobs for local people. The new theme park will need construction workers so local trades could be used. Happiness/wellbeing in community increased due to greater employment opportunities/affluence.	2	Cause and effect response. Any other response that refers to a positive social impact.

The truth table for 18(d):

K	L	M
0	1	0
0	1	1
1	0	0
1	0	0
1	0	0
1	0	0
1	0	0
1	0	0

Question			Expected response	Max mark	Additional guidance
19	**(a)**		120 + 330 = 450Ω $R_T = \frac{(R1 \times R2)}{(R1 + R2)}$ $R_T = \frac{(390 \times 450)}{(390 + 450)}$ $R_T = 210\Omega\ (2sf)\ (209\Omega)$	3	1 mark for series branch total (ignore units) Accept 3 resistors in parallel calculation – 2 marks maximum 1 mark for substitution (allow FTE). 1 mark for answer from working with unit.
	(b)		$V = IR$ $12 = I \times 390$ $I = \frac{12}{390}$ $I = 0 \cdot 031A\ (31mA\ 2sf)$	3	1 mark for substitution. 1 mark for transposition. 1 mark for answer from working with unit.

[END OF SPECIMEN MARKING INSTRUCTIONS]

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Change since last published:

Graphics amended for questions 4 (*page 03*) and 16 (a) (*page 19*).