FOR OFFICIAL USE

N5

National
Qualifications
Specimen Only

Mark

SQ12/N5/01 Engineering Science

Date — Not Applicable

Duration — 1 hour and 30 minutes

SQ12N50101

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
D D	M M	Y Y

Scottish candidate number

Total marks — 90

SECTION 1 — 20 marks

Attempt ALL questions in this section.

Instructions for completion of Section 1 are given on Page two.

SECTION 2 — 70 marks

Attempt ALL questions in this section.

Read all questions carefully before attempting.

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

Show all working and units where appropriate.

You should refer to the National 4/5 Data Booklet which you have been given.

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.

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SQ12N50101

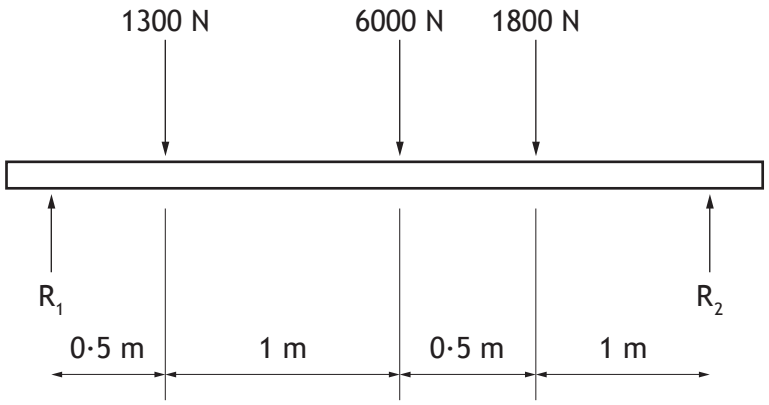
MARKS | DO NOT WRITE IN THIS MARGIN

SECTION 1 — 20 marks

Attempt ALL questions

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

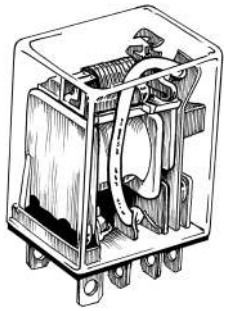
2. The diagram shown below could be used to analyse a structure.



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

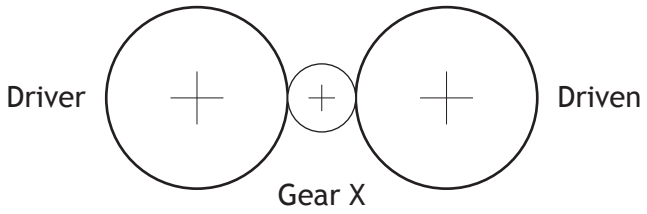
3. Relays, like the one shown in the diagram to the right, are often used in electronic control circuits.

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



MARKS | DO NOT WRITE IN THIS MARGIN

4. The diagram below represents a simple gear train.

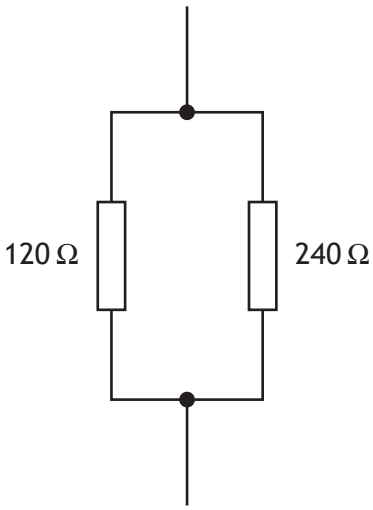


(a) State the name of Gear X. **1**

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

Total marks **2**

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**

MARKS | DO NOT WRITE IN THIS MARGIN

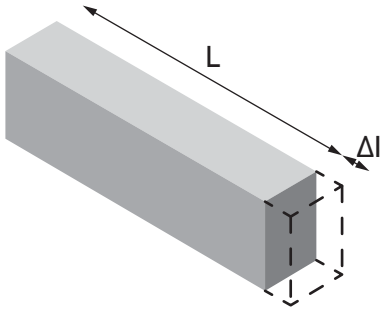
6. Describe **three** possible environmental impacts of constructing a new bridge over a river. **3**

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**

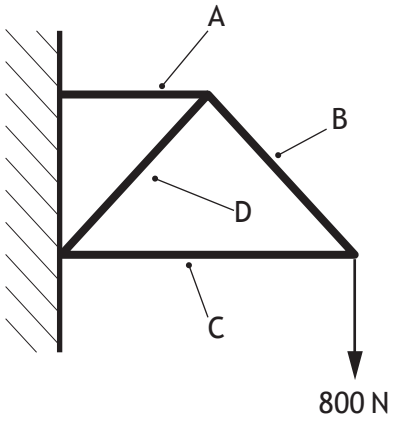
8. A metal bar (see diagram to the right) is 300 mm long and stretches 2 mm when a tensile force is applied.

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



MARKS DO NOT WRITE IN THIS MARGIN

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



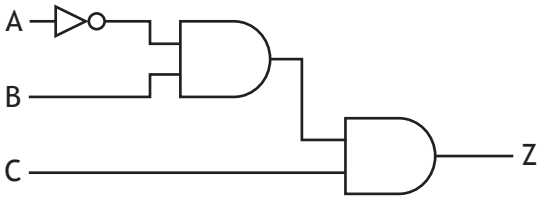
Identify a member of the structure (A–D) that is in:

(a) tension _____ **1**

(b) compression _____ **1**

Total marks 2

10. The logic diagram to the right represents the control system for a child's toy.



Complete the truth table below for the logic diagram: **2**

A	B	C	Z
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	
1	0	0	
1	0	1	0
1	1	0	0
1	1	1	0

SECTION 2 — 70 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 — **Mechanical Engineer** **1**

Role — _____

_____

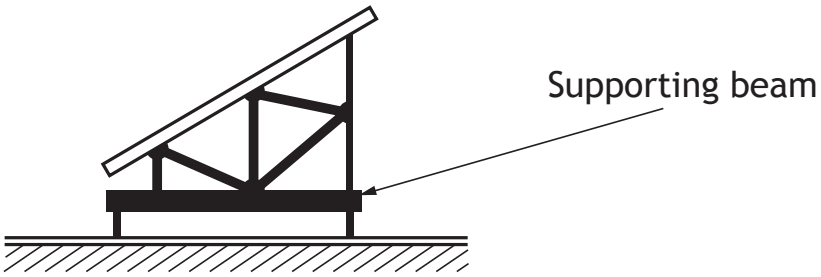
During testing, the panel absorbs 15 MJ of energy and is found to be 73% (0·73) efficient.

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

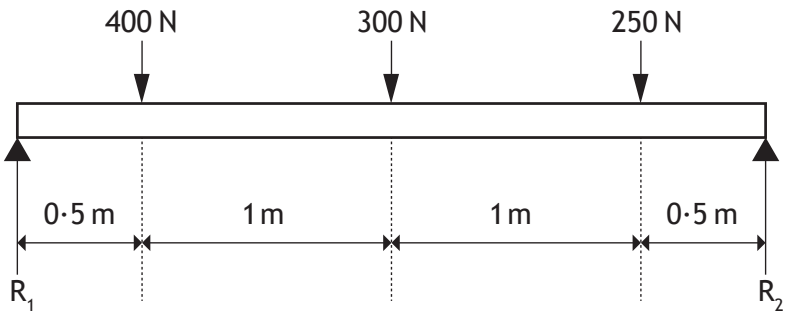
11. (continued)

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

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.

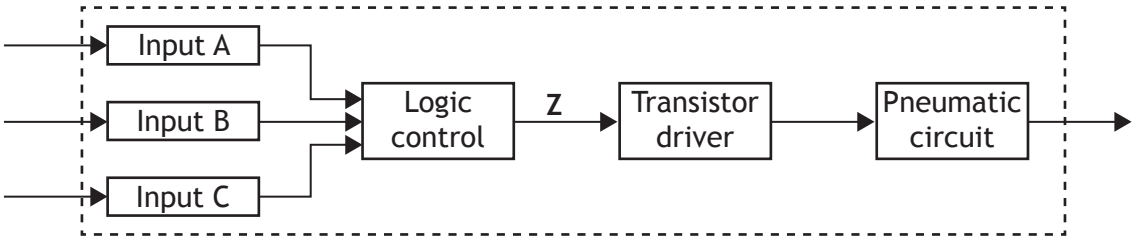


(d) Calculate the size of reaction force R_2 by taking moments about R_1. **3**

Total Marks 10

MARKS DO NOT WRITE IN THIS MARGIN

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

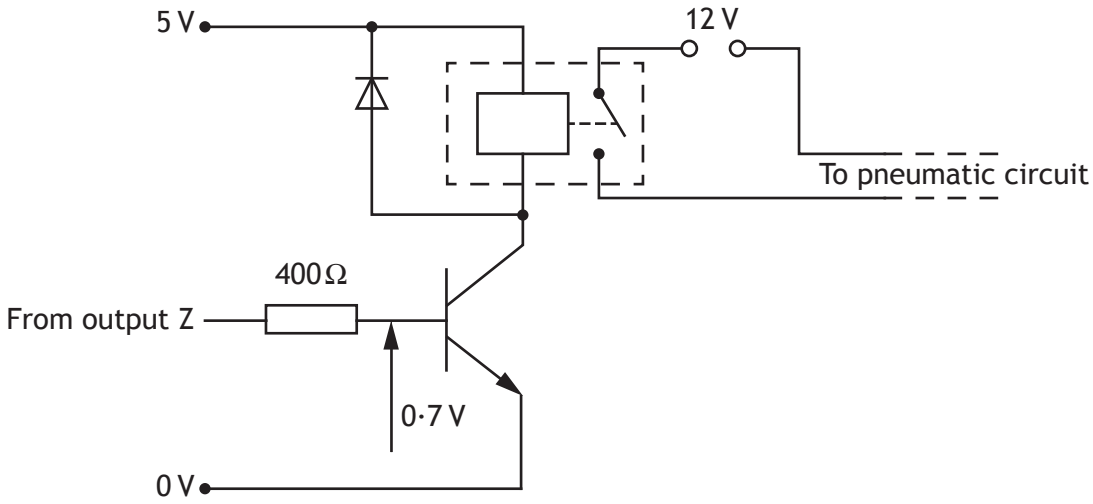


The logic control activates the transistor driver when the following conditions are met:

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

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

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



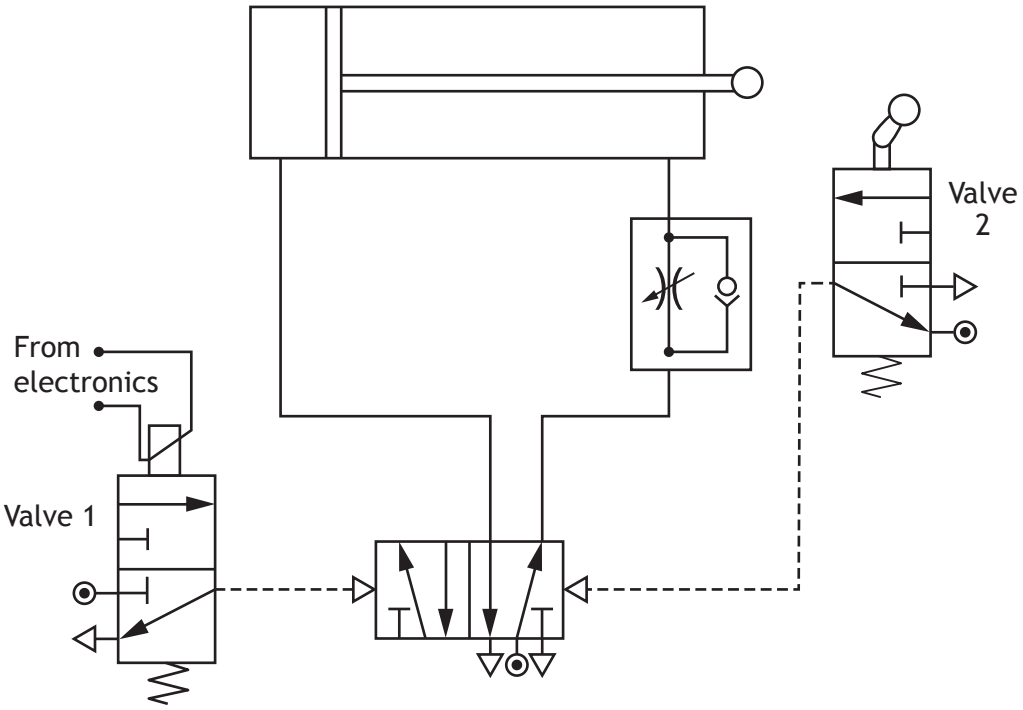
12. (continued)

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

(c) An engineer simulates the electronic system on a computer before building a prototype on breadboard. State **one** reason for simulating the system before building the prototype. **1**

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. **4**

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

_____

_____

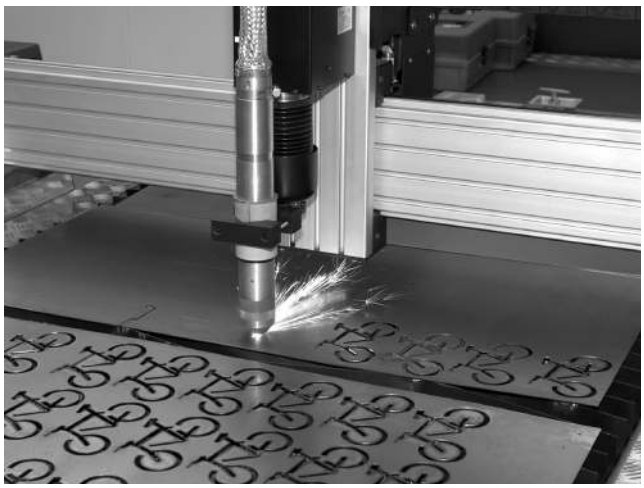
_____

_____

_____

Total Marks 12

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
	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

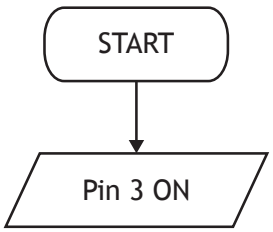
3: Move forward for 0·5 seconds

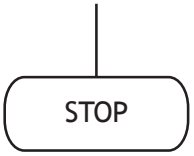
4: Repeat steps 2 and 3 four times

5: Switch off laser and motors

13. (continued)

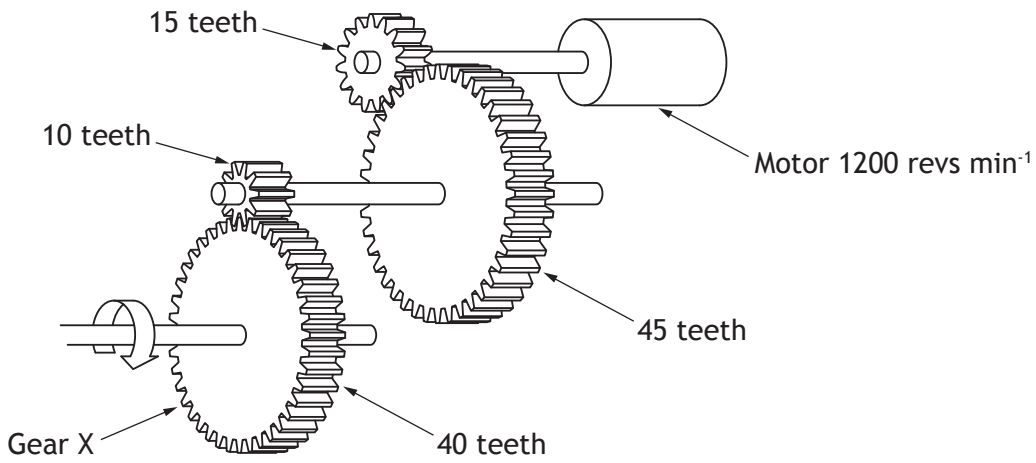
(a) Complete the system flowchart below, to produce the required sequence of operations. The flowchart must include appropriate pin numbers. You may use information from the National 4/5 Data Booklet provided. **7**





13. (continued)

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



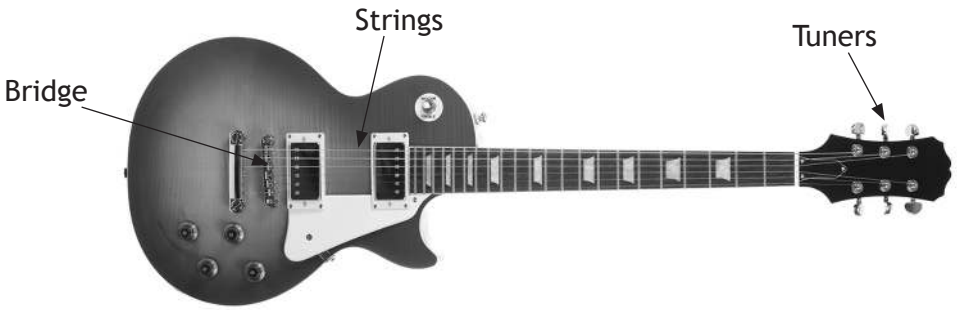
(b) (i) State the name of this type of drive system. **1**

_____

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

Total Marks 12

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, a reason for your choice of alloy. **1**

_____

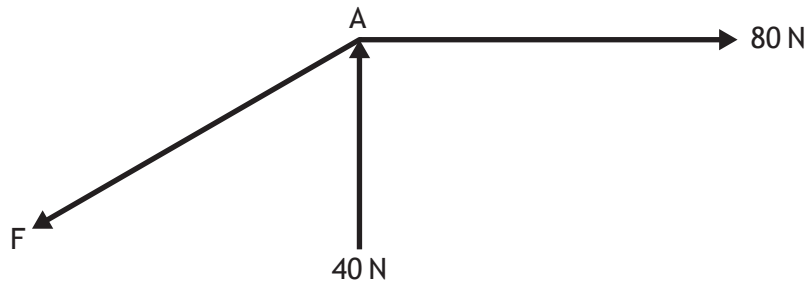
_____

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

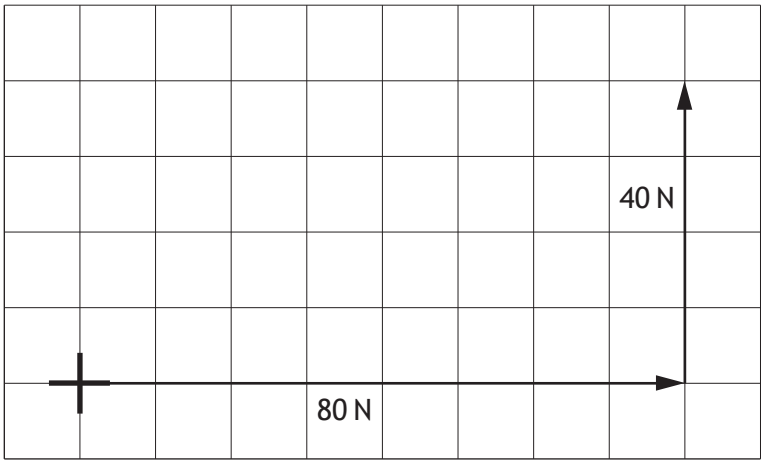
(b) Calculate the stress in the guitar string. **2**

14. (continued)

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



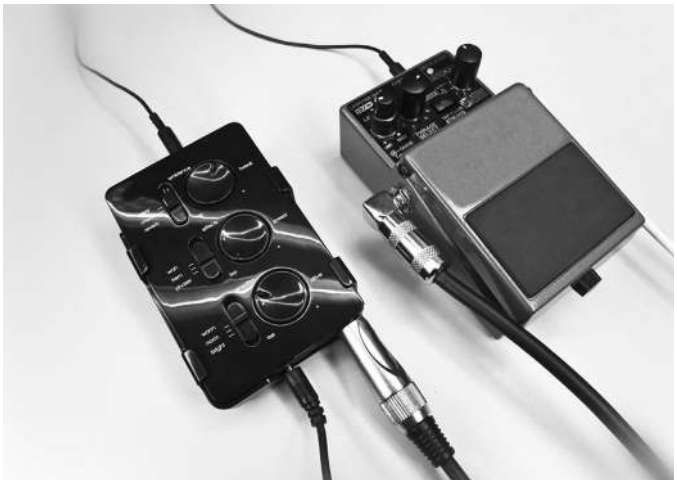
(c) Determine the size of force F using the scale drawing of the triangle of forces shown in the diagram below (or otherwise). **1**



F = _____ N

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) State **two** reasons why a microcontroller might be used in place of a hard wired circuit in the effects pedal. **2**

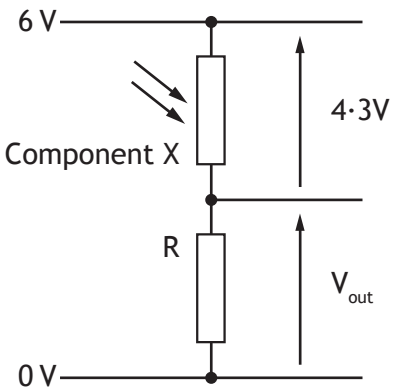
_____

_____

Total Marks 7

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**

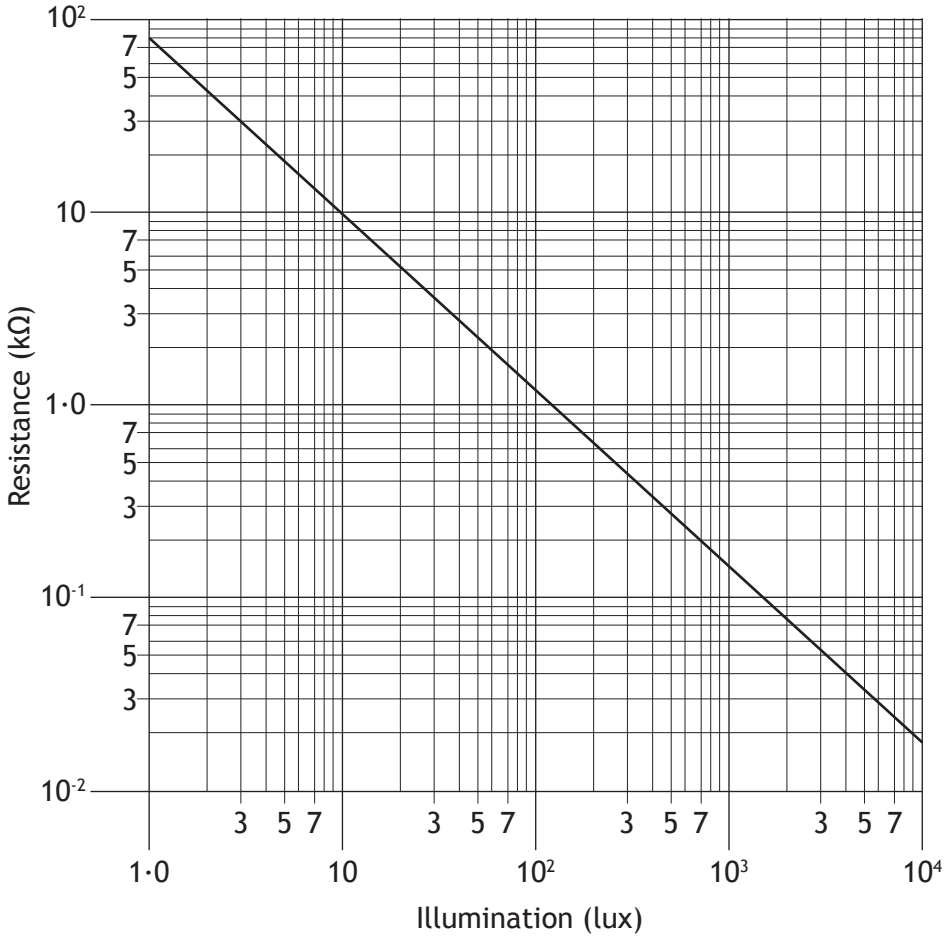
(c) Calculate the value of the V_{out}. **1**

Component X is found to have a resistance of 1.5 kΩ.

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

15. (d) (continued)

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



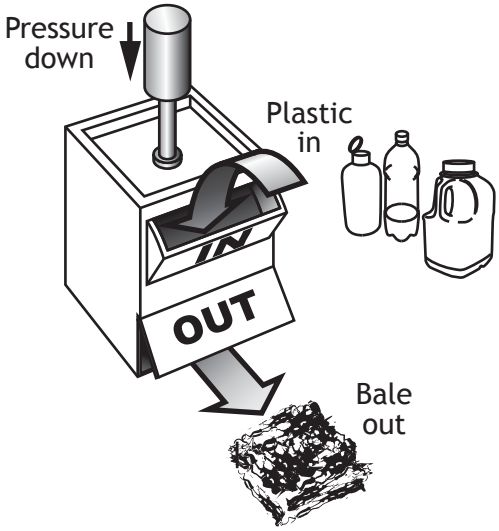
(ii) State, by referring to the graph, the light level when the resistance of component X is 10 kΩ. **1**

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

Total Marks 10

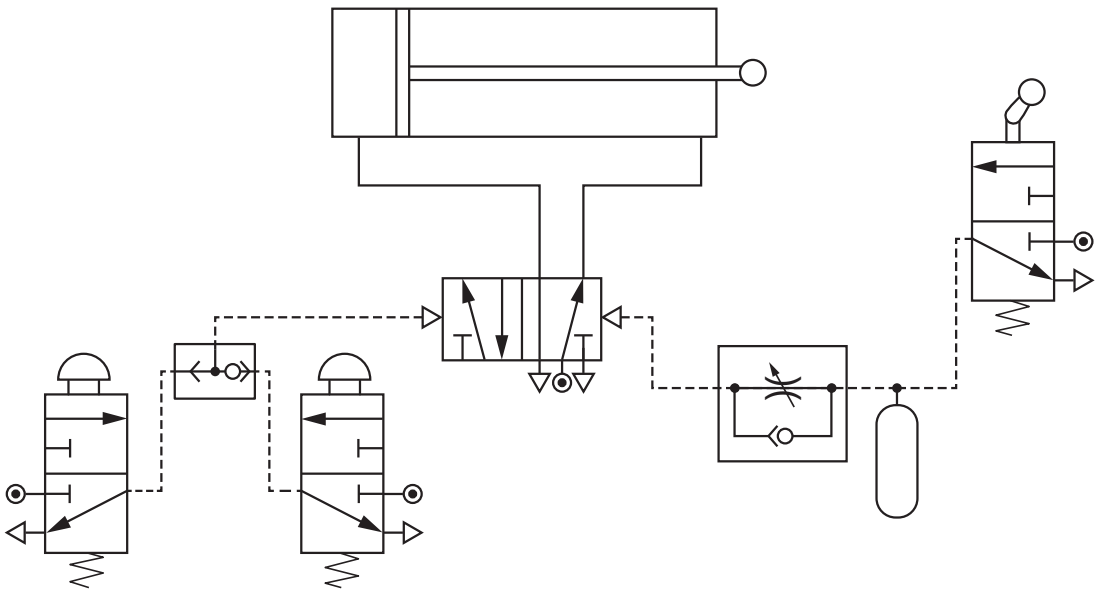
16. A prototype system to compress plastic bottles is operated by pneumatics.

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).



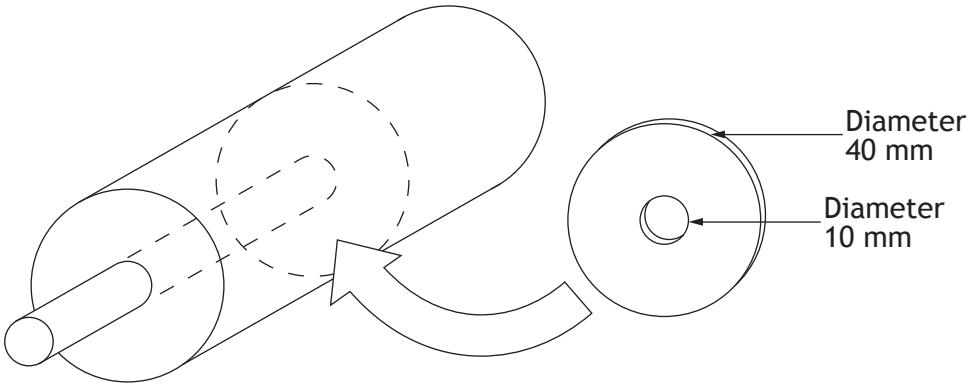
A proposed design for the system is shown in the diagram below but it has been found to have two faults.

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



16. (continued)

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



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

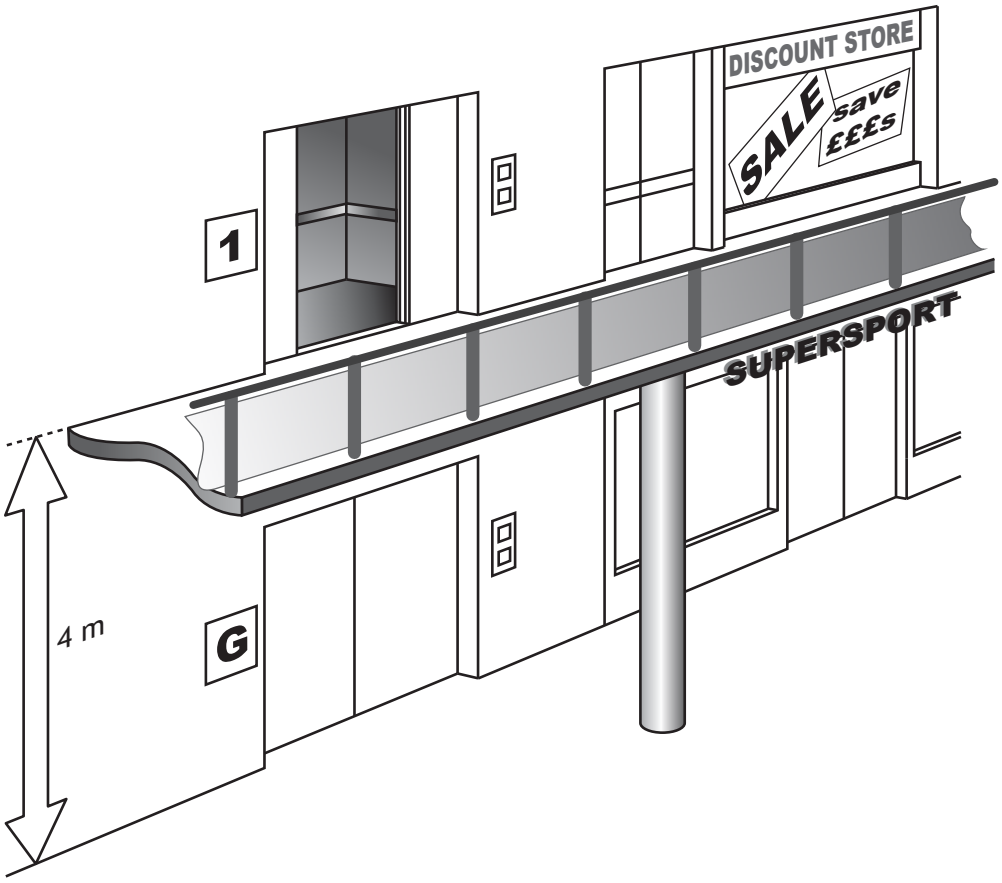
The reservoir and the uni-directional restrictor perform the delay function of the system.

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

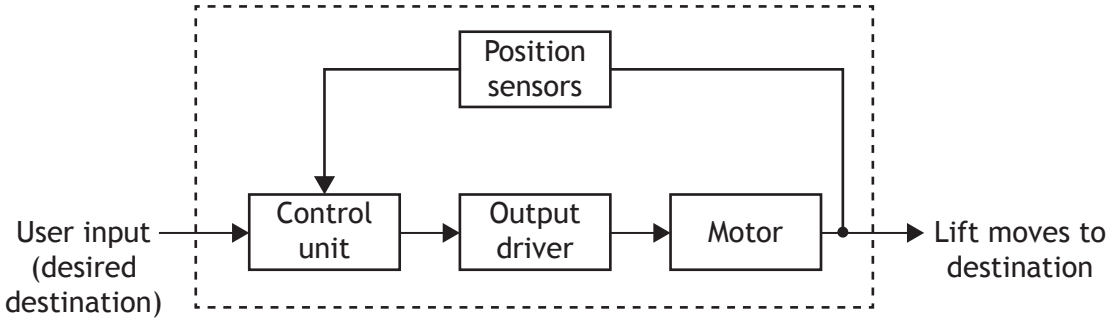
Total Marks 7

MARKS | DO NOT WRITE IN THIS MARGIN

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 operation of the lift **with reference to the diagram** and using appropriate terminology. **3**

17. (continued)

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 moves up the 4 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. **3**

(iii) Explain why the lift will actually take longer than expected to reach the first floor. **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**

Total Marks 12

[END OF SPECIMEN QUESTION PAPER]

National
Qualifications
SPECIMEN ONLY

SQ12/N5/01 Engineering Science

Marking Instructions

These Marking Instructions have been provided to show how SQA would mark this Specimen Question Paper.

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Part One: 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, ie marks should be awarded for what is correct and not deducted for 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).

Part Two: Marking Instructions for each question

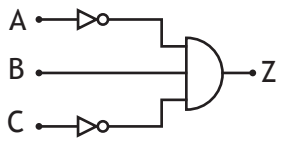
Section 1

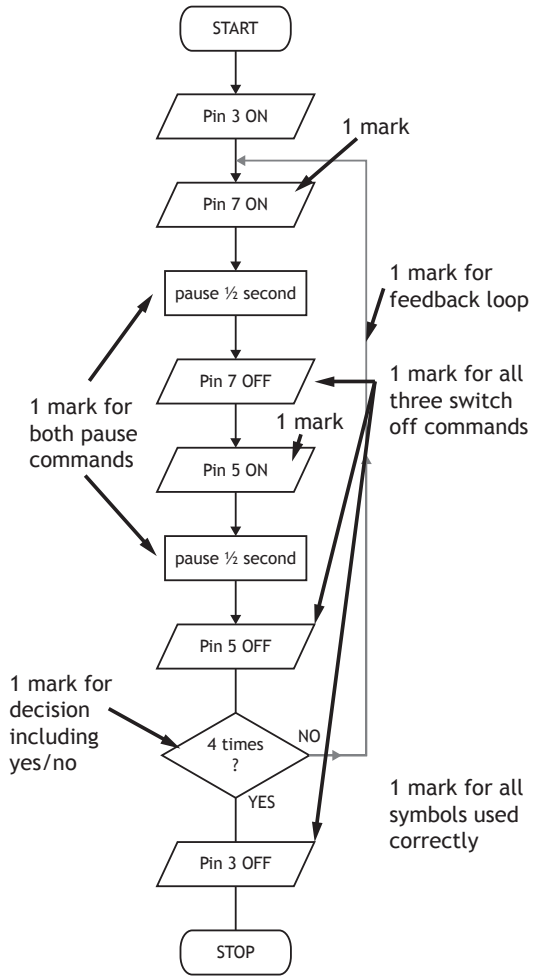
Question			Expected response	Max mark	Additional guidance
1			Open loop systems have no feedback (1). Closed loop systems have feedback (1).	2	
2			Free body diagram	1	
3			It acts as a link allowing a low powered electronic control circuit to switch/ control a high powered electrical circuit	2	1 mark 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			$\varepsilon = \frac{\Delta l}{L}$ $= 2/300$ (1 mark for substitution) $= 0{\cdot}0067$ (1 mark for correct answer from candidate's working)	2	
9	**a**		A or B	1	
9	**b**		C or D	1	
10			Row 4: 1 (1) Row 5: 0 (1)	2	

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**	Mechanical 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 mechanical 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)	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 (400 x 0·5) + (300 x 1·5) + (250 x 2·5) = R2 x 3 (1 for substitution) R2 = $\frac{1275}{3}$ (1 for manipulation) = 425 N (1 for correct answer from candidate's working)	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) $I = \frac{(5 - 0{\cdot}7)}{400}$ (1 mark for calculating voltage) (1 mark for substitution) = 10·7 mA (1 mark for correct answer from candidate's working)	4	
12	c		1 mark for any valid reason described, eg real, expensive components will not be damaged if there is a problem or mistake.	1	
12	d		1 mark for each of any four valid statements, such as: • a pilot signal is sent to the 5/2 valve causing it to change state • main air is then sent to the double acting cylinder causing the piston to outstroke • the piston outstrokes slowly due to the uni-directional restrictor • when it is fully outstroked it actuates the 3/2 valve • the 3/2 valve sends a pilot signal back to the 5/2 valve • this causes it to change state and instroke the piston • the piston instrokes at full speed	4	

Question			Expected response	Max mark	Additional guidance
13	a			7	
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 rev/min (1 mark for answer from candidate's working) *Second pair of gears* 400 x 10 = 40 x Output speed (1 mark for substitution) Output speed = 100 rev/min (1 mark for answer from candidate's working)	4	

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.)
14	**d**		Any two valid points, such as: (1 mark for each) • 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 — 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)	3	
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 20^2 = 1256 mm^2 (1 mark for calculating area) Instroking area = 1256 – (3·14 x 5^2) = 1177·5 mm^2 (1 mark for instroking area) Force = Pressure x Area = 2 x 1177·5 (1 mark for substitution) = 2355 N (1 mark for correct answer from candidate's working)	4	

Question			Expected response	Max mark	Additional guidance
16	**c**		1 mark for a valid method, eg: • change the setting on the uni-directional restrictor • change the size of the reservoir	1	
17	**a**		Up to 3 marks for three 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 output driver provides the power required to operate the motor. • The position sensors provide feedback.	3	
17	**b**	**i**	E_p = mgh = 1250 x 9·8 x 4 (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	
17	**b**	**iii**	Energy would be lost (1) in the form of heat/sound (1).	2	
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	

[END OF SPECIMEN MARKING INSTRUCTIONS]