



FOR OFFICIAL USE

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National  
Qualifications  
2016

Mark

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**X723/76/01****Engineering Science**

WEDNESDAY, 11 MAY

9:00 AM – 11:00 AM



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Fill in these boxes and read what is printed below.

Full name of centre

Town

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Forename(s)

Surname

Number of seat

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Date of birth

Day

Month

Year

Scottish candidate number

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**Total marks — 90****SECTION 1 — 20 marks**

Attempt ALL questions.

**SECTION 2 — 70 marks**

Attempt ALL questions.

**Show all working and units where appropriate.**

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.

Reference may be made to the Engineering Science Higher Data Booklet.

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.

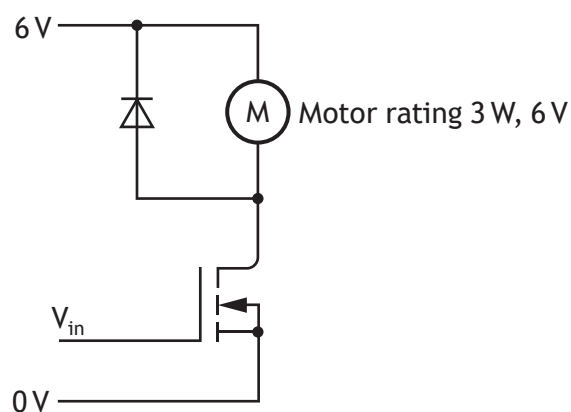


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SECTION 1 — 20 marks

Attempt ALL questions

1. The motor driver circuit shown below is used to switch a motor on and off.



- (a) Calculate the resistance of the motor.

Show all working and final unit.

2

When the circuit is switched on, the resistance of the MOSFET is  $0.5\Omega$ .

- (b) Calculate the MOSFET drain current.

Show all working and final unit.

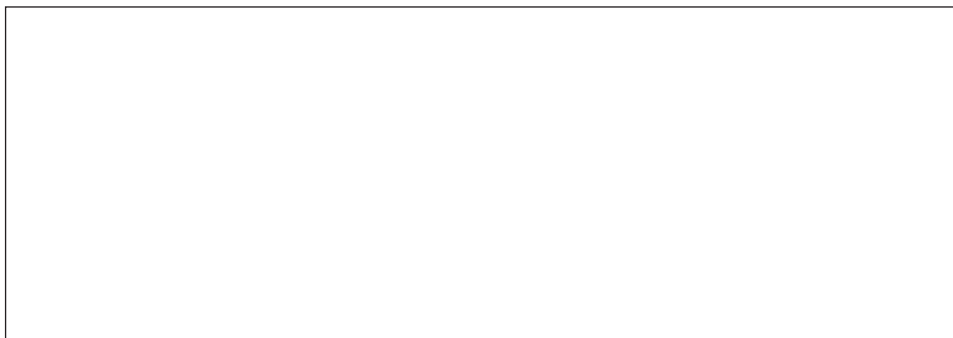
2



## 1. (continued)

- (c) Calculate the power dissipated in the MOSFET when it is switched on.  
Show all working and final unit.

1



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2. A structural member is required to carry a compressive load of 100 kN. The member is made from aluminium alloy and the factor of safety is 4.

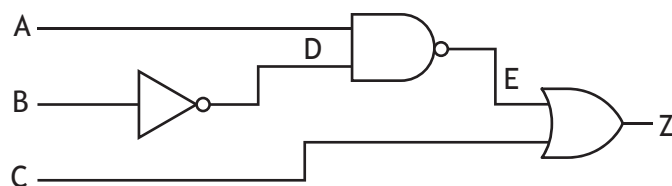
Calculate the diameter of the structural member.

4



\* X 7 2 3 7 6 0 1 0 4 \*

3. A logic circuit for an industrial press is shown below.



(a) Write a Boolean expression for the logic circuit above.

3

(b) Complete the truth table below for the logic circuit. Include the intermediate logic values for D and E.

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			

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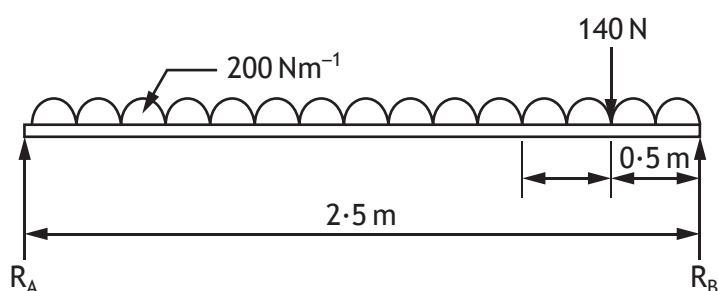
\* X 7 2 3 7 6 0 1 0 5 \*

4. Flat pack furniture and other items are to be stored on shelving in a home improvement store. The shelving must be designed to support both point loads and uniform distributed loads.



mandritoiu/Shutterstock.com

A simplified free body diagram of the forces expected on one shelf is shown below.



Calculate the reaction force  $R_B$ .

3



\* X 7 2 3 7 6 0 1 0 6 \*

5. A manufacturer uses bearings to locate motorcycle wheels.



Explain **two** functions of bearings.

2

Function 1 \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

Function 2 \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

[END OF SECTION 1]

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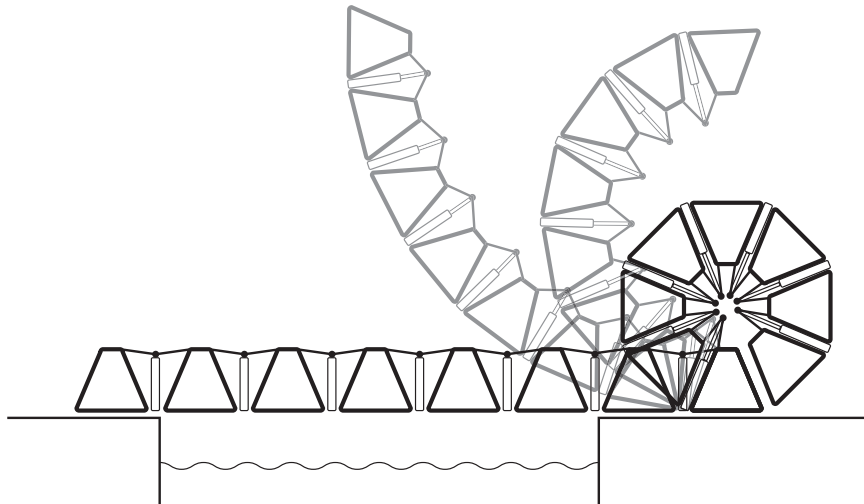


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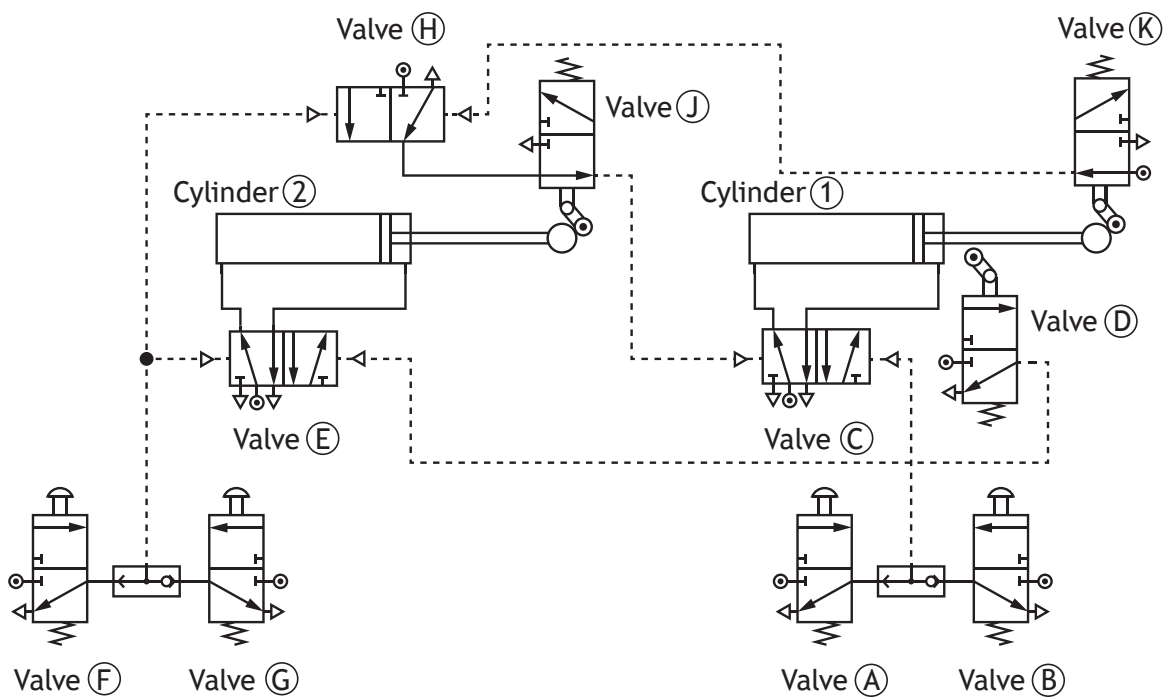
## SECTION 2 — 70 marks

Attempt ALL questions

6. A pneumatically operated bridge is designed to allow pedestrians to cross a canal. It can be extended or retracted by pressing buttons on either side.



The diagram below is a simplified circuit that shows how two of the bridge's cylinders are controlled. As the cylinders instroke the bridge will retract.





8

- [illegible]



\* X 7 2 3 7 6 0 1 0 9 \*

6. (continued)

- (b) Describe **two** modifications that would allow the pneumatics to be controlled electronically.

2

Modification 1 \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

Modification 2 \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

A number of different engineers would be involved in implementation of the bridge project, from design through to completion.

- (c) Describe **two** examples of specialist skills and **one** example of specialist knowledge that a mechanical engineer would use.

3

Skill 1 \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

Skill 2 \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

Knowledge \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_



## 6. (continued)

- (d) Describe the role of one other type of engineer who may be involved in the implementation of the bridge.

2

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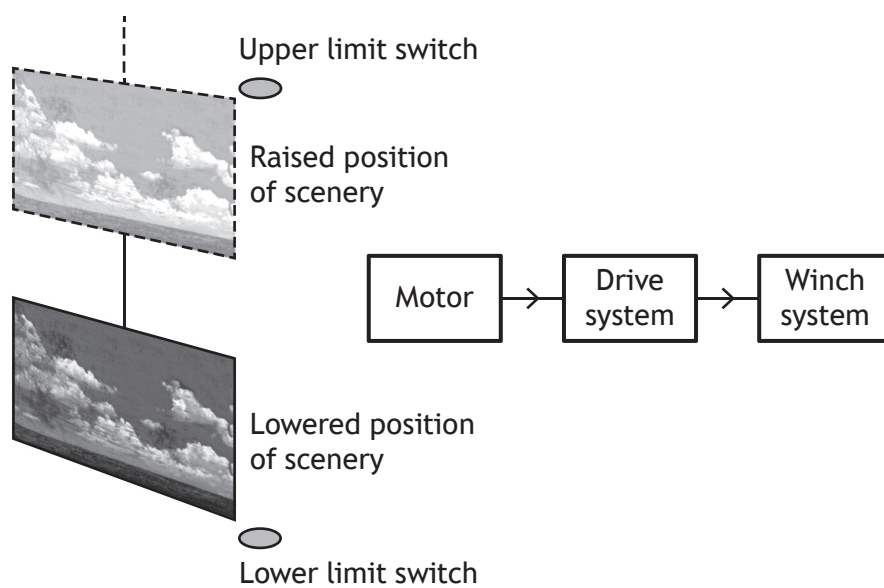


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7. A theatre company requires part of the scenery of their latest play to be raised and lowered by means of an electric winch. The winch has to be controlled by a microcontroller.



An outline diagram of the scenery system is shown below.



**7. (continued)**

Relays are energised when either an Up switch or a Down switch has been activated and a Master switch has also been activated.

The limit switches are used to detect the upper and lower positions of the scenery.

The winch is operated by Relay A and Relay B.

When Relay A is energised the scenery should rise, when Relay B is energised it should lower.

If neither relay is energised, the winch motor should switch off.

Note: the relays are never energised together. The system should run continuously.

The relevant microcontroller connections are shown in the table below.

Inputs	pins	Outputs
	7	Relay A (raise)
	6	Relay B (lower)
	5	
Upper limit switch	4	
Lower limit switch	3	
Down switch	2	
Up switch	1	
Master switch	0	

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## 7. (continued)

- (a) Draw a flowchart to show the control of the winch motor.

8



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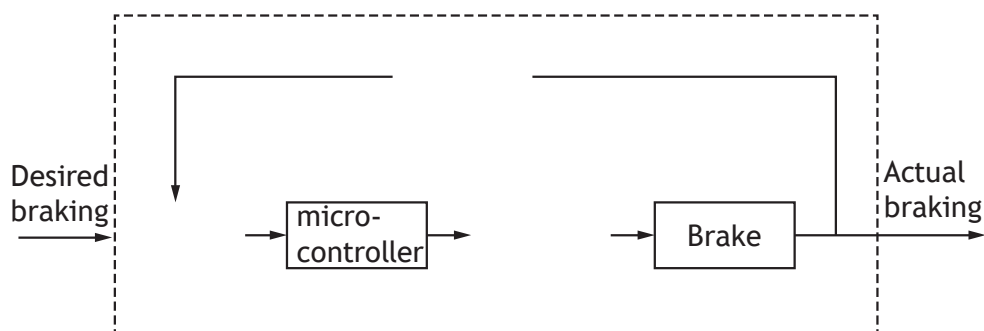
7. (continued)

The electronic engineer used a second microcontroller and interfacing components to design a scenery anti-locking braking system.

- A brake sensor produces a signal when the brake is applied.
- The brake actuator turns on the hydraulic braking system.

(b) Complete the **three** missing parts for the control diagram of the scenery braking system shown below.

3



An Electronic and Electrical engineer would be involved in the design of the scenery system.

(c) (i) Describe **two** examples of specialist knowledge that an Electronic and Electrical engineer would have.

2

Knowledge 1 \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

Knowledge 2 \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

(ii) Describe **two** examples of specialist skills that an Electronic and Electrical engineer would use.

2

Skill 1 \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

Skill 2 \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

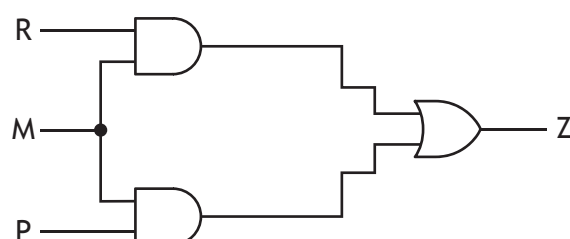


\* X 7 2 3 7 6 0 1 1 5 \*

8. A garage shutter door can be operated via a remote control (R) or a push-button (P). Neither will operate if a main switch (M) is turned off.

INPUTS	OUTPUT
R (= 1 when the remote control is operated)	Z (= 1 to operate the garage door)
M (= 1 when the main switch is on)	
P (= 1 when the push-button is operated)	

The logic diagram below shows the control of the garage shutter door.



- (a) Write a Boolean expression for the logic diagram above.

3

Z = \_\_\_\_\_

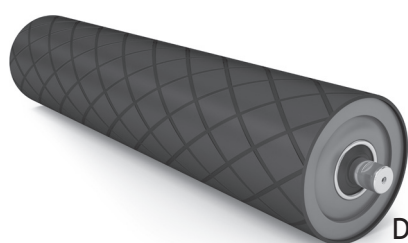
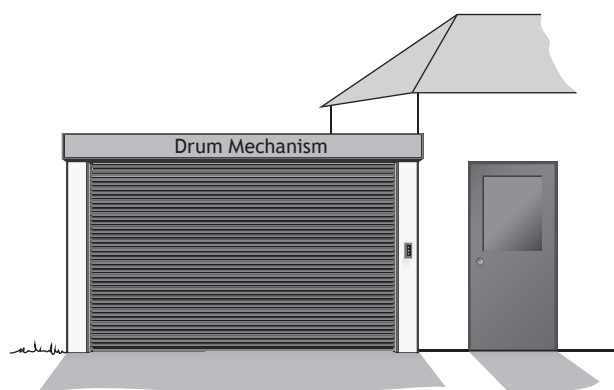
- (b) Using only two-input NAND gates, draw a logic system equivalent to the logic system shown above. Simplify if appropriate.

4



## 8. (continued)

The shutter slats are rolled up and down over a drum mechanism with a diameter of 0.22 m. The mass of the garage door is 62 kg.



- (c) Calculate the torque supplied to the drum mechanism to begin to lift the garage door at constant speed.

Show all working and final unit.

2

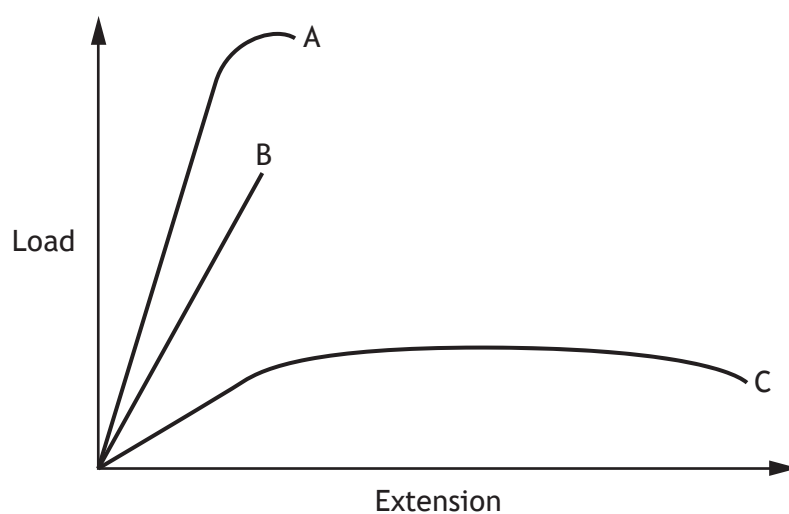


## 8. (continued)

An engineer is to design a bracket to hold the drum mechanism and shutter.



The tensile strength of three newly developed materials A, B and C has been tested and the results are shown on the Load-Extension graph below.



(d) Describe the properties of materials A, B and C in **relation** to each other.

4

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8. (continued)

During a tensile test, a 100 mm long cylindrical sample of material A stretched by 0.7 mm. The sample had a diameter of 15 mm and a Young's Modulus of  $202 \text{ kN mm}^{-2}$ .

- (e) Calculate the load applied to the sample piece.

4

Show all working and final unit.

The drum mechanism uses a mineral based lubricant to reduce friction. The crude oil based lubricant in the mechanism is to be replaced with a vegetable based lubricant.

- (f) Describe **two** environmental and **one** economic effect of this decision.

3

Environmental effect 1 \_\_\_\_\_

Environmental effect 2 \_\_\_\_\_

Economic effect \_\_\_\_\_

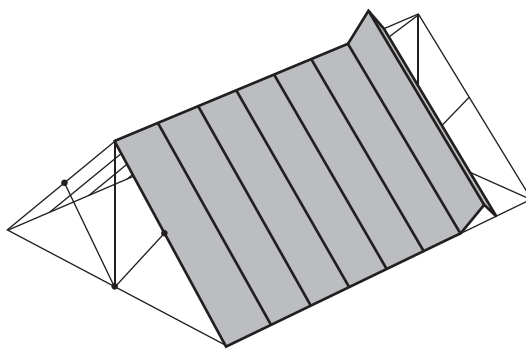


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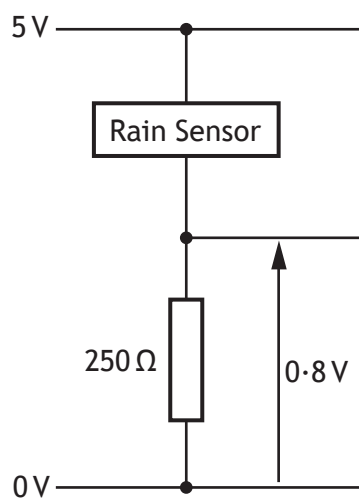
9. A sports centre is building a retractable roof over a synthetic pitch.



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.



## 9. (continued)

- (a) Calculate the resistance of the rain sensor.

2

- (b) 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  $+0.8\text{ V}$  to  $+4\text{ V}$ .

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

1

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- (ii) Calculate the required gain.

1

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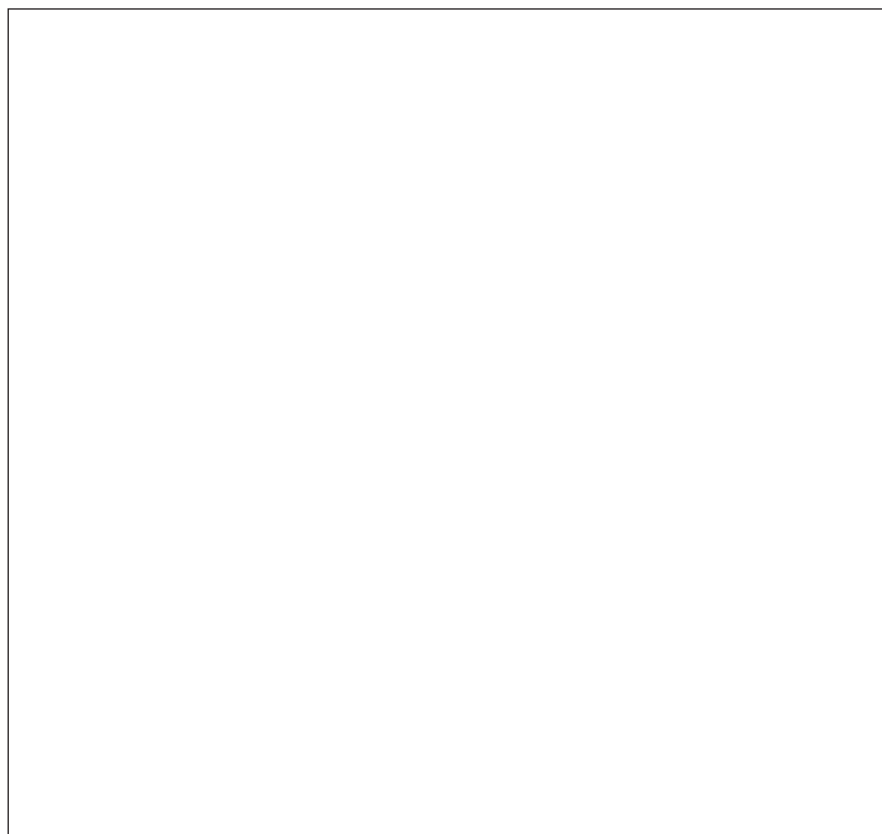


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## 9. (b) (continued)

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

2



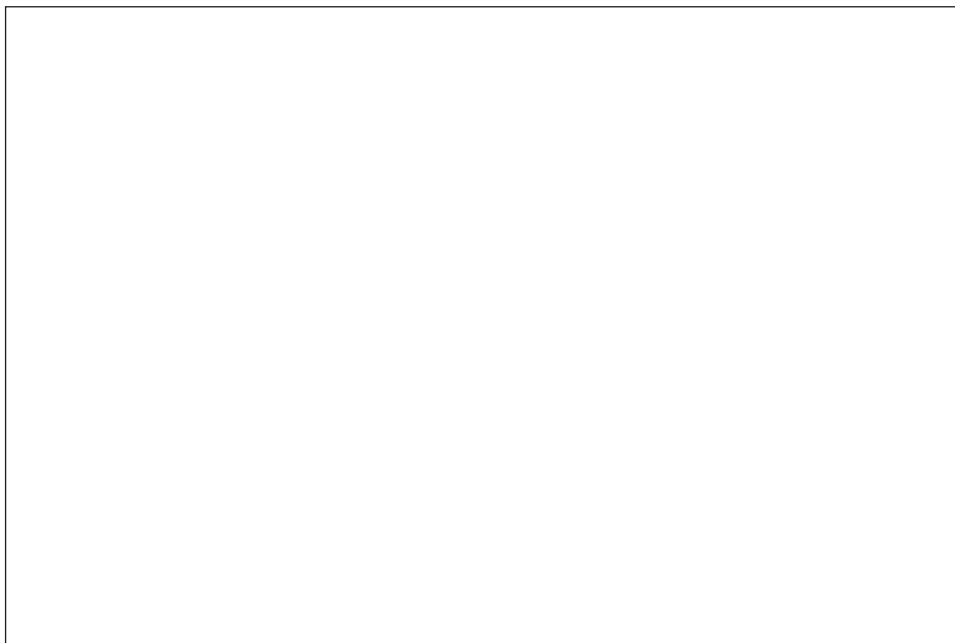
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9. (continued)

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

(c) Sketch a circuit diagram below, showing appropriate resistor values.

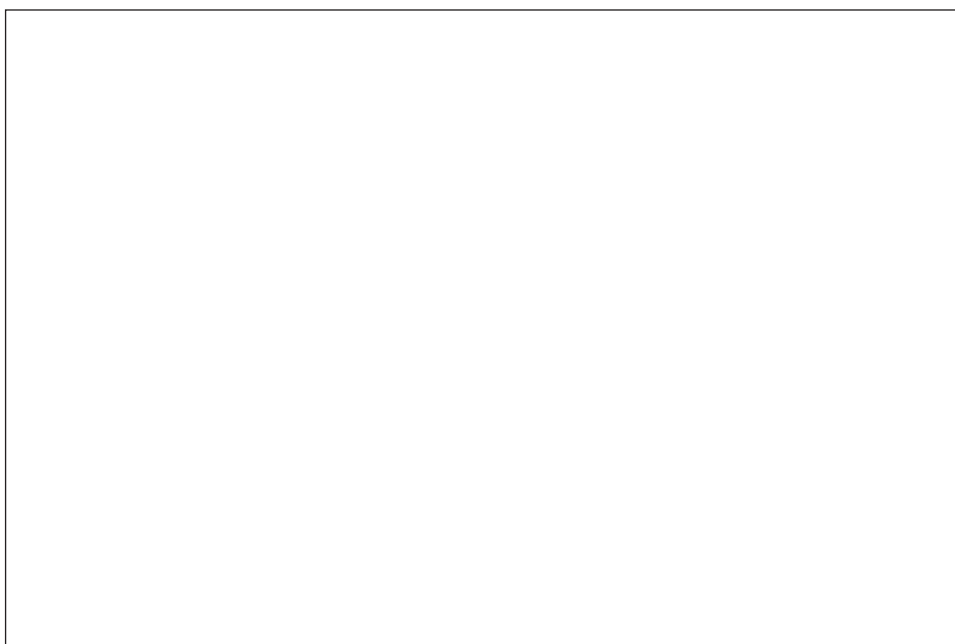
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The roof motor is supplied with 230 V, 3 A. The motor provides a torque of 18.6 Nm at a speed of 300 revs min<sup>-1</sup>. Two motors are positioned symmetrically to open and close the roof.

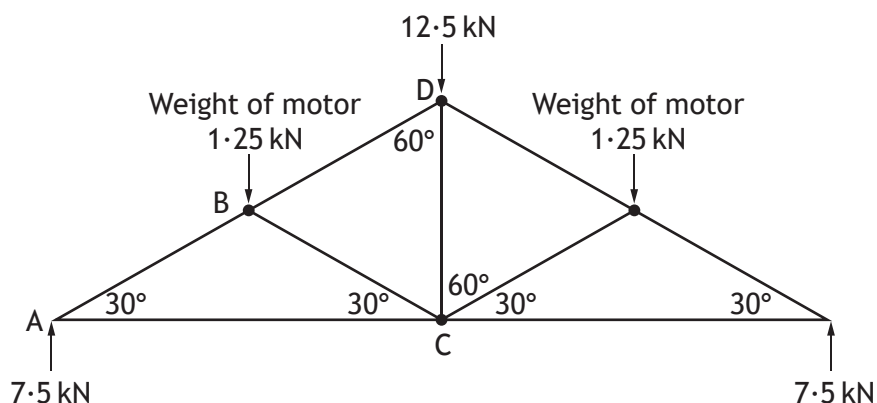
(d) Calculate the efficiency of the roof motor.

3



9. (continued)

- (e) 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.

[END OF QUESTION PAPER]



\* X 7 2 3 7 6 0 1 2 4 \*



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