



FOR OFFICIAL USE

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National
Qualifications
SPECIMEN ONLY

Mark

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SQ13/H/01

Engineering Science

Date — Not applicable

Duration — 2 hours



Fill in these boxes and read what is printed below.

Full name of centre

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Town

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Forename(s)

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Surname

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Number of seat

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Date of birth

Day

Month

Year

D	D
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M	M
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Y	Y
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Scottish candidate number

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Total marks — 90

SECTION 1 — 20 marks

Attempt ALL questions.

SECTION 2 — 70 marks

Attempt ALL questions.

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.

Numerical answers should include units, and be rounded to an appropriate number of significant figures.

Show all working and units where appropriate.

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

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.

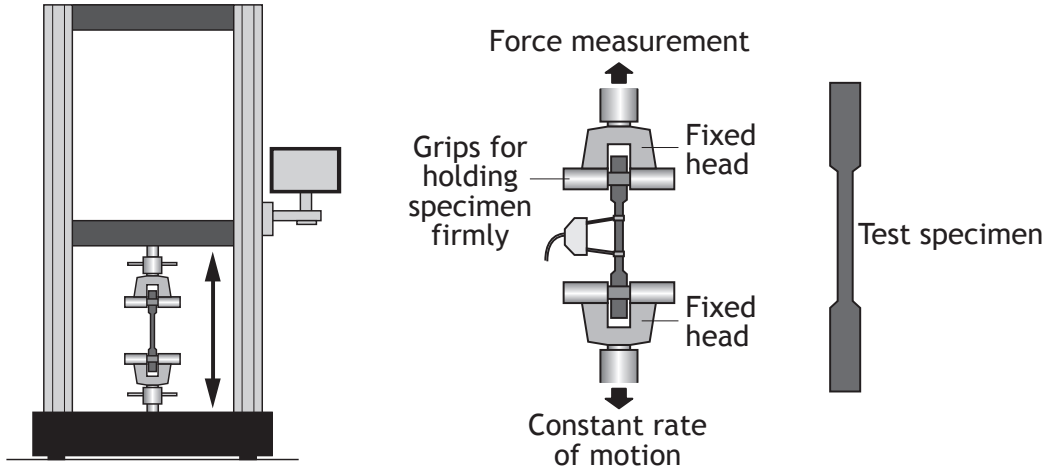


SECTION 1 — 20 marks

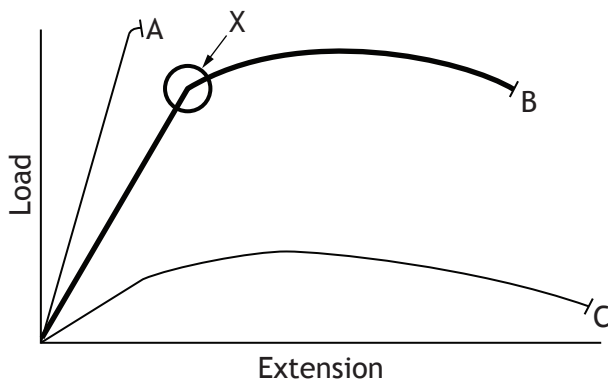
Attempt ALL questions

MARKS
DO NOT WRITE IN THIS MARGIN

1. A structural engineer has asked for a tensile strength test to be carried out on three metal specimens (A, B and C) using the equipment shown.



The results are displayed on the load extension graph shown below.



- (a) (i) State which of these metals has the highest value of Young's Modulus. 1

- (ii) Describe what this means. 1

- (b) Describe, using appropriate terminology, the way in which metal B responds to loading around X. 2

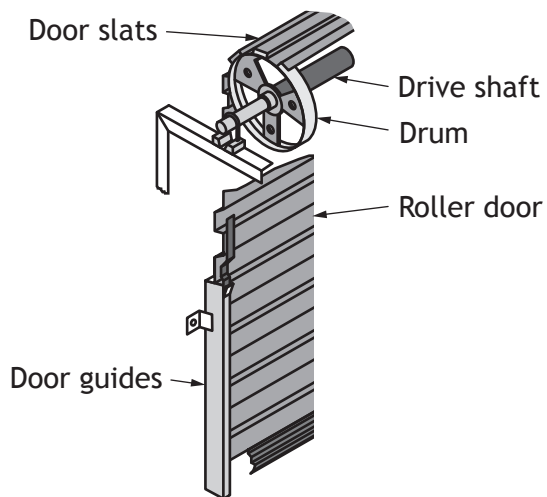


2. A mechanical engineer is developing the drive and control system for the automatic garage roller door shown.

The door is to be opened and closed using a direct current motor controlled by a microcontroller.

The motor rolls the door slats around a drum to open and close it as shown.

For safety, the garage door must slow down gradually and stop when it is fully open or closed.



(a) Sketch a graph of the pulses sent to the motor by the microcontroller as the door approaches being fully closed. Label both axes of the graph, a mark and a space. You should show at least 6 pulses.

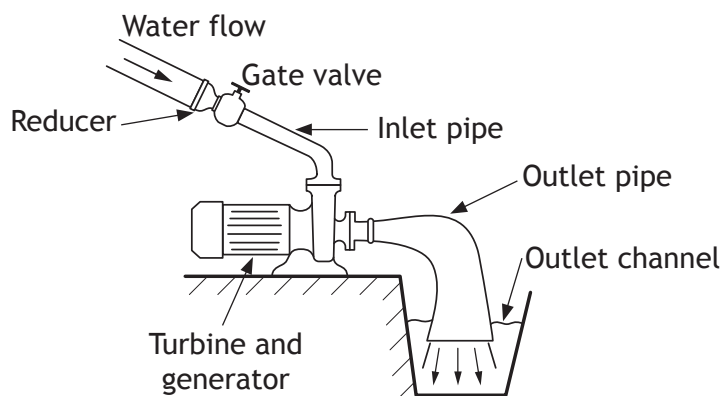
3

The diameter of the drum is 0.186 m and the force required to be applied to the roller slat is 127 N.

(b) Calculate the torque supplied by the drive shaft.

2

3. An energy engineer is carrying out an audit on the micro-hydro system shown.



The engineer measured the electrical output from the generator to be 22 A at 230 V. The mass of water flowing through the inlet pipe into the generator was 2500 kg every second at an average flow rate of 3.2 ms^{-1} .

(a) Calculate the efficiency of the system.

3

(b) (i) Explain why it is impossible to achieve 100% efficiency in any system.

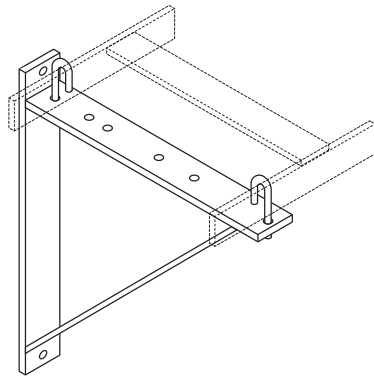
1

(ii) Describe **one** modification that could be made to this system to improve its efficiency.

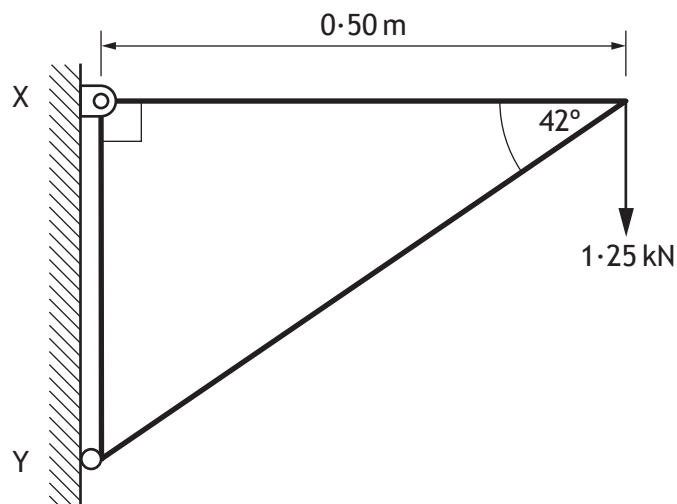
1



4. 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.

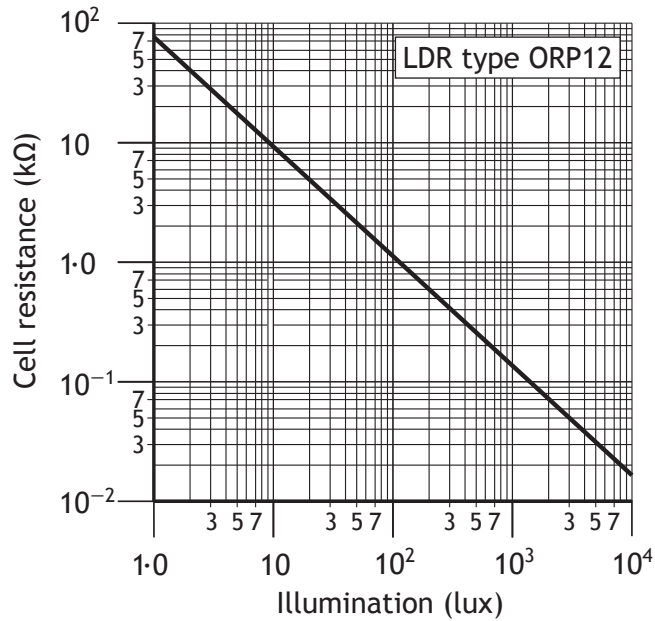
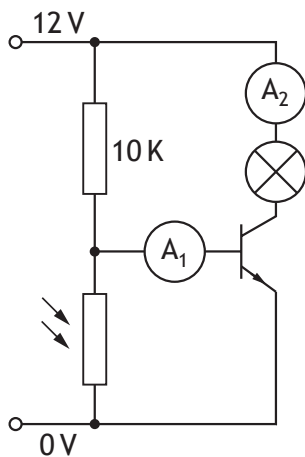
3



5. An engineering technician is testing the circuit shown below to determine the gain of the bipolar junction transistor (BJT).

MARKS

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- (a) Determine the light level to fully saturate the transistor. Refer to the graph shown, which shows how the resistance of the LDR responds to light level. Assume $V_{BE} = 0.7\text{V}$.

2

The two currents measured at A_1 and A_2 were 1.2mA and 110mA respectively.

- (b) Calculate the h_{FE} value.

1



SECTION 2 — 70 marks

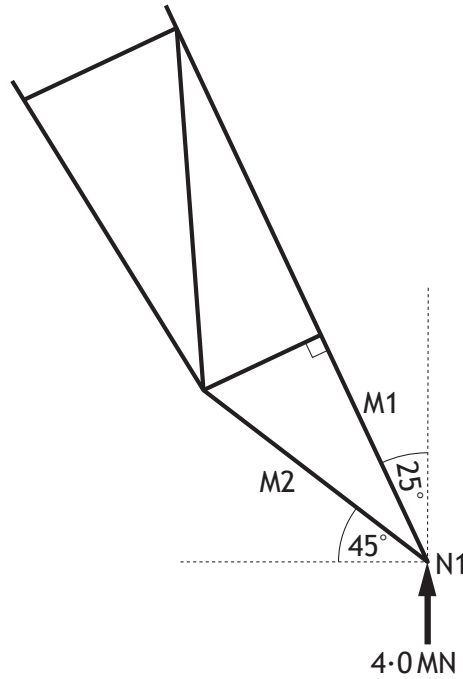
Attempt ALL questions

MARKS

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1. A new railway station is being built. A structural engineering company has been asked to produce detailed information about a possible station roof.

Detail from a proposed design for one of the roof's steel support legs is shown.



- (a) Node N1 is in static equilibrium. M2 is a tie.

Calculate the magnitude of the forces in members M1 and M2.

5



* S Q 1 3 H 0 1 0 7 *

1. (continued)

(b) Describe **three** examples of how a structural engineer would **apply** knowledge of materials, and/or skills in carrying out calculations, in the design of the structure shown above.

3

Example 1 _____

Example 2 _____

Example 3 _____

(c) Describe **two** positive **economic** impacts and **one** negative **economic** impact that the station project might have on the local community **during the construction phase.**

3

Positive impact 1 _____

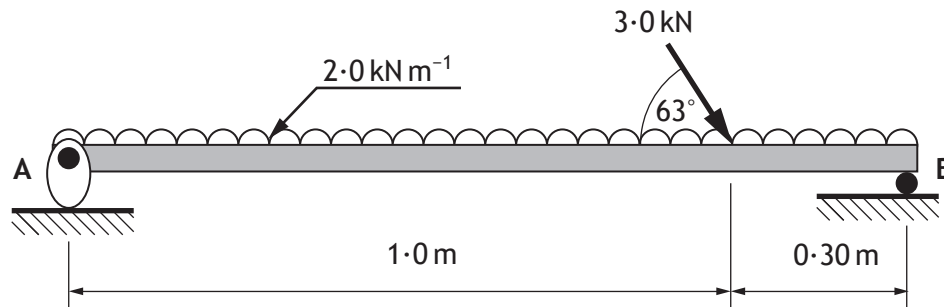
Positive impact 2 _____

Negative impact _____



1. (continued)

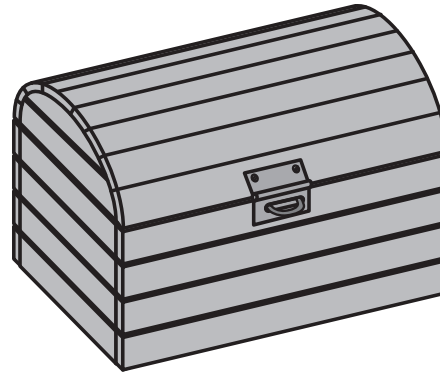
During the design phase, a scale model of a particular loading condition was constructed, as shown below.



(d) Determine the magnitude and direction of the reaction at A.

4

2. The research and development department of a toy company has appointed an engineering team to redesign the wooden treasure chest shown.



- (a) The development team includes a mechanical engineer and an electrical/electronic engineer.

For each type of engineer, state **one specialist skill** and **one piece of specialist knowledge** which they could contribute to the redesign.

4

Mechanical engineer

Specialist skill _____

Specialist knowledge _____

Electrical/electronic engineer

Specialist skill _____

Specialist knowledge _____

- (b) Suggest an alternative material which could be used instead of wood to construct the treasure chest, and explain why it would be an improvement.

1



2. (continued)

The first prototype developed has an electronic control system with three inputs and one output.

The inputs are:

- a micro-switch (L) which goes low when the lid is opened
- a lock/unlock switch (O) which goes high when set to the unlock position
- a secret security button (S) which goes high when it is pressed

The output is:

- a buzzer (B) which sounds when it goes high

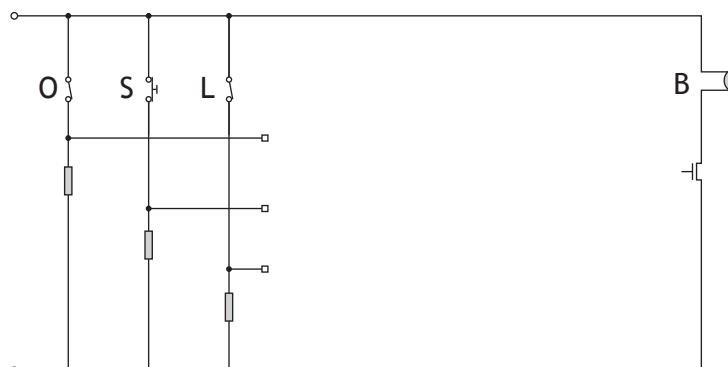
The buzzer must **not** sound when the lid is shut.

The buzzer must **not** sound when the lid is unlocked by its owner, while the secret security button is pressed.

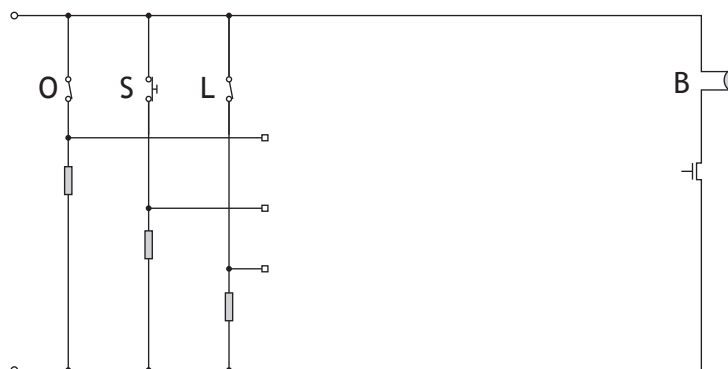
- (c) (i) Write a Boolean expression for the buzzer **not to sound** (in its simplest form). 1

$\bar{B} =$ _____

- (ii) Complete the circuit diagram below to carry out this function using only a combination of AND, OR and NOT gates. 3



- (iii) Redraw the circuit diagram using only two-input NAND gates to carry out the same function. Cross out any redundant gates. 3



2. (continued)

A second prototype uses a microcontroller to process a three digit code to control the locking system.

Each button can only be pressed once; when pressed, it latches on and stays high.



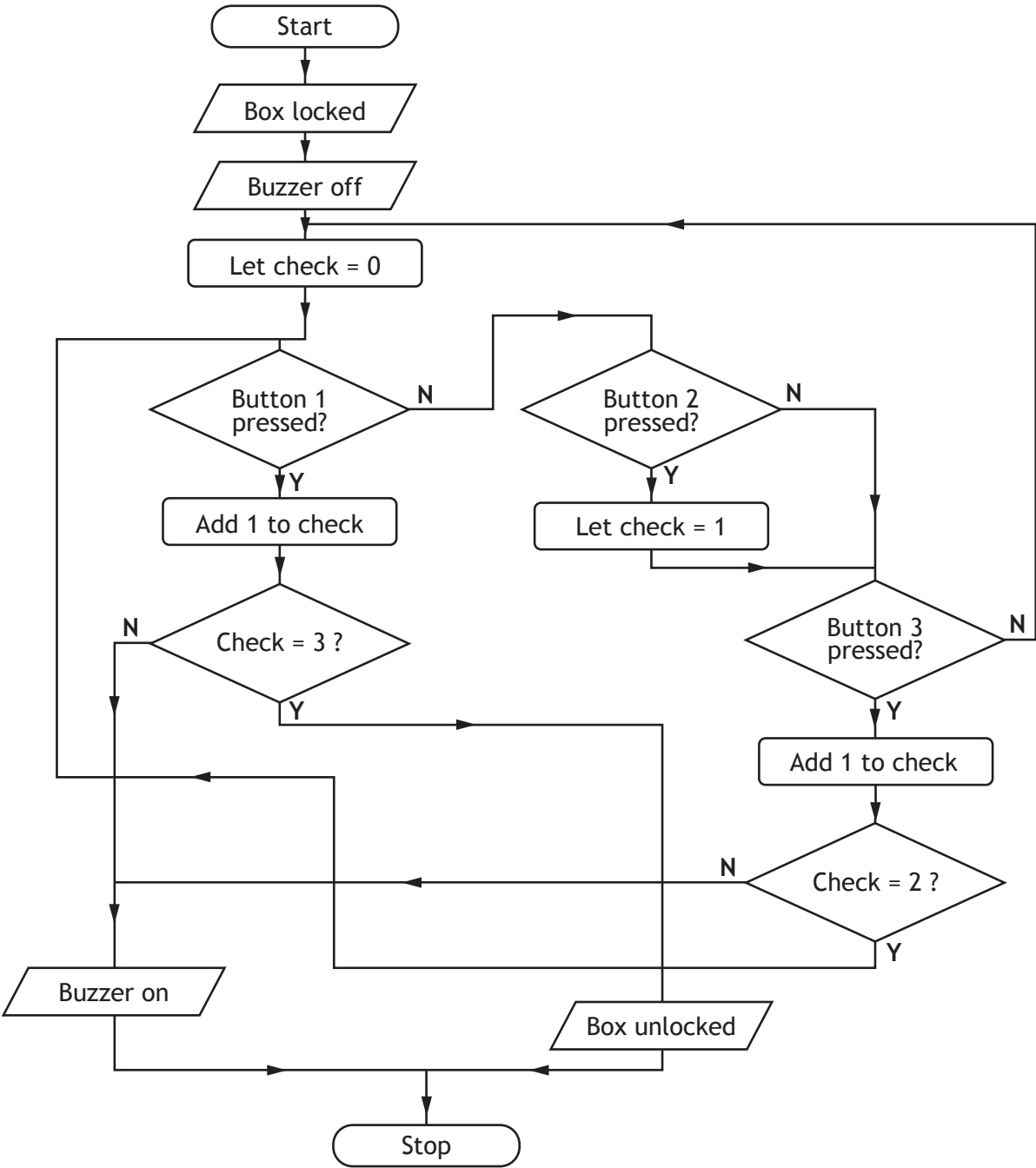
(d) The partly completed table below lists all possible codes that could be entered. Only one of these codes will open the box without sounding the buzzer.

Code	Buzzer sounds	Box unlocked	Correct code?
123	✓	✗	no
132			
213	✓	✗	no
231			
312			
321	✓	✗	no

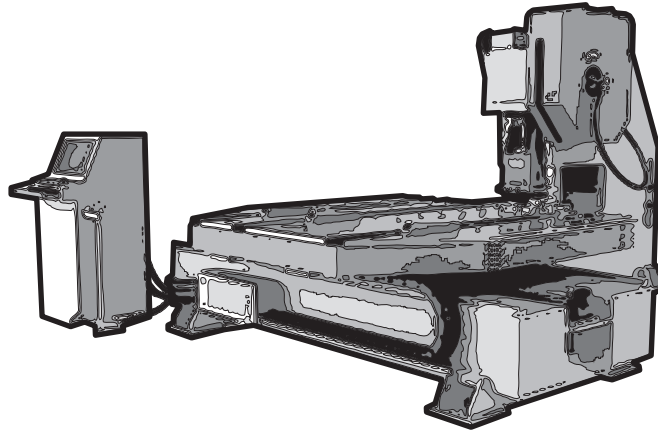
Use the flowchart on the following page to complete the table above, and so identify the correct code to open the box without sounding the buzzer.

3

2. (d) (continued)



3. A punch press for making aluminium cans is shown below. A sequential pneumatic circuit is used to control two cylinders. Cylinder A opens and closes a clamp which holds a piece of aluminium alloy, and cylinder B lowers and raises the head which punches out the can.



During the design stage of the machine, the team of engineers must consider the sustainability of their design.

- (a) Describe **two** aspects of the design of this machine which could improve its sustainability. 2

1 _____

 2 _____

The cylinders are sequentially controlled to repeat the following four steps in a continuous loop:

1. Cylinder A outstrokes (A+)
2. Cylinder B outstrokes (B+)
3. Cylinder B instrokes (B-)
4. Cylinder A instrokes (A-)

- (b) (i) Complete the circuit on the following page, to carry out this sequence.

You may use the **top diagram** for rough working.

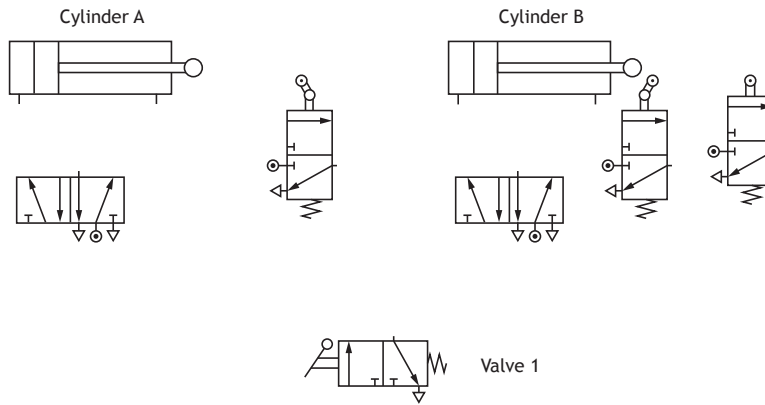
Use the **lower diagram** for your final version. 6



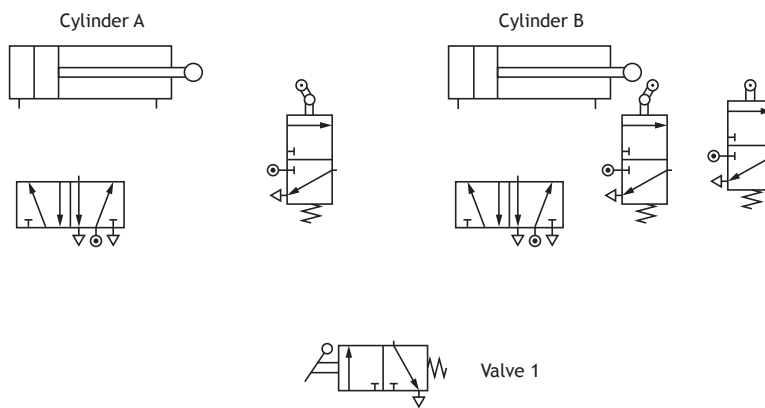
3. (b) (continued)

MARKS DO NOT WRITE IN THIS MARGIN

For rough working only



Final version



- (ii) As a safety feature, the designer of the machine decided to add an extra valve to the circuit. In this new system, two valves have to be actuated together for the sequence to start, producing AND control. Add the valve and actuators to your circuit diagram above and connect it to the rest of the circuit to produce this type of control.

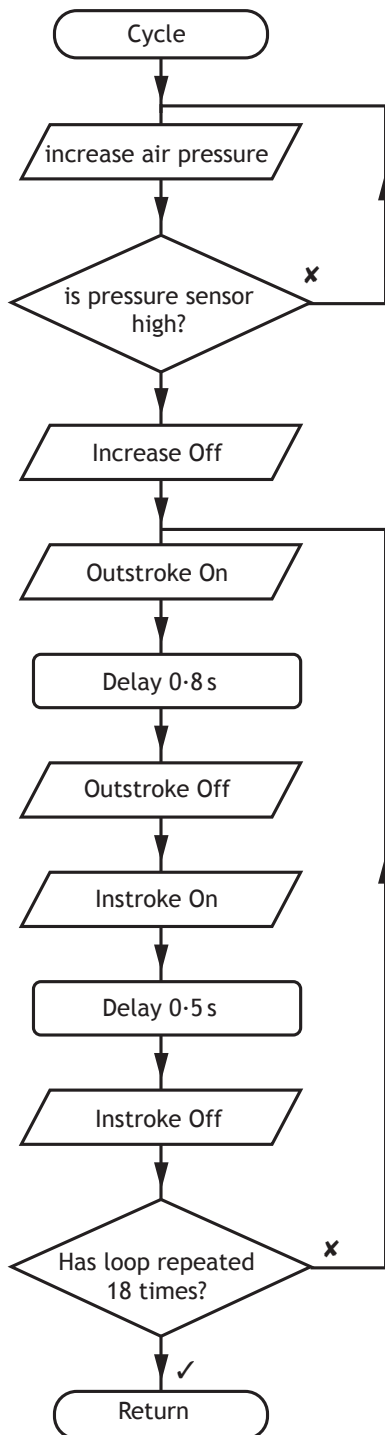
2



* S Q 1 3 H 0 1 1 5 *

3. (continued)

In an alternative design, the punch press is controlled by a microcontroller which provides the sequence of operations required to punch out the can shape. Part of the program sequence is the sub-procedure *cycle*, as described in the flowchart and input/output table below.



Input	Pin	Output
	7	Air pressure increase
	6	Outstroke actuator
	5	Instroke actuator
Pressure sensor	1	

(c) Using a high level language appropriate for programming microcontrollers, write program code which will carry out the sequence required.

4



3. (c) (continued)

MARKS DO NOT
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Write your program code here

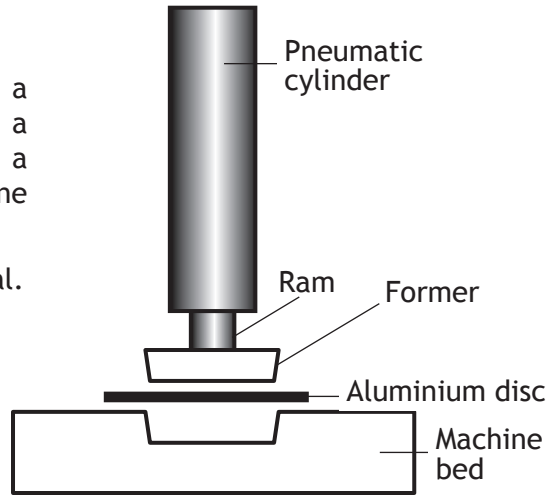


* S Q 1 3 H 0 1 1 7 *

3. (continued)

To make the base of the can, a pneumatic ram and former presses a disc of aluminium alloy into a suitably shaped cavity in the machine bed as shown.

Aluminium alloy is a ductile material.



MARKS

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- (d) Explain why being ductile makes the alloy suitable for this application. 1

The ram is made from alloy steel and applies a force of 6.0 kN to make the aluminium alloy cup. The result of this pressure is **compressive** stress which causes a small change in the length of the ram.

The ram has a diameter of 65 mm and an original length of 120 mm.

- (e) Calculate:

- (i) the change in length of the ram during the pressing operation; 3

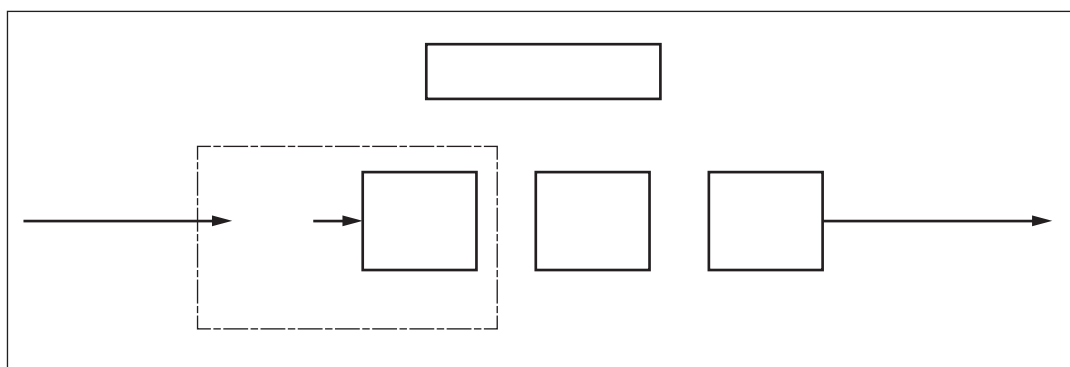
- (ii) the strain energy within the ram due to this change in length. 2



4. The laser level device shown below has an automatic electronic control system. The system uses an accelerometer to sense whether the laser beam is horizontal. If it is not horizontal, a motor adjusts the laser levelling platform position.



(a) Complete a labelled control diagram for this device.



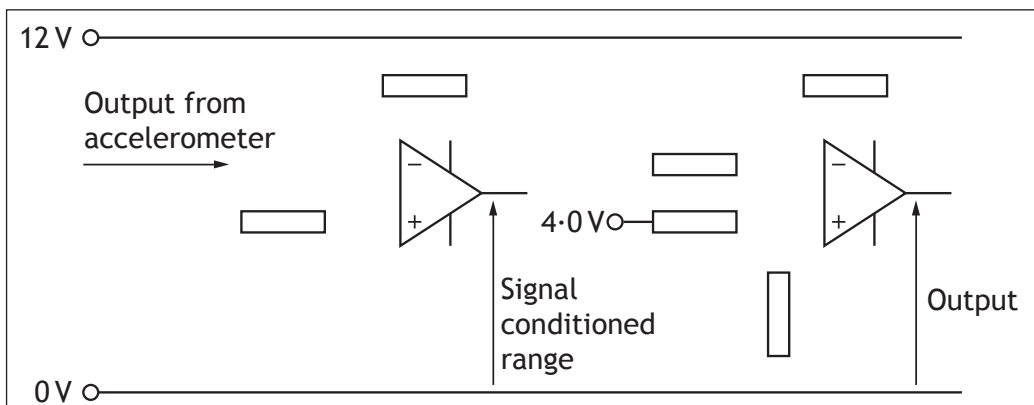
4. (continued)

An electronic engineer designing an op-amp control system for the device has developed the following specification:

- the voltage which represents the laser being horizontal is 4.0V
- the accelerometer produces an output in the range 10–30 mV
- the output from the accelerometer must be amplified to a range of 2.0–6.0 V
- the amplified range should be compared to the desired level voltage (4.0V), and the difference between them amplified by 3.0 to produce the output.

(b) Complete the op-amp control system below. Show all working and component values. You do not need to show the +ve and -ve supplies to the op-amps.

6

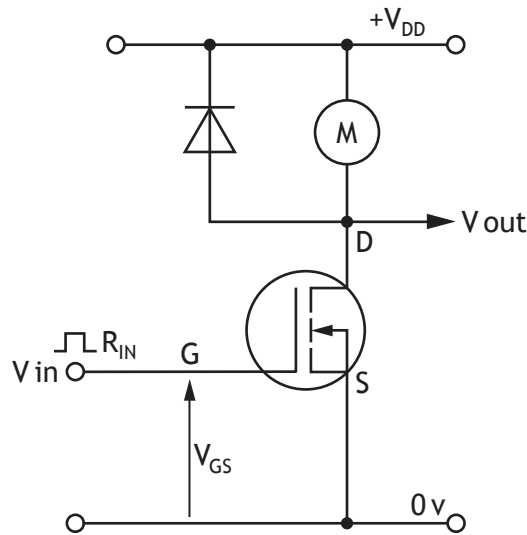


Show working here



4. (continued)

An electronic engineer decided that one of the platform levelling motors would be controlled using the circuit shown below. The motor is controlled by a microcontroller using Pulse Width Modulation (PWM) and it is important the control system uses as little power as possible. The motor has a power rating of 12 V 200 W and the n-channel MOSFET has an R_{DS} value of 0.1Ω and is fully saturated.



(c) Explain why the electronic engineer might choose to use a MOSFET rather than a BJT for this particular application.

4

(d) Describe an emerging technology which may significantly change the design of transistors and other electronic components in the near future.

1



MARKS

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4. (continued)

(e) A particular levelling motion takes 2.3 s.

Calculate the energy dissipated in the MOSFET during the levelling motion.

3

[END OF SPECIMEN QUESTION PAPER]



* S Q 1 3 H 0 1 2 2 *

ADDITIONAL SPACE FOR ANSWERS



* S Q 1 3 H 0 1 2 3 *

ADDITIONAL SPACE FOR ANSWERS

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* S Q 1 3 H 0 1 2 4 *

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