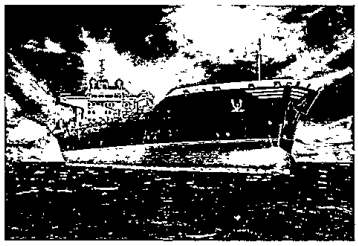
Candidate 1 evidence

SECTION 1 — 20 marks

Attempt ALL questions

1. A new material is being tested for use in the manufacture of ships.



The results of a tensile test on the material are shown in **Figure 1.**

The range of 0 to A is shown magnified in **Figure 2.**

Figure 1

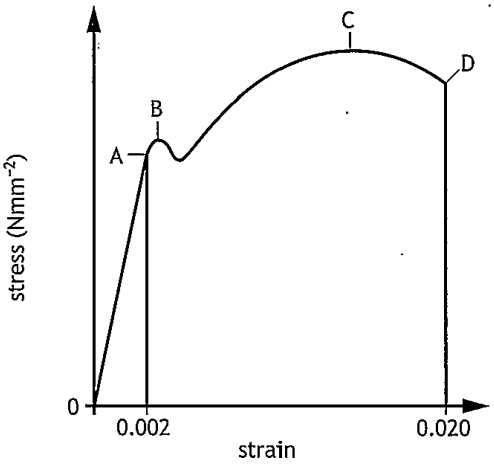
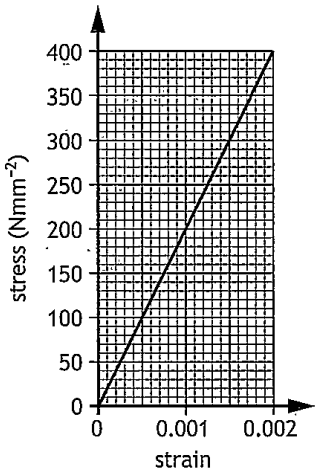


Figure 2



MARKS

1. **(continued)**

(a) (i) State the name of the range 0 to A. **1**

elastic range

(ii) State the name of the range A to D. **1**

plastic range

(b) (i) Calculate, using the information from **Figure 2**, Young's Modulus for this material. **1**

$E = \frac{\sigma}{\epsilon}$

$= \frac{400}{0.002}$

$= 200 \times 10^3 \ N\,mm^{-2}$

$= 200 kN\,mm^{-2}$

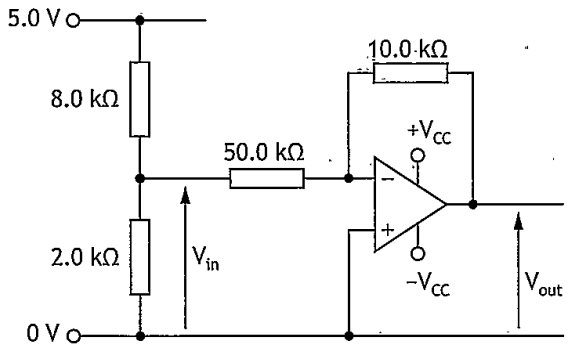
(ii) State the property identified by point C on **Figure 1**. **1**

maximum load

[Turn over

MARKS

2. Part of an electronic circuit is shown.



(a) Calculate V_{out}. 2

$V_{in} = \frac{2}{10} \times 5$

$= 1V$

$V_o = -\frac{10}{50} \times 1$

$= -0.2V$

(b) Describe how the gain of this op-amp circuit could be decreased. 1

increasing the value of R_f.

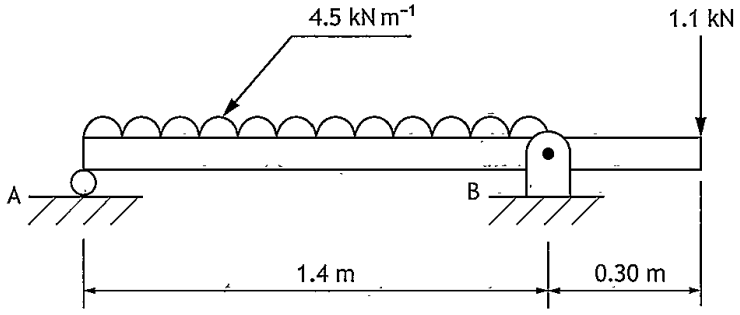
After testing, it was decided to add an additional op-amp configuration to change the polarity of V_{out}.

(c) State the name of the op-amp configuration required to perform this task. 1

inverting

MARKS

3. A beam used in the construction of a covered walkway is shown.



Calculate by taking moments about B, the vertical reaction at A. 3

$4.5 \times 1.4 = 6.3\text{kN}$

~~$1.4A = (6.3 \times 0.7) + (1.1 \times 0.3)$~~

$1.4A = 4.74$

$A = 3.39\text{kN}$

$1.4A + (1.1 \times 0.3) = (6.3 \times 0.7)$

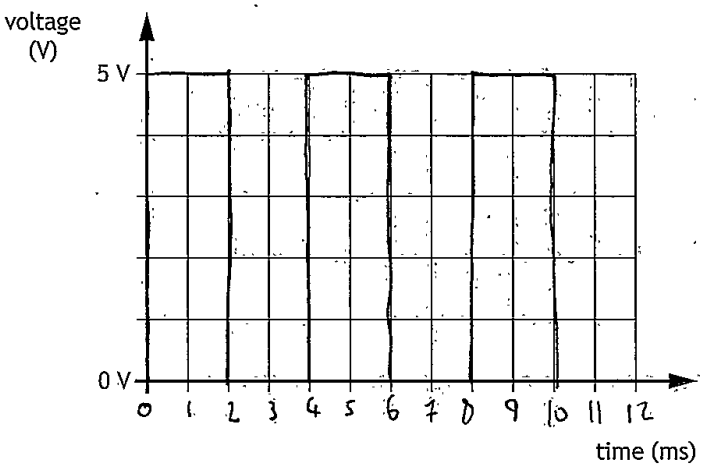
$A = 2.9\text{kN}$

MARKS

4. The speed at which an automatic garage door opens is controlled by a motor using pulse-width modulation (PWM).

(a) Complete the graph below to show how PWM could be used to make the motor rotate at half speed.

You should include at least three pulses. 2



(b) Describe how the speed of this motor could be decreased using PWM. 1

By increasing the space time (gaps inbetween pulses) or by decreasing the mark time (time of pulses).

MARKS

4. (continued)

An alternative method of speed control involves varying the size of the DC voltage supplied to the motor.

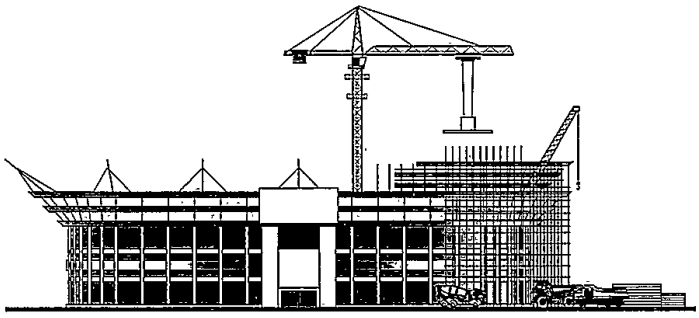
(c) Describe one advantage of using PWM in comparison to varying the size of the voltage supply. 1

It is easier to vary the size of the pulses. Suddenly changing the size of DC voltage can cause large, PWM allows 'soft start'.

[Turn over

MARKS

5. The capacity of a sports stadium is being increased. This needs an additional stand to be built on top of the existing structure.



A structural engineer is involved in the design of this new structure.

Describe two examples of how the structural engineer will use their knowledge of materials in the design of the new structure. 2

Example 1 It is a Sports Stadium so the risk to human life is high if anything fails. The Structural engineer will know what materials to select to ensure the highest factor of Safety needed.

Example 2 The Structural engineer will also have knowledge of the Stresses different materials can withstand before necking. They can use this to help figure out the factor of Safety. The Structural engineer will need to estimate the load put on the materials by the people in the Stadium. The Structural engineer will also need to analyse the old Stand to ensure it can withstand a new one on top of it and potentially where it needs to be reinforced.

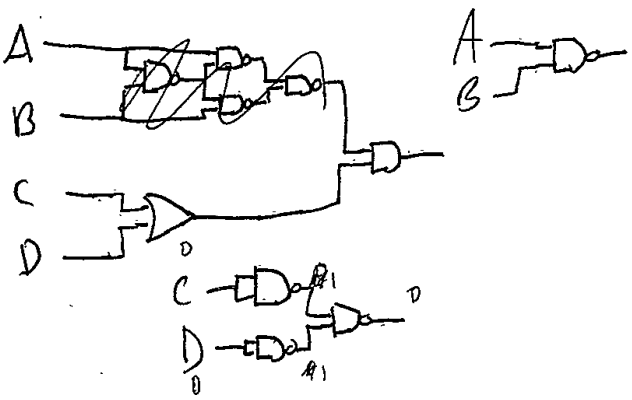
MARKS

6. An electronic engineer has designed a combinational logic circuit according to the Boolean equation, shown below.

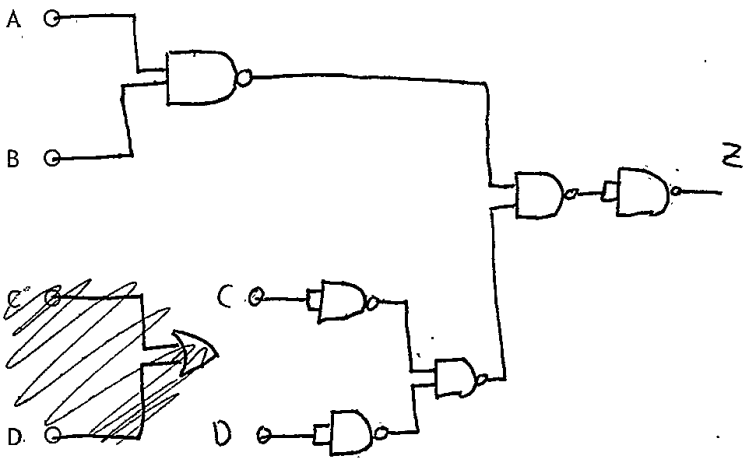
$$Z = \overline{(A \bullet B)} \bullet (C + D)$$

Draw a NAND equivalent circuit for this Boolean equation. 3

Space for working



Final answer

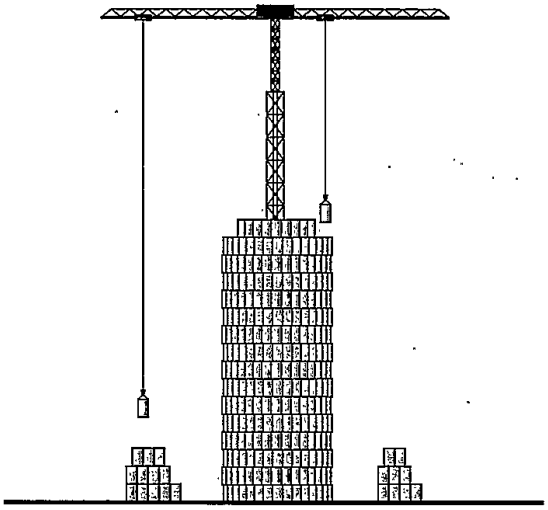


MARKS

SECTION 2 — 90 marks

Attempt ALL questions

7. An engineering team has produced a prototype system to store excess energy from power plants.



When electricity production exceeds demand, electric motors are used to lift concrete blocks and place them in 'towers'. When the blocks are returned to ground level electricity is reclaimed by generators.

The first block has a mass of 10,000.0 kg. The system that raises this block is 92% efficient.

(a) Calculate the energy required to raise this block 32 m. 2

$E = mgh$

$= 10,000 \times 9.8 \times 32$

$= 3136\ kJ \times 1.08$

$= 3387\ kJ$

$= 3390\ kJ$

$= 3.39 \times 10^6\ kJ$

MARKS

7. (continued)

A second block applies a force of 80.0 kN to the supporting wire rope.

As this block is returned to ground level (at constant speed) its supporting wire rope turns a generator and electricity is reclaimed. This part of the system is 87% efficient.

(b) Calculate the power output from the generator if this block descends 15 m in 11 seconds. 3

$P = \frac{e}{t}$

$= \frac{130 \times 10^6}{11}$

$= 11.8\,MW$

$e = mgh$

$= (80 \times 10^3 \times 9.8) \times 9.8 \times 15$

$= 115 \times 10^6\,J$

115×1.13

$= 130 \times 10^6\,J$

The wire rope holding the 80.0 kN block as it is lifted is made from mild steel and has a diameter of 48 mm.

(c) Calculate the factor of safety in the wire rope when it raises this block at a steady speed. 4

$F.O.S = \frac{430}{44.2}$

$= 9.73$

$\sigma = \frac{80 \times 10^3}{\pi \times (\text{illegible})^2}$

$= 44.2$

7. (continued) MARKS

(d) Describe two economic and two environmental impacts that this system would have. 4

Economic impact 1 This could have an impact on the local sobs as this machine could replace people's jobs and leave them unemployed. This would have a negative impact on the local economy.

Economic impact 2 This could have a positive impact on the local economy as if excess energy can be used then there could it will be cheaper in the times it is needed this could help people by lowering their energy bills.

Environmental impact 1 This is good for the environment as it is more efficient and is a way to potentially store renewable energy.

Environmental impact 2 This could have a negative impact on the local environment as many trucks and heavy machinery would be in the area, disturbing wildlife and causing pollution.

(e) Describe two advantages that this system has over a chemical battery storage system for excess electrical energy. 2

Advantage 1 Batteries need to be disposed of once used so it will be cheaper for the company if they don't need to have to spend money properly disposing batteries.

Advantage 2 It is better for the environment as used batteries can cause harm to nature due to the chemicals inside of them, which can leak out.

8. An anti-lock braking system is used to control the speed of an elevator as it descends. This uses a form of pulse-width modulation operated by a microcontroller.

   If the speed of the elevator is too fast, the brakes will increase the proportion of operating time.

   The table below identifies the connections to the microcontroller.

Input	Pin	Output
	7	brake
ground level sensor	1	
speed sensor (analogue)	0	

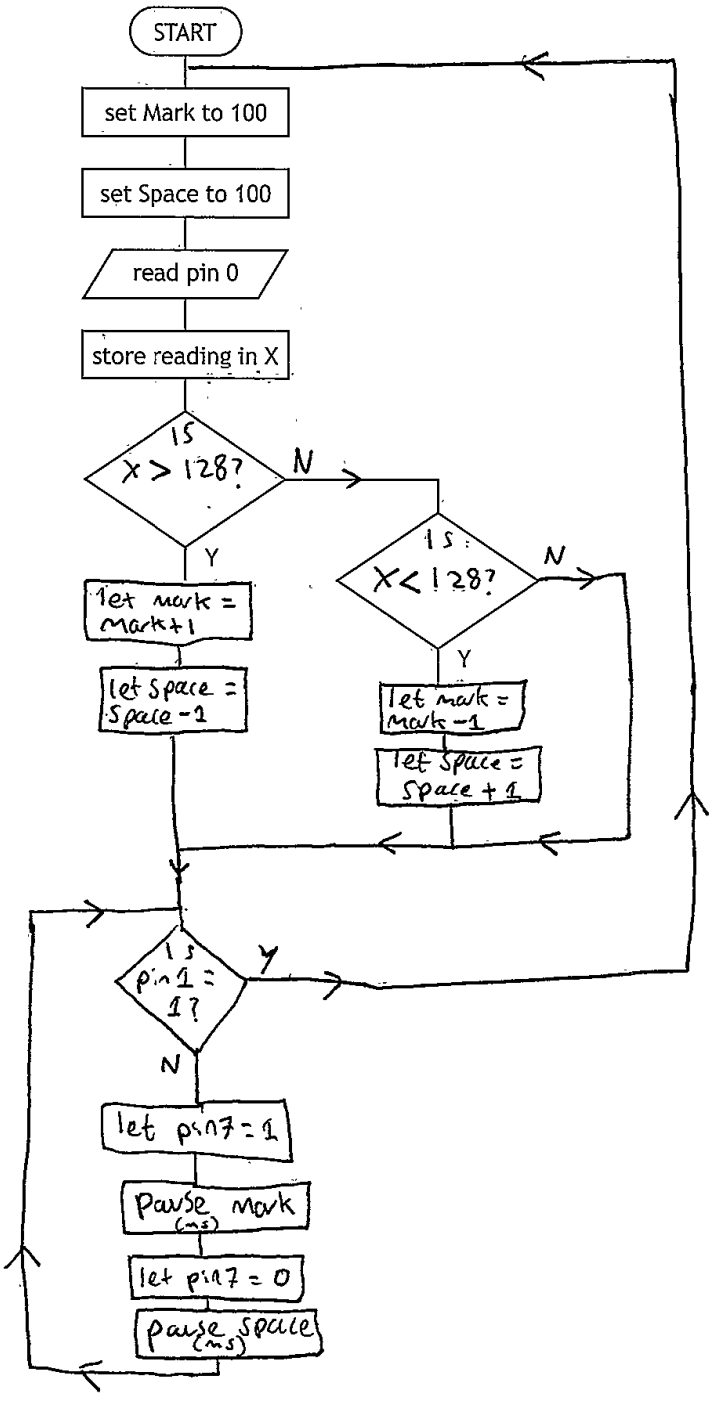
The system must perform the following steps.

- Values for **mark** and **space** both need to be initially set to a value of 100
- A reading must be taken from a speed sensor and its value stored in variable X
- If the value of X is greater than 128 then **mark** increases by 1 and **space** decreases by 1
- If the value of X is smaller than 128 then **mark** decreases by 1 and **space** increases by 1
- If the value of X is 128 then **mark** and **space** do not change
- The brake must be switched on and off for the times specified **mark** and **space** (this will be in milliseconds)
- The process must continue until the ground level sensor is activated

MARKS

8. (continued)

(a) Complete, with reference to the specification and the input/output table, this flow chart for the control of the system. 8



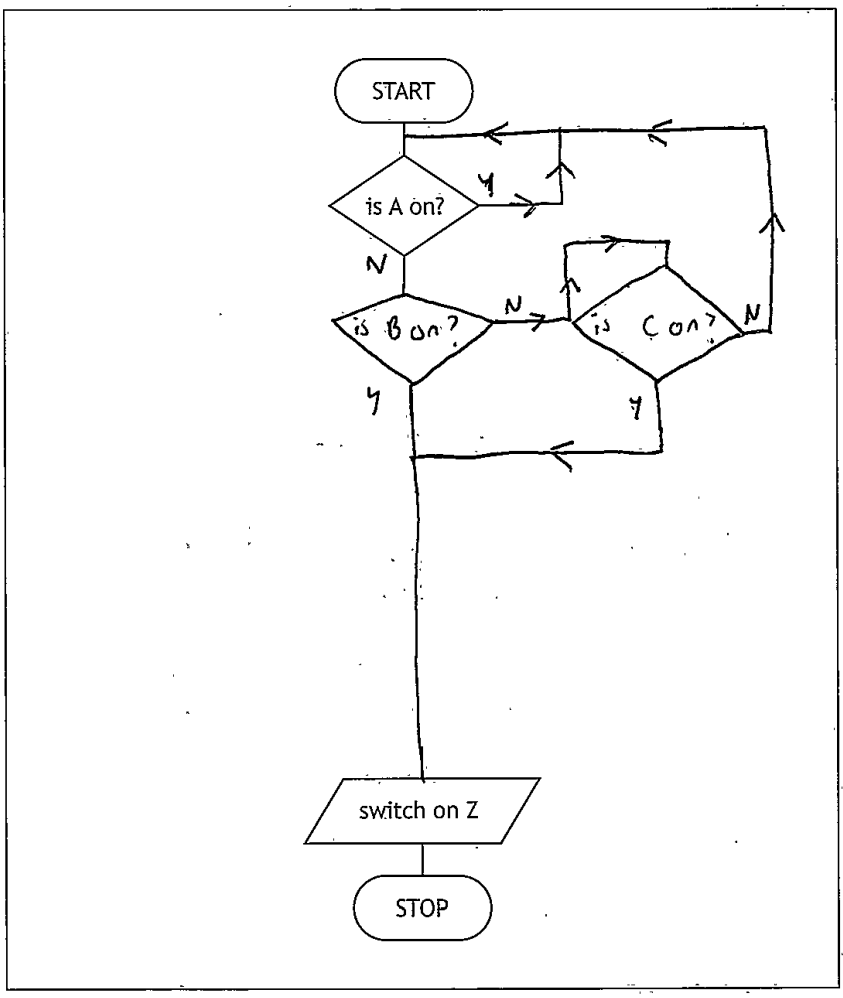
MARKS

8. (continued)

An alarm (Z) is part of the elevator's operating system and needs to be activated under the conditions given by the following Boolean equation.

$$Z = \overline{A} \bullet (B + C)$$

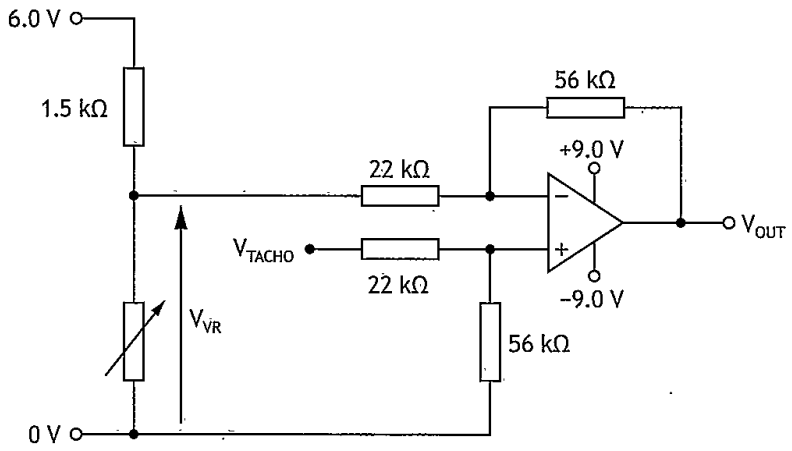
(b) Complete the following flowchart to perform the function described above. 3



MARKS

8. (continued)

An alternative system to control the force applied by the brake is also tested. As the speed of the elevator varies from a reference value the output of the circuit changes proportionately. The speed of the elevator is monitored by a tachogenerator.



When testing the circuit, the voltage from the tachogenerator (V_{TACHO}) was found to be 2.3 V.

(c) (i) Calculate the resistance of the variable resistor in the circuit shown above when the output voltage of the op-amp is +4.5 V. 4

$V_1 = \frac{R_2}{1.5\times10^3+R_2} \times 6$

$V_0 = \frac{R_f}{R_i}(V_2 - V_1)$

$4.5 = \frac{56}{22} \times (2.3 - V_1)$

$V_1 = 0.53\,V$

$0.53 = \frac{R_2}{1.5\times10^3+R_2} \times 6$

$0.08... = \frac{R_2}{1.5\times10^3+R_2}$

$133 + 0.08...R_2 = R_2$

$\frac{133}{R_2} = 1 - 0.08...$

$\frac{133}{0.911...} = R_2$

$R_2 = 146\,\Omega$

MARKS

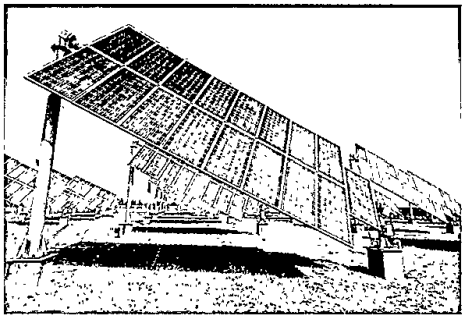
8. (c) (continued)

(ii) Describe, with reference to the circuit, how the reference speed of the elevator could be increased. 1

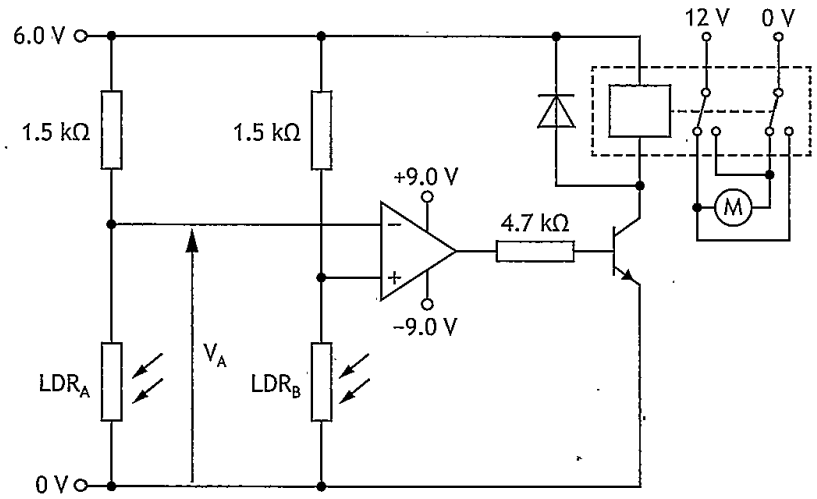
By increasing the value of R_f or decreasing the value of R_i.

[Turn over

9. A system is needed to alter the position of a solar panel so that it is constantly facing the sun during daylight hours. If one sensor gives a higher reading than the other, a motor will turn the panel in the brighter direction.



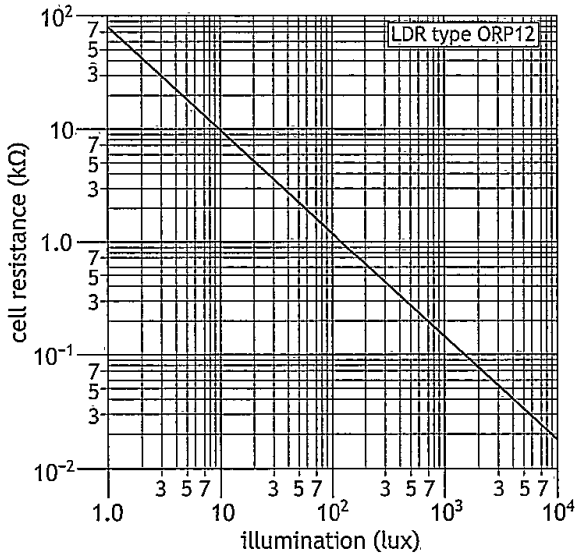
A preliminary design of the control circuit is shown below.



MARKS

9. (continued)

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



(a) Calculate V_A if the light level on LDR_A is 20 lux. **2**

5kΩ

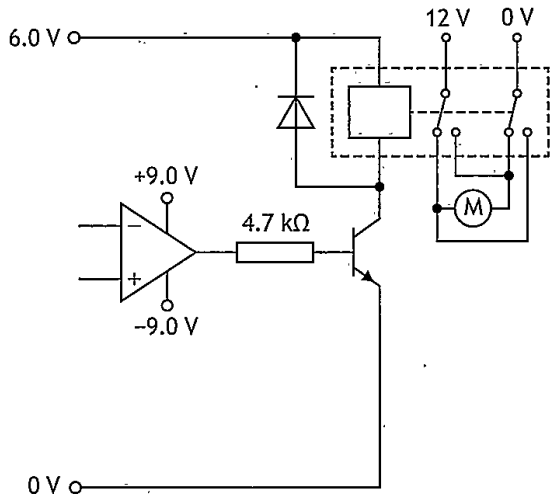
$V_A = \frac{5}{1.5+5} \times 6$

$= 4.6\text{V}$

MARKS

9. **(continued)**

Part of the control circuit is shown below.



(b) (i) Calculate the base current to the transistor when the op-amp saturates positively.

Assume V_{be} is 0.70 V. The op-amp output saturates at 75% of the supply voltage. 3

$6 \times 0.75 = 4.5\ V$

$4.5 + 0.7 = 5.2\ V$

$V = IR$

$I_b = \frac{6.2}{4.7 \times 10^3}$

$= 1.11\ mA$

MARKS

9. (b) (continued)

The relay has a resistance of 5.0 Ω.

(ii) Calculate the minimum current gain of the transistor to ensure it is fully saturated when the op-amp is saturated positively. 2

$h_{fe} = \frac{I_c}{I_b}$

$= \frac{1.2}{1.11 \times 10^{-3}}$

$= 1081$

$I_c = \frac{V}{R}$

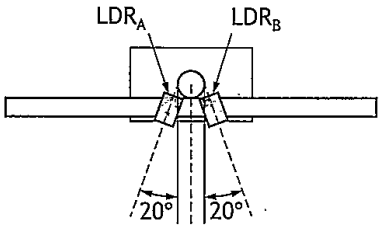
$= \frac{6}{5}$

$1.2\,A$

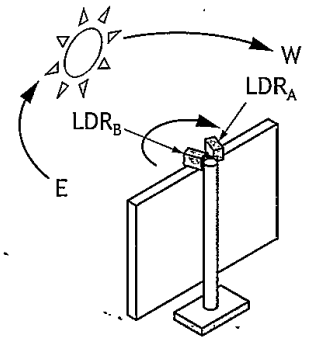
[Turn over

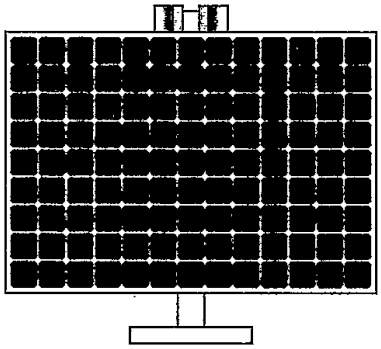
9. **(continued)**

While testing the circuit, V_A was found to be less than V_B and the motor rotated, moving the solar panel towards the sun's position.

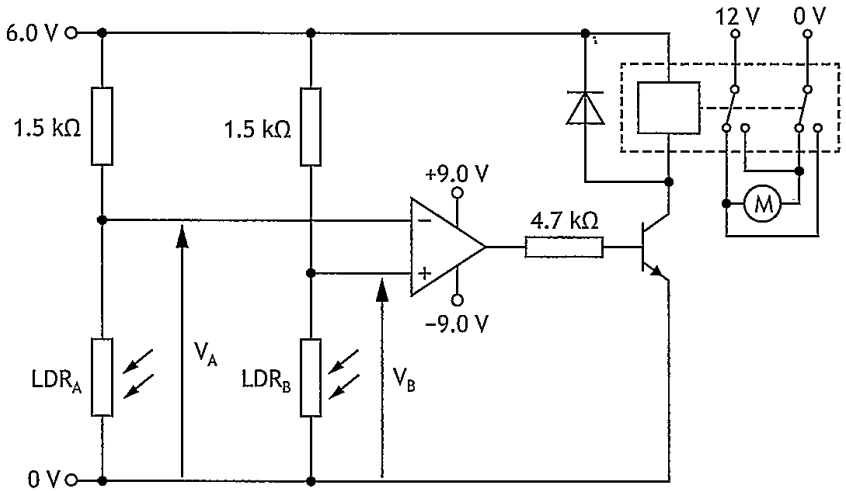


TOP VIEW





FRONT VIEW



MARKS

9. (continued)

(c) Describe, referring to the circuit on the opposite page, what will happen as the solar panel moves.

Your answer must refer to the input voltage dividers, the op-amp and transistor, and the relay and motor. 6

Input voltage dividers If it moves West, LDR_A will increase, this will reduce the value for V_A. If it moves east however, LDR_B will increase this will reduce the value for V_B. The higher the light level, the smaller the value for V_A / V_B.

Op-amp and transistor If it moves West $V_A < V_B$ so the op-amp will Saturate positively. If it moves east, $V_A > V_B$ so the op-amp will saturate negatively.

Relay and motor Based on whether the op amp will Saturate positively or negatively the direction of the motor will change. If the light level is higher the output voltage from the op-amp will be lower, reducing how fast the motor turns, to keep it in the Sun.

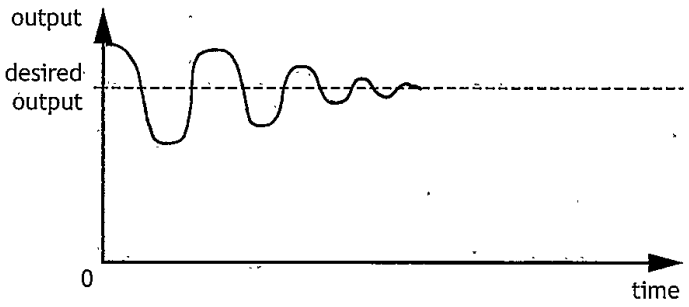
[Turn over

MARKS

9. **(continued)**

The op-amp control circuit uses two-state control.

(d) (i) Complete the graph below to show how the output of a two-state control system changes as it approaches the desired output. 2



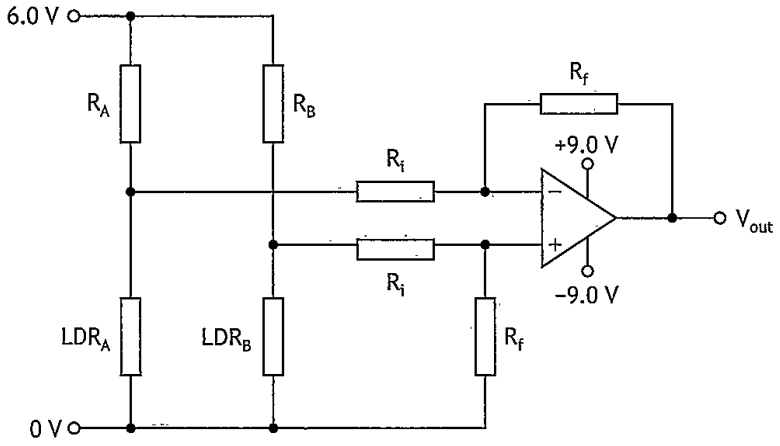
(ii) Describe the impact that this type of control would have on the mechanical output of the system. 1

The panels would be moving east to west before stabilising.

MARKS

9. (continued)

An alternative control circuit is also tested.



(e) (i) State the type of control produced by this type of circuit. 1

Two-State

(ii) Describe the difference between the control produced by this circuit and a two-state control system. You can use diagrams or graphs to illustrate your answer. 3

[Turn over

MARKS

10. An engineering team is experimenting with different control systems to operate a number of pneumatic cylinders. The following truth table shows the conditions under which one of the cylinders must outstroke.

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

(a) Write a Boolean equation for the output Z. **2**

Z = $C \cdot (\bar{D} + (A \cdot B))$

A —
B —
C —
D —

C · $(\bar{D} + (A \cdot B))$

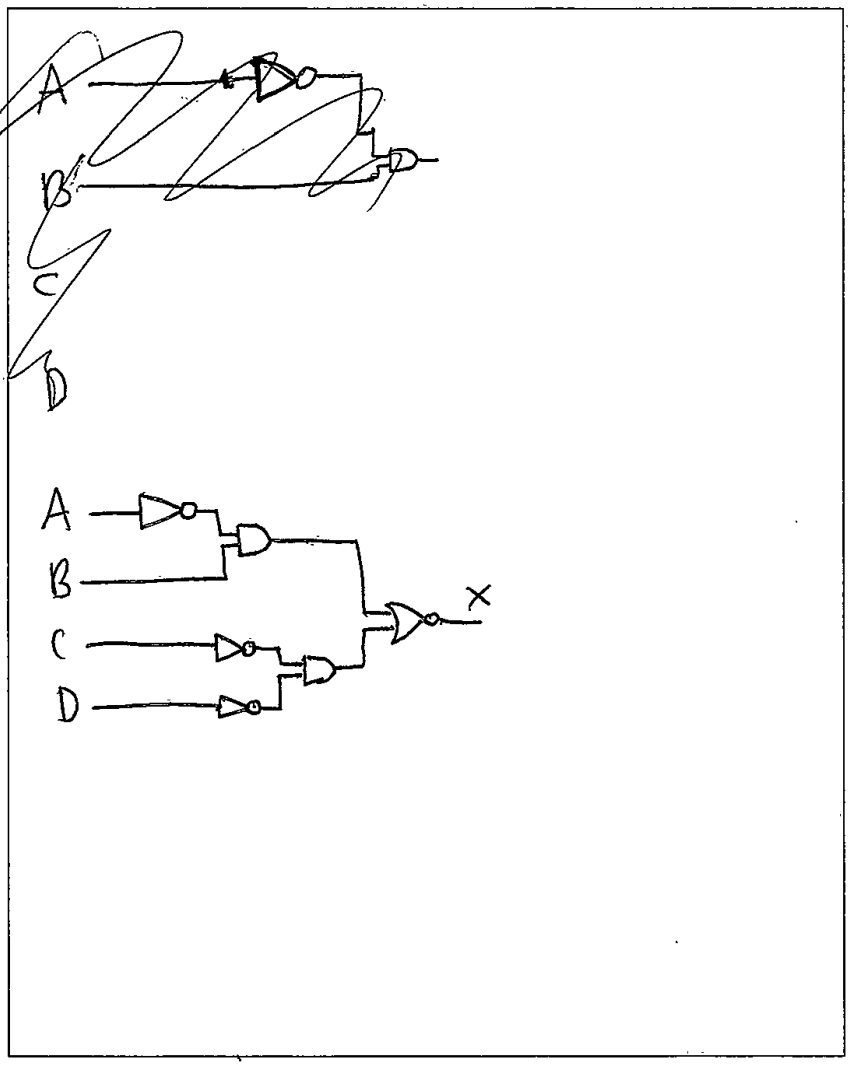
MARKS

10. (continued)

A second cylinder operates under the following conditions.

$$X = \overline{A} \cdot B \oplus (\overline{C \cdot D})$$

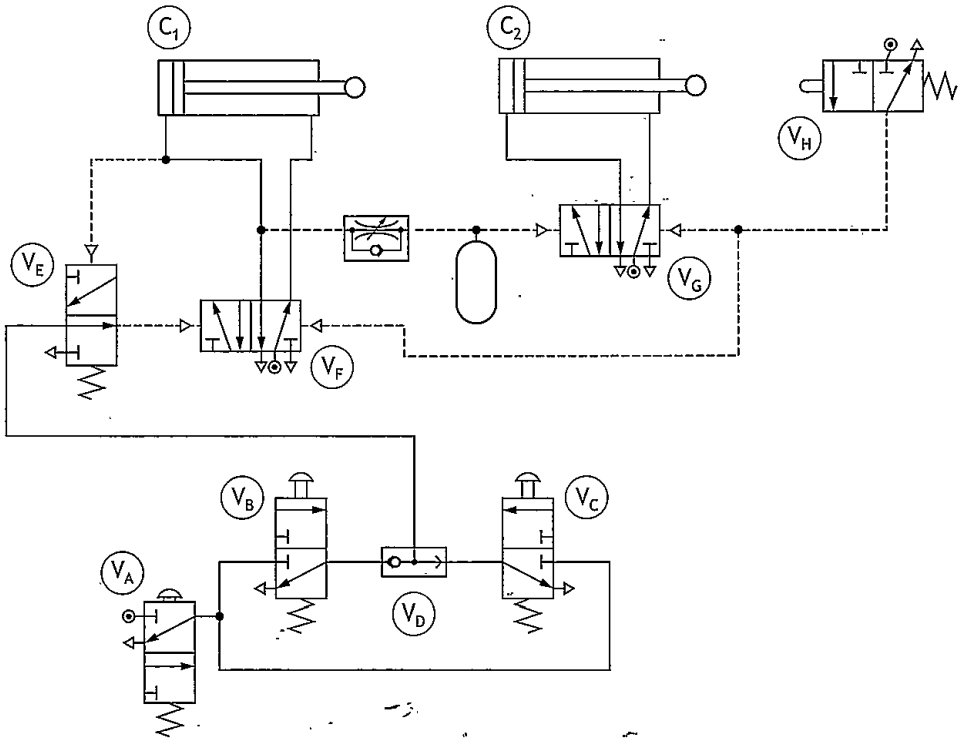
(b) Draw a logic diagram to perform this function. 4



[Turn over

10. (continued)

Two further cylinders are to be controlled by the following circuit.



MARKS

10. (continued)

(c) (i) Describe the operation of this circuit, highlighting the function of each component and the conditions that will cause the cylinders to instroke and outstroke. 6

When V_A... is pressed and V_B or V_C, pilot air passes through V_D and towards V_E. That* sets pilot air to V_F which will outstroke C_1. The pilot air also travels through a time delay to activate V_G. This will outstroke C_2, pushing the button at V_H, activating it. This will send pilot air back to V_G, but due to the buttons, V_A, V_B and V_C being all spring loaded no conflict will occur. This will instroke C_2. The air will also go to V_F which will cause C_1 to instroke. ~~But the start V_B or V_C are pressed, a conflict will occur and the system locks~~ will at the start both V_A, V_B and V_C are pressed, conflict occur at V_D.

The engineering team are considering changing the circuit shown opposite to one that is operated by a microcontroller.

(ii) Describe two reasons why using a microcontroller-based system is preferred to a fully pneumatic system. 2

Micro-adjustments can be made rather than just on or off.

Safer, Compressed air can be dangerous.

If cylinders are only needed to be halfway it can be.

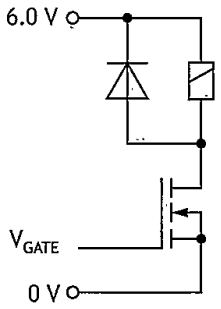
More reliable, less chance of problems occuring from air leaking or other issues.

Safer

MARKS

10. (continued)

In order to use a microcontroller-based system, solenoid valves need to be used. The following circuit has been designed to actuate one of the solenoids.



The solenoid is rated 12 W at 6.0 V. The MOSFET has a resistance of 0.70 Ω when switched on.

(d) (i) Calculate the resistance of the solenoid. 1

$P = \frac{V^2}{R}$

$R = \frac{6^2}{12}$

$= 3\,\Omega$

(ii) Calculate the current through the MOSFET when it is fully switched on. 1

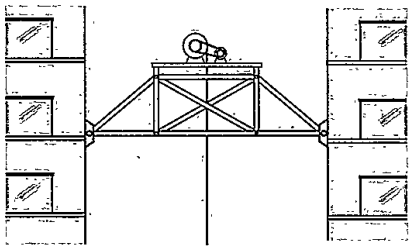
$V = IR$

$I = \frac{6}{0.7}$

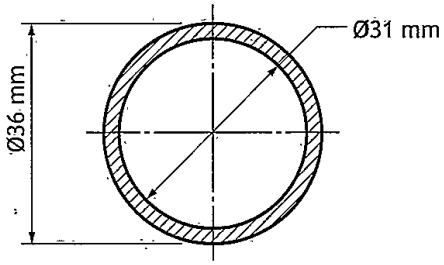
$= 8.6\,A$

MARKS

11. During a construction project in a city centre location, a lifting platform is installed between two high rise buildings.



One of the members in the structure has a cross-section as shown below, with an internal diameter of 31 mm, and an external diameter of 36 mm.



This mild steel member has a strain of 4.6×10^{-5} when subjected to a load.

(a) Calculate the load carried by this member. 4

$E = 196$

$\epsilon = \frac{\sigma}{E}$ $\sigma = \frac{F}{A}$ $A_E = \pi r^2$

$\sigma = 4.6 \times 10^{-5} \times 196 \times 10^3$ $= \pi \times 36^2$

$= 9.016$ $= 1296\pi$

$A_{small} = \pi r^2$

$= \pi \times 31^2$

$= 961\pi$

$F = 9.016 \times 10^3 \times 335\pi$

$= 9.5\,N$

$1296\pi - 961\pi$

$= 335\pi\ mm^2$

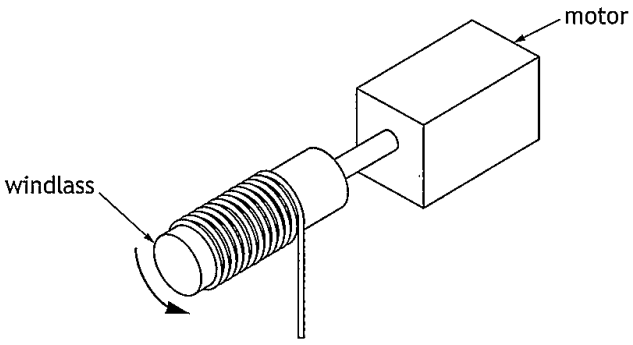
$F = 9.016 \times 335\pi$

$= 9.5\,kN$

MARKS

11. (continued)

A motor-driven winch system is used for lifting construction materials with up to 12,000 kg of mass. The windlass, with 320 mm diameter, rotates at 12 revolutions per minute.



(b) Calculate the mechanical power required by this motor. 5

$P = 2\pi nT$

$T = Fr$

$= (12{,}000 \times 9.8) \times (160 \times 10^{-3})$

$= 18.8\ kNm$

$P = 2\pi \times 0.2 \times 18.8 \times 10^{3}$

$= 23.6\ kW$

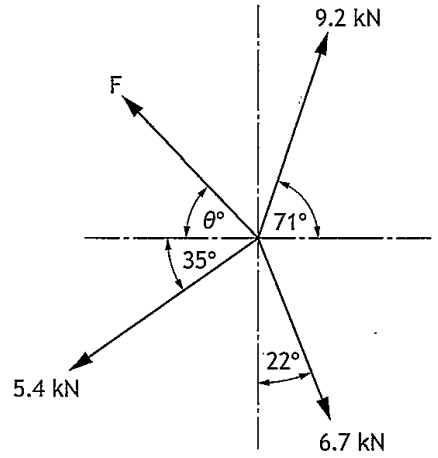
$\frac{12}{60} = 0.2\ revs^{-1}$

MARKS

11. (continued)

Later in the construction project, the lifting platform supports cables used to suspend a concrete beam above the site until it is ready for positioning.

The diagram below represents the concurrent force system while the beam is in suspension.



(c) Calculate the magnitude and angle of the force F, required to maintain equilibrium. 6

$9.2 \times \sin 71 + F\sin\theta = 5.4\sin 35 + 6.7\cos 22$

$9.2 \times \cos 71 + 6.7 \times \sin 22 = 5.4 \times \cos 35 + F\cos\theta$

~~$F\sin\theta = 1.07$~~

$F\cos\theta = 1.08$

$F\sin\theta = 0.61$

$\frac{F\sin\theta}{F\cos\theta} = \frac{0.61}{1.08}$

$\tan\theta = 0.56$

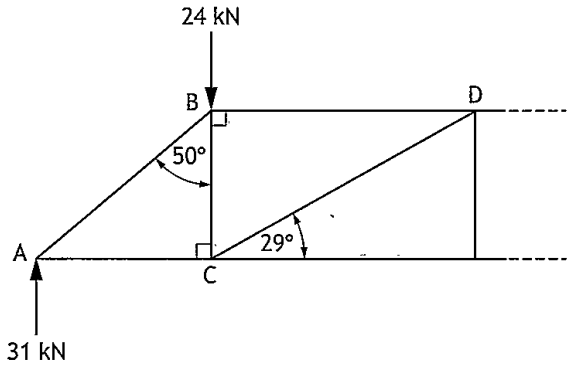
$\theta = 29°$

$F = 1.24\text{kN}$ at $29°$

$F = \frac{0.61}{\cos 29 \sin 29}$ $F = 1.24\text{kN}$

MARKS

12. The free-body diagram for part of a structure and its loading is shown below.



Calculate, using nodal analysis, the magnitude and nature of forces in members AB, AC, BC, BD and CD.

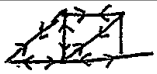
Show all working and final units on the page opposite.

Complete the table below. **8**

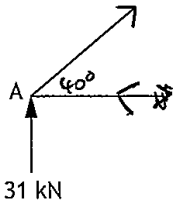
Member	Magnitude	Nature
AB	48kN	strut
AC	37kN	tie
BC	55kN	tie
BD	37kN	Strut
CD	113kN	Strut

12. (continued)

Space for working



node A



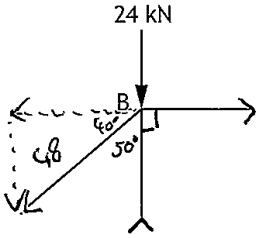
$AB \sin 40 = 31$

$AB = 48\ kN$

$AC = AB \cos 40$

$= 37\ kN$

node B



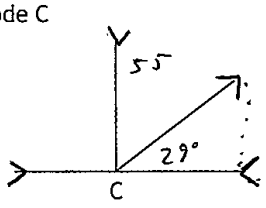
$24 + 48 \sin 40 = BC$

$BC = 55\ kN$

$48 \times \cos 40 = BD$

$BD = 37\ kN$

node C



$\frac{1}{2} CD \sin 29 = 55$

$CD = 113\ kN$

[END OF QUESTION PAPER]

Candidate 2 evidence

SECTION 1 — 20 marks
Attempt ALL questions

1. A new material is being tested for use in the manufacture of ships.

The results of a tensile test on the material are shown in **Figure 1.**
The range of 0 to A is shown magnified in **Figure 2.**

Figure 1

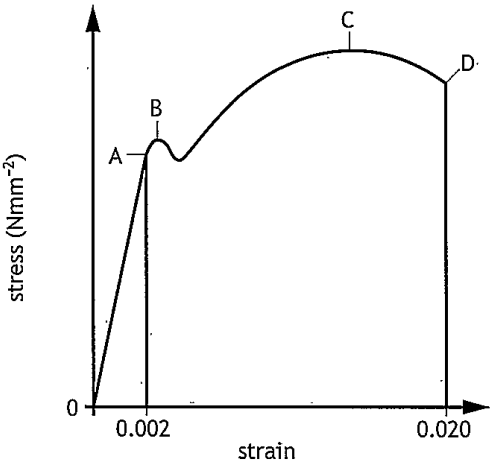
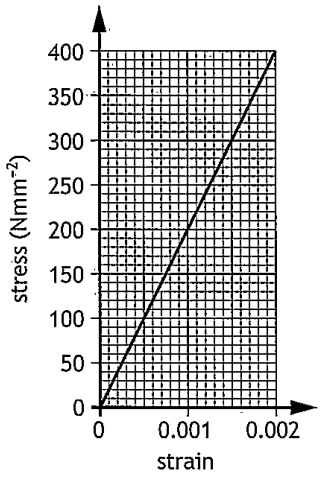


Figure 2



MARKS

1. (continued)

(a) (i) State the name of the range 0 to A. 1

Yield

(ii) State the name of the range A to D. 1

(b) (i) Calculate, using the information from **Figure 2**, Young's Modulus for this material. 1

$E = \frac{\sigma}{\epsilon}$

$E = \frac{400}{0.002}$

$E = 200,000 N mm^{-2}$

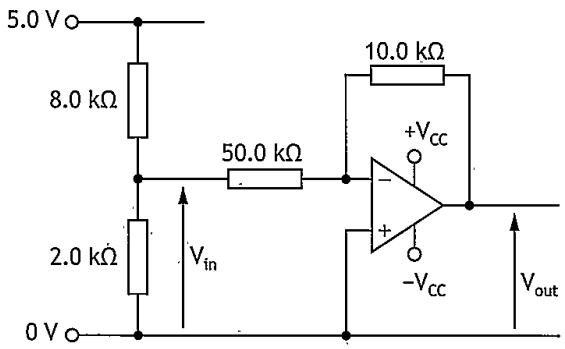
(ii) State the property identified by point C on **Figure 1**. 1

Ultimate Stress

[Turn over

MARKS

2. Part of an electronic circuit is shown.



(a) Calculate V_{out}. 2

$V_o = -\frac{R_f}{R_i} \times V_i$

$V_o = -\frac{10}{50} \times 5$

$V_o = -1\ V$

(b) Describe how the gain of this op-amp circuit could be decreased. 1

By increasing the resistance

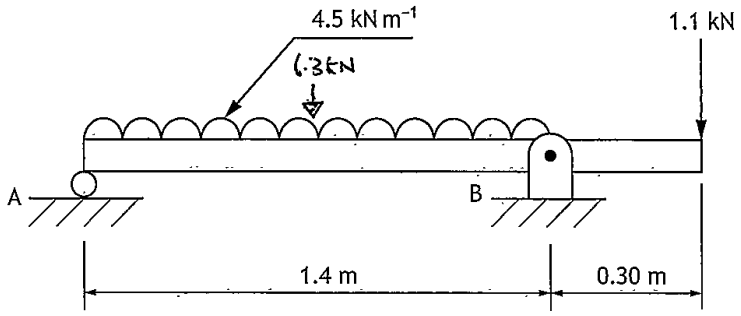
After testing, it was decided to add an additional op-amp configuration to change the polarity of V_{out}.

(c) State the name of the op-amp configuration required to perform this task. 1

Inverting op-amp

MARKS

3. A beam used in the construction of a covered walkway is shown.



Calculate by taking moments about B, the vertical reaction at A. 3

$4.5 \times 1.4 = 6.3$kN

$\Sigma CWM = \Sigma ACWM$

$(1.1 \times 0.3) = (6.3 \times 0.7) R_B$

$4.41 R_B = 0.33$

$R_B = \frac{0.33}{4.41}$

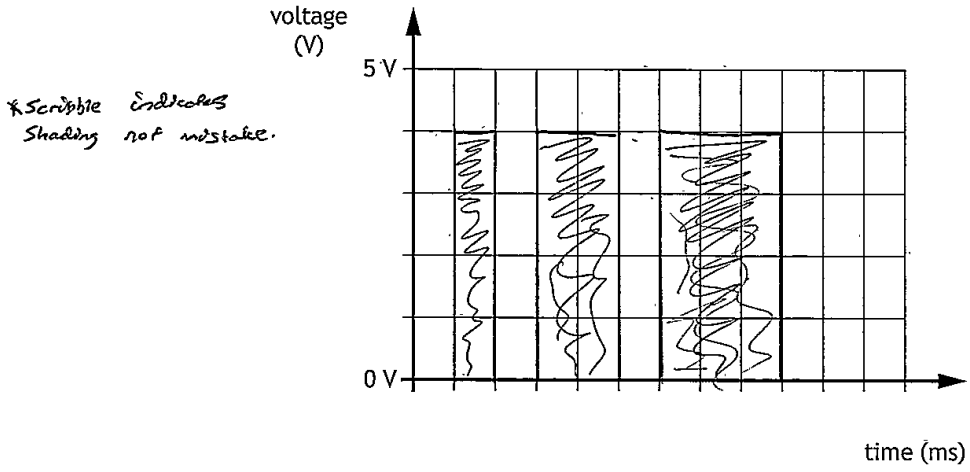
$R_B = 0.07$kN

MARKS

4. The speed at which an automatic garage door opens is controlled by a motor using pulse-width modulation (PWM).

(a) Complete the graph below to show how PWM could be used to make the motor rotate at half speed.

You should include at least three pulses. 2



*Scribble indicates shading not mistake.

(b) Describe how the speed of this motor could be decreased using PWM. 1

The speed of the motor could be decreased using PWM by decreasing the voltage.

MARKS

4. **(continued)**

An alternative method of speed control involves varying the size of the DC voltage supplied to the motor.

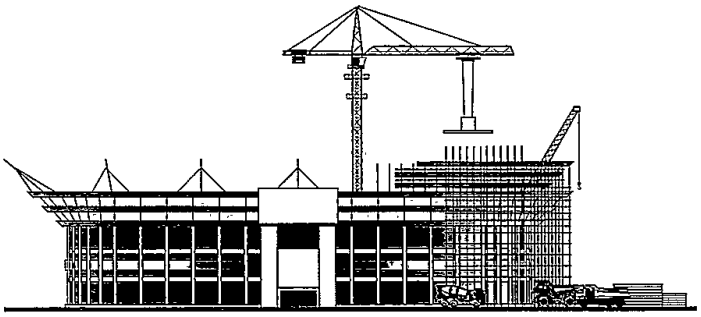
(c) Describe one advantage of using PWM in comparison to varying the size of the voltage supply. 1

With a PWM you don't have to constantly replace it. meanwhile with varying the size you have to constantly replace the size of the voltage supply.

[Turn over

MARKS

5. The capacity of a sports stadium is being increased. This needs an additional stand to be built on top of the existing structure.



A structural engineer is involved in the design of this new structure.

Describe two examples of how the structural engineer will use their knowledge of materials in the design of the new structure. 2

Example 1 The structural engineer would calculate the forces acting on the materials so that it wouldn't collapse under pressure.

Example 2 The structural engineer would analyse the properties of the materials to see if it would withstand the natural elements.

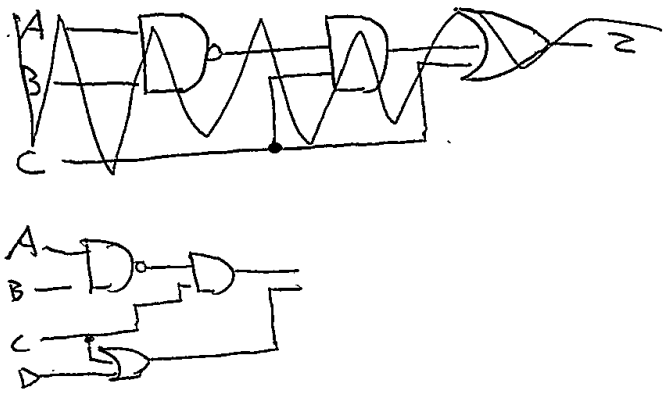
MARKS

6. An electronic engineer has designed a combinational logic circuit according to the Boolean equation, shown below.

$$Z = \overline{(A \bullet B)} \bullet (C + D)$$

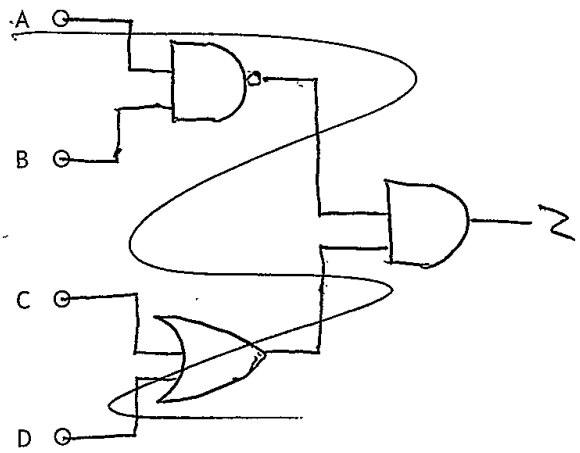
Draw a NAND equivalent circuit for this Boolean equation. 3

Space for working



Final answer

* On additional Pages at the back *

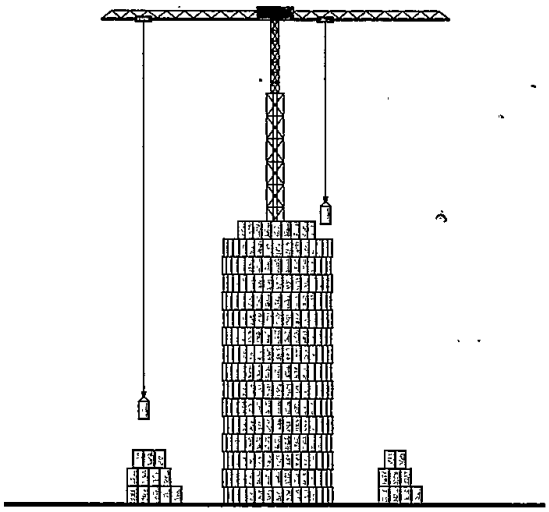


MARKS

SECTION 2 — 90 marks

Attempt ALL questions

7. An engineering team has produced a prototype system to store excess energy from power plants.



When electricity production exceeds demand, electric motors are used to lift concrete blocks and place them in 'towers'. When the blocks are returned to ground level electricity is reclaimed by generators.

The first block has a mass of 10,000.0 kg. The system that raises this block is 92% efficient.

(a) Calculate the energy required to raise this block 32 m. 2

$E_P = m g h$

$E_P = 10{,}000 \times 9.8 \times 32$

$E_P = 3136000\ J$

$0.92 \times 3136000 = 2885120\ J$

MARKS

7. (continued)

A second block applies a force of 80.0 kN to the supporting wire rope.

As this block is returned to ground level (at constant speed) its supporting wire rope turns a generator and electricity is reclaimed. This part of the system is 87% efficient.

(b) Calculate the power output from the generator if this block descends 15 m in 11 seconds. 3

$\eta = \frac{\text{Power out}}{\text{Power in}}$

$P = \frac{E}{t}$

$0.87 = \frac{2850\,90}{262283}$

$P = \frac{3136000}{11}$

↱ on additional pages

$P = 285090.90$

$P = 285090\text{W}$

$P = 262283\text{W}$

The wire rope holding the 80.0 kN block as it is lifted is made from mild steel and has a diameter of 48 mm.

(c) Calculate the factor of safety in the wire rope when it raises this block at a steady speed. 4

$FoS = \frac{US}{SWS}$

$FoS = \frac{43.0}{1.6}$

$FoS = 268.75$

$FoS = 270$

$\sigma = \frac{F}{A}$

$\sigma = \frac{80,000}{0.48}$ $\frac{80}{48}$

$\sigma = 1.6\,\text{Nmm}^{-2}$

7. (continued) MARKS

(d) Describe two economic and two environmental impacts that this system would have. 4

Economic impact 1 It would provide job opportunities for people to earn money for their families etc...

Economic impact 2 The system is cheaper to store since storing chemical battery's are more expensive to keep safe.

Environmental impact 1 It's a 'cleaner' way to store energy since ~~their~~ they're not being stored inside the power plants.

Environmental impact 2 ~~Nearby residents No habitats would be ruined if there was a leak since~~ Some habitats may be affected by ~~pollution~~ pollution by making the electrical energy from power plants.

(e) Describe two advantages that this system has over a chemical battery storage system for excess electrical energy. 2

Advantage 1 If there is a leak, chemicals won't spill meaning its safer.

Advantage 2 Electrical energy is ~~safer~~ better for the environment to store rather than storing chemical battery's.

8. An anti-lock braking system is used to control the speed of an elevator as it descends. This uses a form of pulse-width modulation operated by a microcontroller.

If the speed of the elevator is too fast, the brakes will increase the proportion of operating time.

The table below identifies the connections to the microcontroller.

Input	Pin	Output
	7	brake
ground level sensor	1	
speed sensor (analogue)	0	

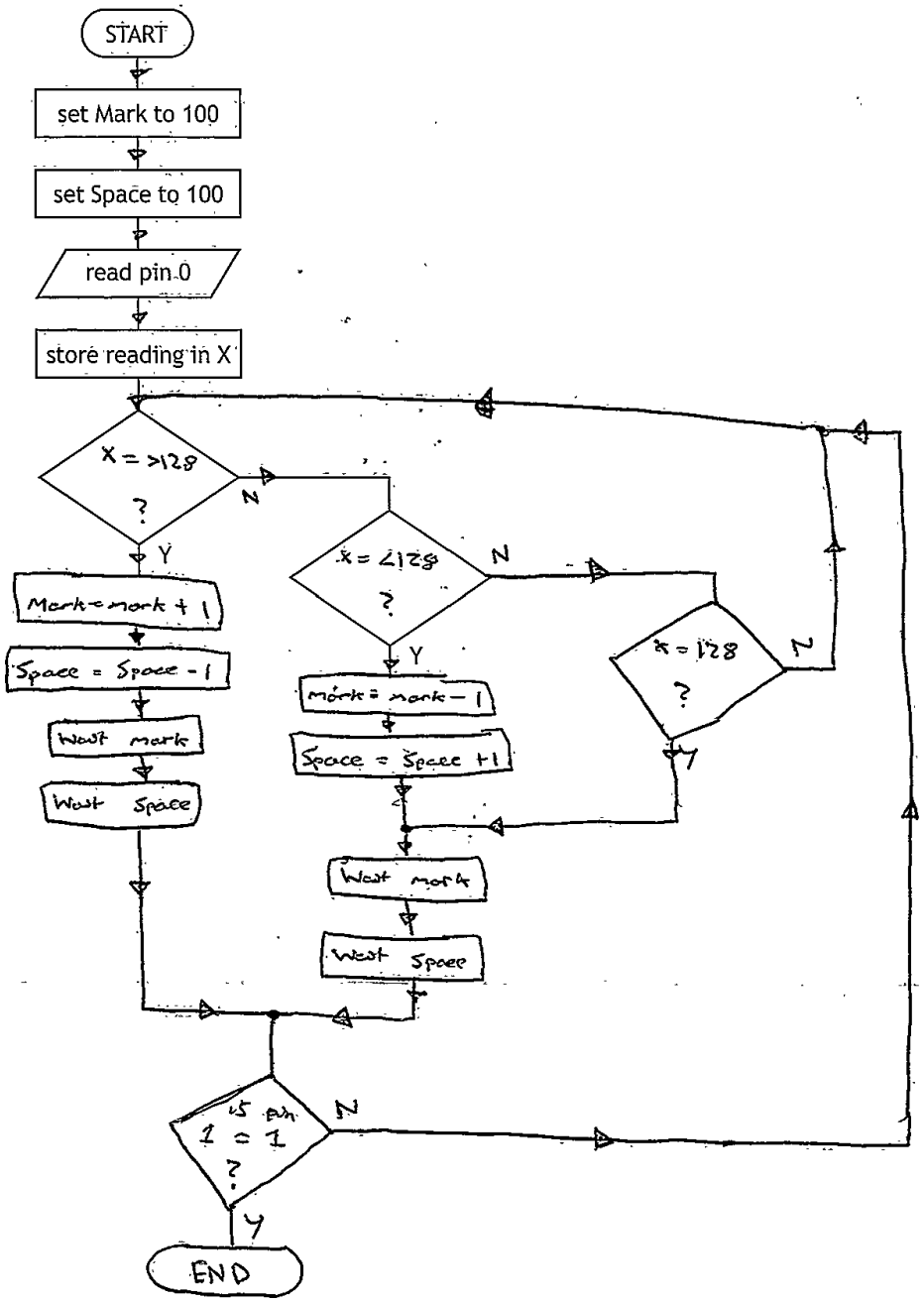
The system must perform the following steps.

- Values for **mark** and **space** both need to be initially set to a value of 100
- A reading must be taken from a speed sensor and its value stored in variable X
- If the value of X is greater than 128 then **mark** increases by 1 and **space** decreases by 1
- If the value of X is smaller than 128 then **mark** decreases by 1 and **space** increases by 1
- If the value of X is 128 then **mark** and **space** do not change
- The brake must be switched on and off for the times specified **mark** and **space** (this will be in milliseconds)
- The process must continue until the ground level sensor is activated

MARKS

8. **(continued)**

(a) Complete, with reference to the specification and the input/output table, this flow chart for the control of the system. 8



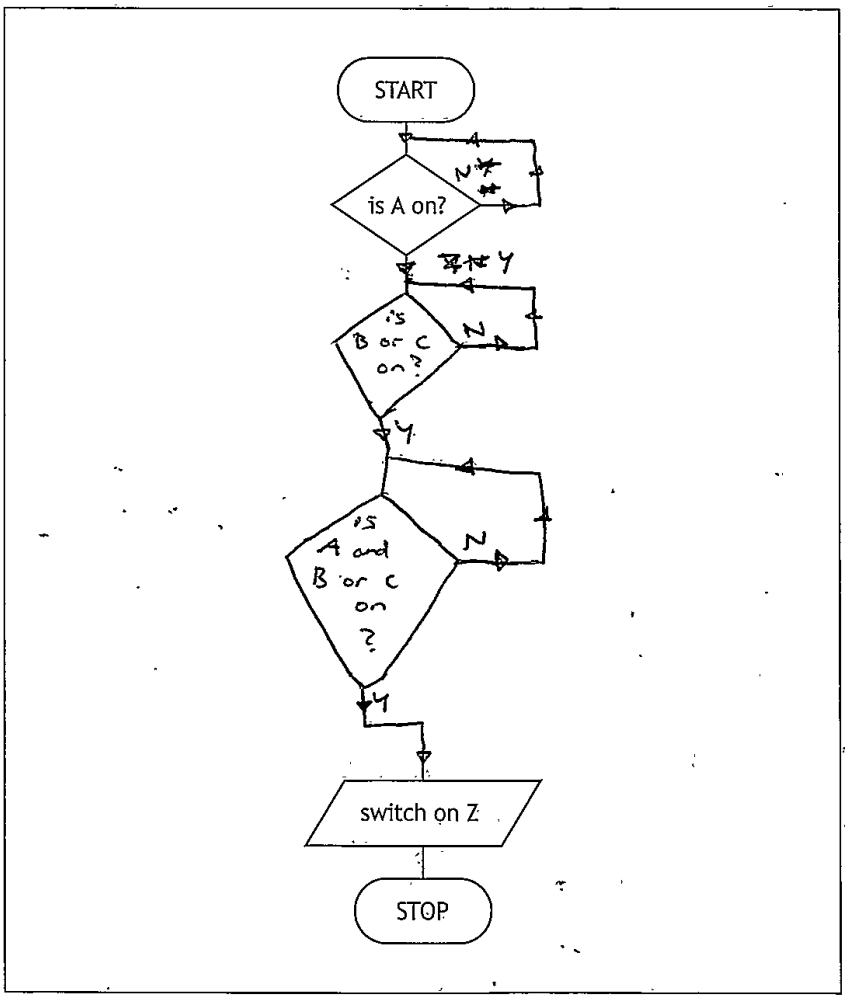
MARKS

8. (continued)

An alarm (Z) is part of the elevator's operating system and needs to be activated under the conditions given by the following Boolean equation.

$$Z = \overline{A} \bullet (B+C)$$

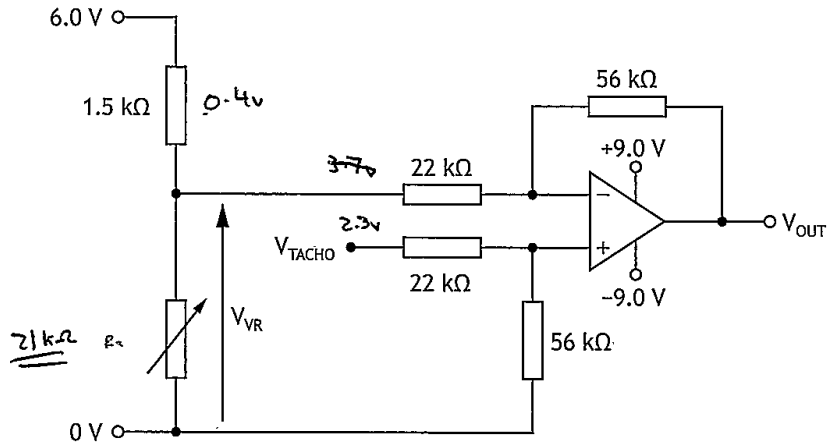
(b) Complete the following flowchart to perform the function described above. **3**



MARKS

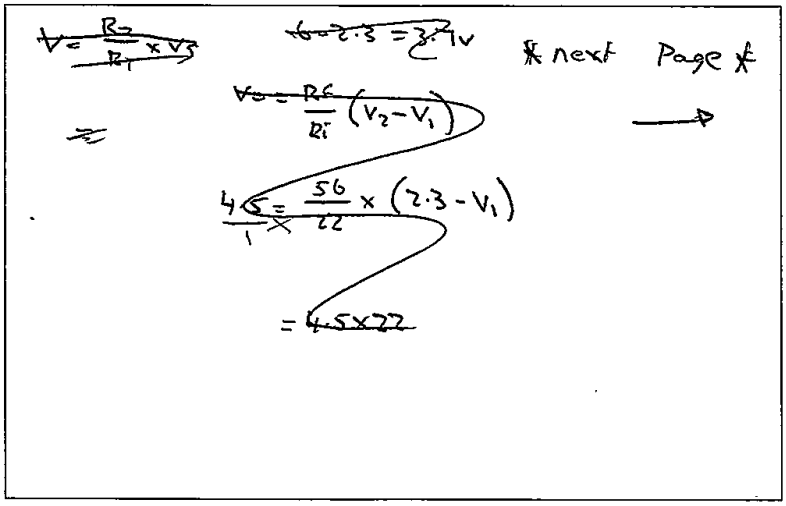
8. (continued)

An alternative system to control the force applied by the brake is also tested. As the speed of the elevator varies from a reference value the output of the circuit changes proportionately. The speed of the elevator is monitored by a tachogenerator.



When testing the circuit, the voltage from the tachogenerator (V_{TACHO}) was found to be 2.3 V.

(c) (i) Calculate the resistance of the variable resistor in the circuit shown above when the output voltage of the op-amp is +4.5 V. 4



MARKS

8. (c) (continued)

(ii) Describe, with reference to the circuit, how the reference speed of the elevator could be increased. 1

The Speed could be increased by decreasing the resistor values. So that more current can flow.

[Turn over

Q8 c(b)

$$V_o = \frac{R_F}{R_i}(V_2 - V_1)$$

$$4.5 = \frac{56}{22} \times (2.3 - V_1)$$

~~$$V_1 = \frac{56}{22} \times (4.5 - 2.3)$$~~

$$V_{VR} = \frac{56}{22} \times (2.3 - 4.5)$$

$$V_{VR} = -5.6V$$

$$\frac{V_1}{V_2} = \frac{R_1}{R_2}$$

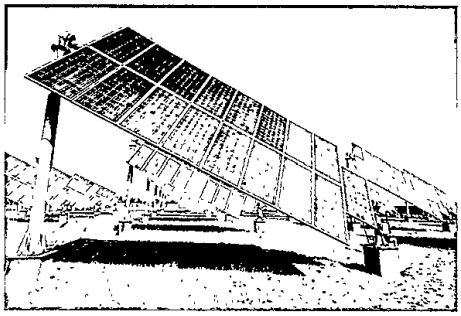
$$\frac{0.4}{5.6} = \frac{1.5}{R_2}$$

$$0.4\,R_2 = 1.5 \times 5.6$$

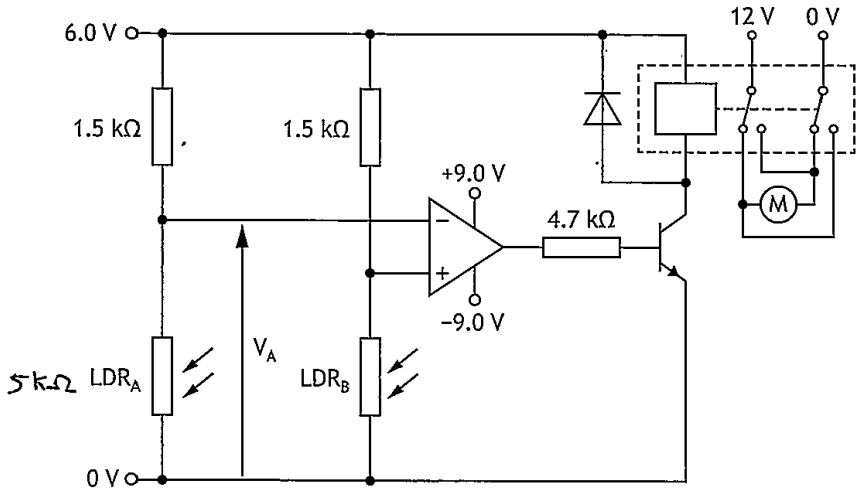
$$R_2 = \frac{1.5 \times 5.6}{0.4}$$

$$R_2 = 21\,k\Omega$$

9. A system is needed to alter the position of a solar panel so that it is constantly facing the sun during daylight hours. If one sensor gives a higher reading than the other, a motor will turn the panel in the brighter direction.



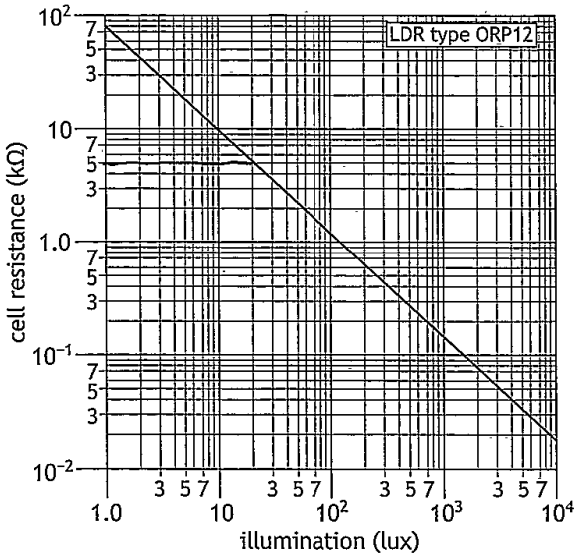
A preliminary design of the control circuit is shown below.



MARKS

9. (continued)

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



(a) Calculate V_A if the light level on LDR_A is 20 lux. 2

20 lux = 5000Ω

$V_A = \frac{R_2}{R_T} \times V_S$

$V_A = \frac{5}{1.5} \times 6$

$V_A = \frac{5}{6.5} \times 6$

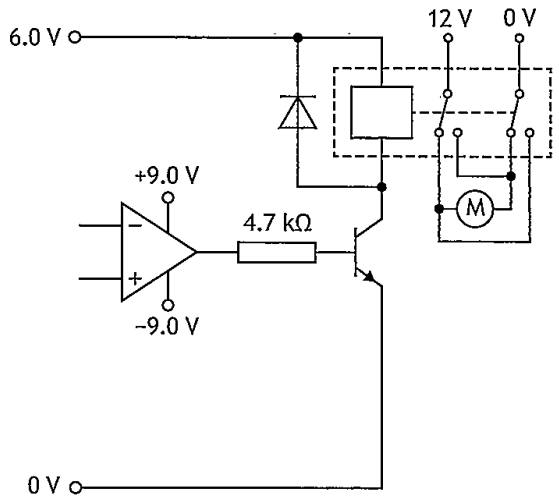
$V_A = 4.62V$

$V_A = 20V$

MARKS

9. (continued)

Part of the control circuit is shown below.



(b) (i) Calculate the base current to the transistor when the op-amp saturates positively.

Assume V_{be} is 0.70 V. The op-amp output saturates at 75% of the supply voltage. 3

$6 - 0.7 = 5.3V$

$0.75 \times 5.3 = 3.98V$

~~$V = I R$~~

~~$3.98 = I \times 4700$~~

~~$4700I = 3.98$~~

~~$I = \frac{3.98}{4700}$~~

~~$I = 0.00085A$~~

$V = I R$

$3.98 = I \times 4.7$

$I = \frac{3.98}{4.7}$

$I = 0.85A$

MARKS

9. (b) (continued)

The relay has a resistance of 5.0 Ω.

(ii) Calculate the minimum current gain of the transistor to ensure it is fully saturated when the op-amp is saturated positively. 2

$V = I R$

$5.3 = I \times 5$

$I = \frac{5.3}{5}$

$I_c = 1.06\ A$

$h_{fe} = \frac{I_c}{I_b}$

$h_{fe} = \frac{1.06}{0.85}$

$h_{fe} = 1.25$

$h_{fe} = \frac{I_c}{I_b}$

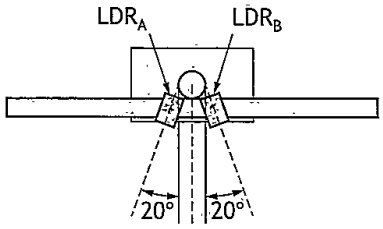
$h_{fe} = \frac{1.06}{0.0085}$

$h_{fe} = 1247$

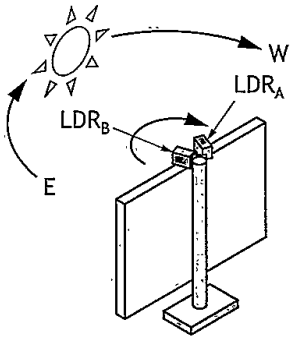
[Turn over

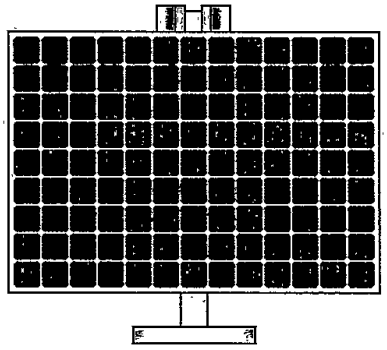
9. (continued)

While testing the circuit, V_A was found to be less than V_B and the motor rotated, moving the solar panel towards the sun's position.

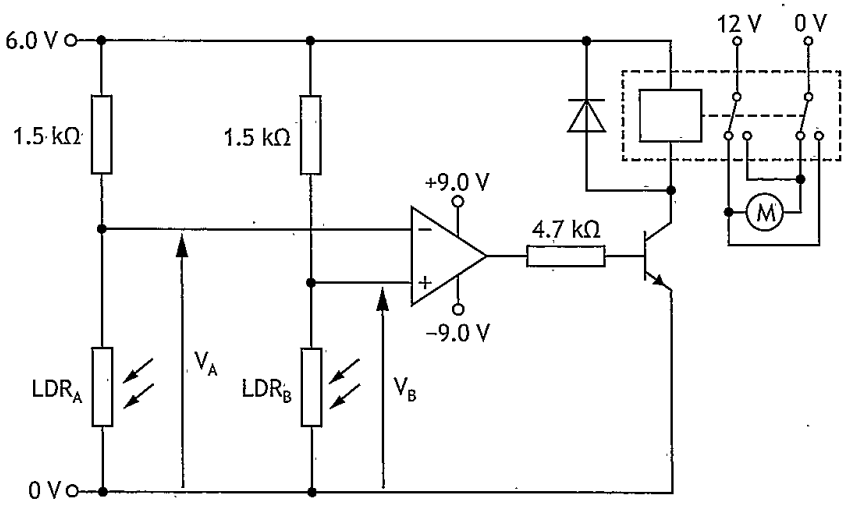


TOP VIEW





FRONT VIEW



MARKS

9. (continued)

(c) Describe, referring to the circuit on the opposite page, what will happen as the solar panel moves.

Your answer must refer to the input voltage dividers, the op-amp and transistor, and the relay and motor. 6

Input voltage dividers When light level drops in LDR resistance ~~increases~~ and voltage increases which results in the the voltage to be higher than LDRA since LDRA's light level increases so resistance and voltage for LDRA is low.

Op-amp and transistor Since LDRB's voltage is higher than LDRA's that means that the op-amp will saturate positively resulting in the transistor to switch on as the voltage is above 0.7v. The resistor protects the transistor from too much current.

Relay and motor Since the transistor is on that means that the relay switches on which causes it to change state which causes the 12v to flow to the motor switching it on. The diode protects the relay from back EMF.

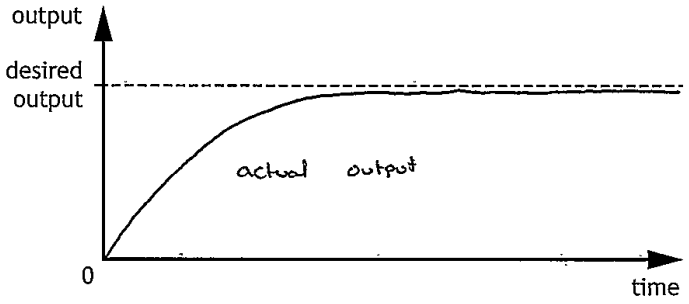
[Turn over

MARKS

9. **(continued)**

The op-amp control circuit uses two-state control.

(d) (i) Complete the graph below to show how the output of a two-state control system changes as it approaches the desired output. 2



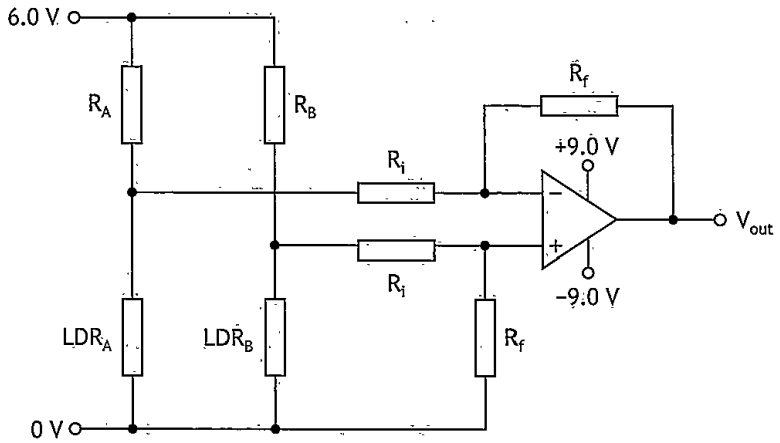
(ii) Describe the impact that this type of control would have on the mechanical output of the system. 1

This would cause the mechanical output to lag. never reach the desired out put.

MARKS

9. (continued)

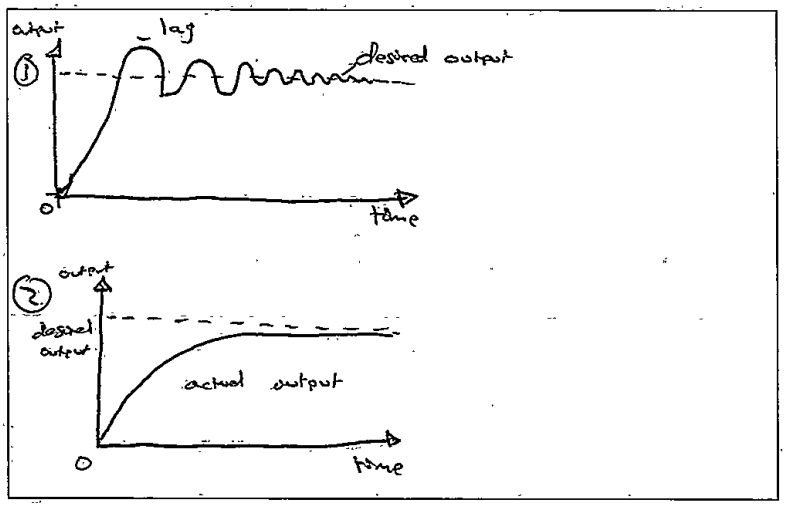
An alternative control circuit is also tested.



(e) (i) State the type of control produced by this type of circuit. 1

Proportional

(ii) Describe the difference between the control produced by this circuit and a two-state control system. You can use diagrams or graphs to illustrate your answer. 3



[Turn over

MARKS

10. An engineering team is experimenting with different control systems to operate a number of pneumatic cylinders. The following truth table shows the conditions under which one of the cylinders must outstroke.

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

$\bar{A} \cdot B \cdot \bar{C} \cdot D$

(a) Write a Boolean equation for the output Z. 2

$Z = (\bar{A} \cdot B \cdot \bar{C} \cdot D) + (\bar{A} \cdot \bar{B} \cdot \bar{C} \cdot D) + (\bar{A} \cdot \bar{B} \cdot \bar{C} \cdot \bar{D})$

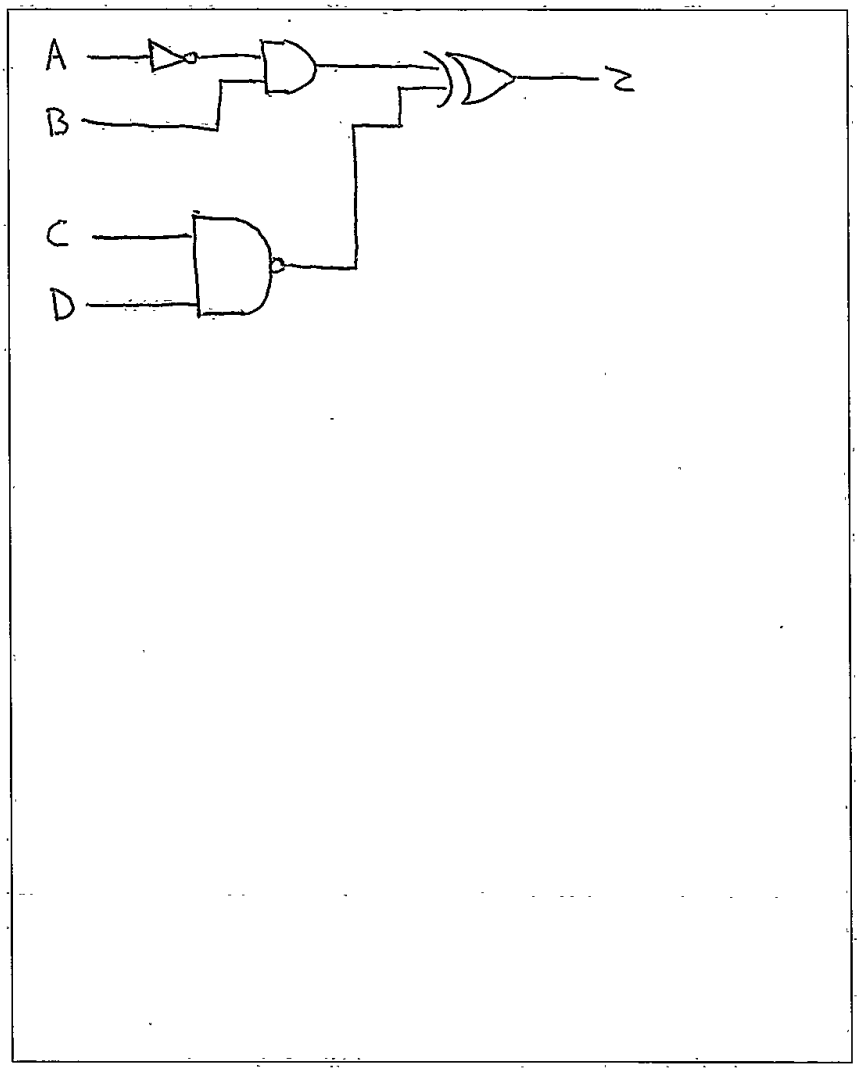
MARKS

10. (continued)

A second cylinder operates under the following conditions.

$$X = \overline{A} \cdot B \oplus (\overline{C \cdot D})$$

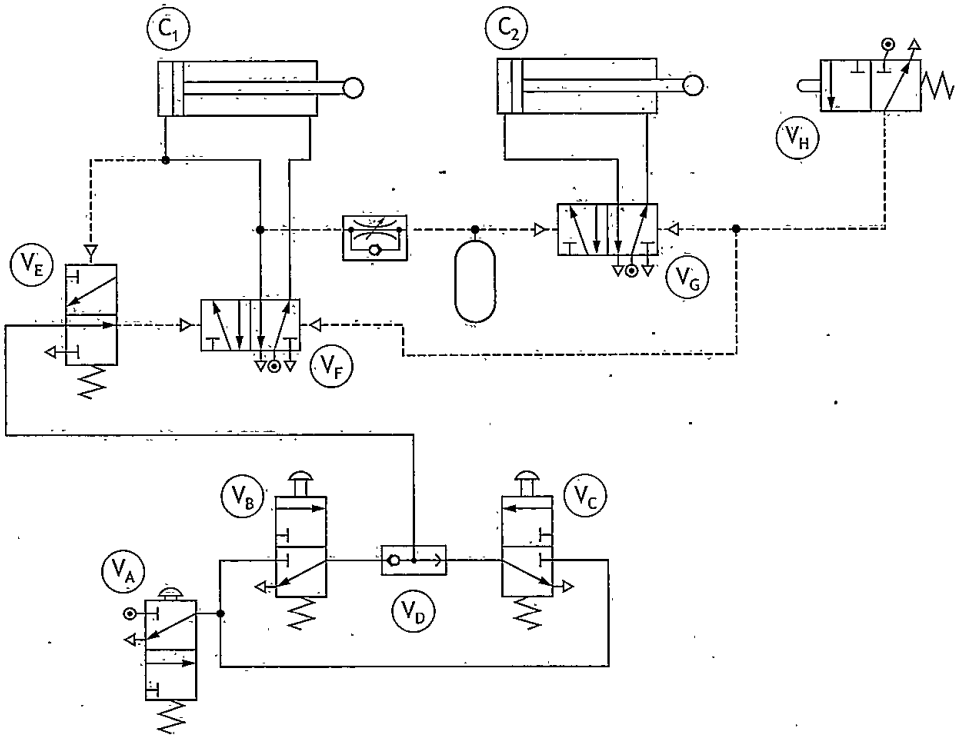
(b) Draw a logic diagram to perform this function. 4



[Turn over

10. (continued)

Two further cylinders are to be controlled by the following circuit.



MARKS

10. (continued)

(c) (i) Describe the operation of this circuit, highlighting the function of each component and the conditions that will cause the cylinders to instroke and outstroke. 6

When V_A... is pressed ~~makes air~~ and either V_B or V_C is pressed make air flows to V_E and into V_F causing C_1 to outstroke. meanwhile pilot air flows to the uni-directional restrictor and reservoir causing a time delay and into V_G, this causes C_2 to outstroke which activates V_H causing pilot air to flow to V_G causing C_2 to instroke meanwhile pilot air flows down to V_F which causes C_1 to instroke. air inside C_1 gets pushed back and changes to pilot air which flows to V_E which cuts off the main air supply from V_B or V_C. This causes the system to reset.

The engineering team are considering changing the circuit shown opposite to one that is operated by a microcontroller.

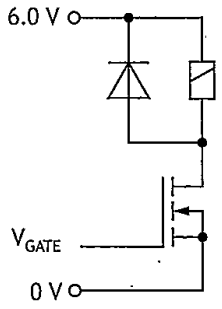
(ii) Describe two reasons why using a microcontroller-based system is preferred to a fully pneumatic system. 2

A microcontroller is very small and compact meaning that you don't need to spend a lot of money on components. It's also easy to repair since all you have to do is re-programme rather than replacing the parts (components).

MARKS

10. (continued)

In order to use a microcontroller-based system, solenoid valves need to be used. The following circuit has been designed to actuate one of the solenoids.



The solenoid is rated 12 W at 6.0 V. The MOSFET has a resistance of 0.70 Ω when switched on.

(d) (i) Calculate the resistance of the solenoid. 1

$P = \frac{V^2}{R}$

$\frac{12}{1} = \frac{6^2}{R}$

$R = \frac{6^2}{12}$

$R = 3\,\Omega$

(ii) Calculate the current through the MOSFET when it is fully switched on. 1

$V = I R$

$6 = I \times 0.70$

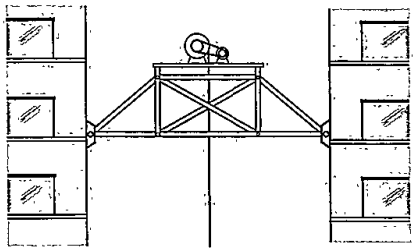
$0.70I = 6$

$I = \frac{6}{0.70}$

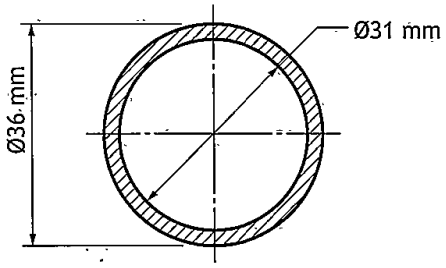
$I = 8.6\,A$

MARKS

11. During a construction project in a city centre location, a lifting platform is installed between two high rise buildings.



One of the members in the structure has a cross-section as shown below, with an internal diameter of 31 mm, and an external diameter of 36 mm.



This mild steel member has a strain of 4.6×10^{-5} when subjected to a load.

(a) Calculate the load carried by this member. 4

$A_1 = \frac{\pi d^2}{4}$

$A_1 = \frac{\pi \times 31^2}{4}$

$A_1 = 754.77 mm^2$

$A_2 = \frac{\pi d^2}{4}$

$A_2 = \frac{\pi \times 36^2}{4}$

$A_2 = 1017.88 mm^2$

$A_T = A_2 - A_1$

$A_T = 1017.88 - 754.77$

$A_T = 263.11 mm^2$

$\sigma = \frac{F}{A}$

$\frac{4.6 \times 10^{-5}}{1} = \frac{F}{263.11}$

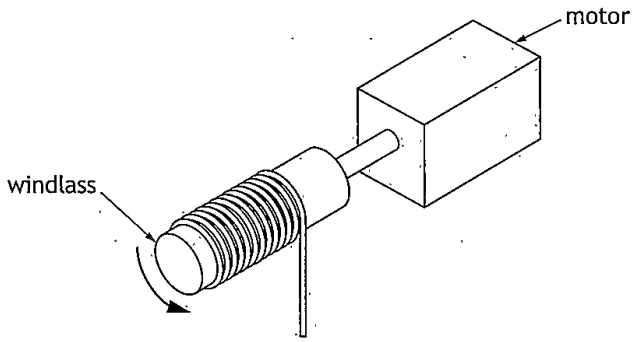
$F = 4.6 \times 10^{-5} \times 263.11$

$F = 0.012N$

MARKS

11. (continued)

A motor-driven winch system is used for lifting construction materials with up to 12,000 kg of mass. The windlass, with 320 mm diameter, rotates at 12 revolutions per minute.



(b) Calculate the mechanical power required by this motor. 5

12 ÷ 60 = 0·2 revs per s

P = 2πnT

P = 2π × 0·2 × 2400

P = 4825486W

12,000 × 9·8 = 117600

F = Fr

= 12,000 × 0·2

= 2400

T = Fr

T = 117600 × 0·2

T = 23520Nm

12 ÷ 60 = 0·2 revs per second

T = Fr 12,000 × 9·8 = 117600N r = 320 ÷ 2

r = 160

T = 117600 × 160

T = 18816000Nm

P = 2πnT

P = 2π × 0·2 × 18,816,000

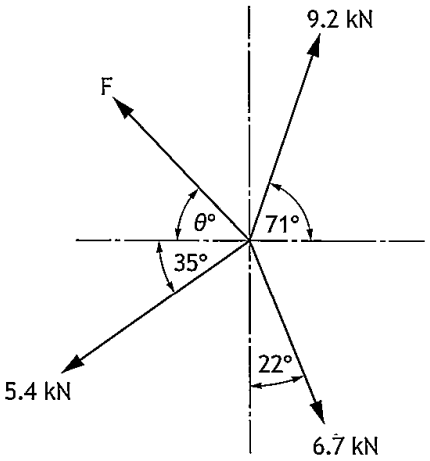
P = 23,644,882W

MARKS

11. (continued)

Later in the construction project, the lifting platform supports cables used to suspend a concrete beam above the site until it is ready for positioning.

The diagram below represents the concurrent force system while the beam is in suspension.



(c) Calculate the magnitude and angle of the force F, required to maintain equilibrium. **6**

$\Sigma F_V = 0$

$F\uparrow = F\downarrow$

$9.2\sin 71 + F = 6.7\sin 22 + 5.4\sin 35$

$8.70F = 2.51 + 3.10$

$F = \frac{2.51 + 3.10}{8.70}$

$F = 0.64N$

$\Sigma F_H = 0$

$F\rightarrow = F\leftarrow$

$9.2\cos 71 + 6.7\cos 22 = 5.4\cos 35 + F$

$2.99 + 6.21 = 4.4F$

$F = \frac{2.99 + 6.21}{4.4}$

$F = 2N$

$\Sigma F_H = 0$

$F\rightarrow = F\leftarrow$

$9.2\cos 71 + 6.7\cos 22$

$R = \sqrt{0.64^2 + 2^2}$

$R = 2N$

$\tan\theta = \frac{O}{A}$

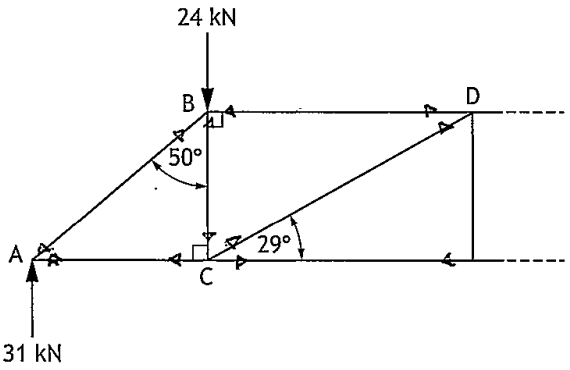
$\theta = \tan^{-1}\left(\frac{0.64}{2}\right)$

$\theta = 17.74°$

$\theta = 18°$

MARKS

12. The free-body diagram for part of a structure and its loading is shown below.



Calculate, using nodal analysis, the magnitude and nature of forces in members AB, AC, BC, BD and CD.

Show all working and final units on the page opposite.

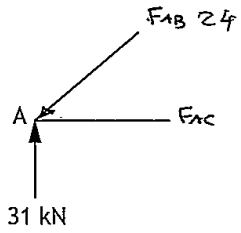
Complete the table below. **8**

Member	Magnitude	Nature
AB	7kN	strut
AC	4.5 kN	tie
BC	6kN	Strut
BD	8kN	Strut
CD	3.2kN	Tie

12. (continued)

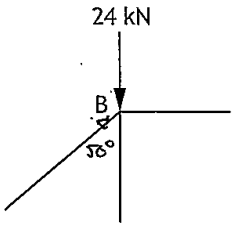
Space for working

node A

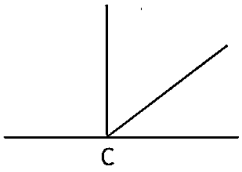


$F_{AB} = 31$

node B



node C



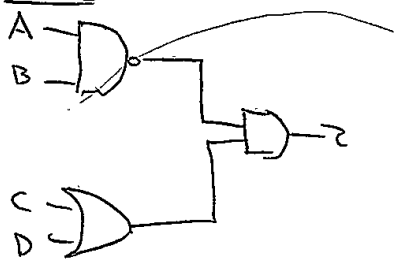
[END OF QUESTION PAPER]

MARKS

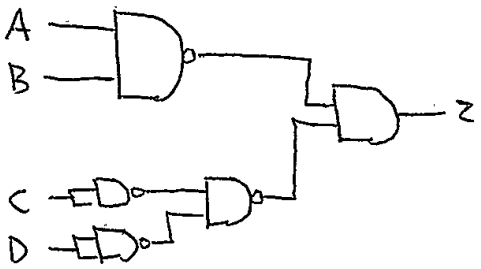
ADDITIONAL SPACE FOR ANSWERS

Q6 $Z = (\overline{A \cdot B}) \cdot (C + D)$

Working



Final answer



Q7

$P = \frac{E}{t}$

$P = \frac{2885120}{11}$

$P = 262283\,W$

$E_p = mgh$

$E_p = 8163.27 \times 9.8 \times 15$

$E_p = 1{,}200{,}000\,J$

$80{,}000 \div 9.8 = 8163.27\,kg$

$0.87 \times 1{,}200{,}000$

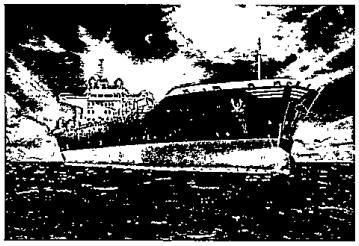
$P_{out} = 1{,}044{,}000\,J$

Q=

Candidate 3 evidence

SECTION 1 — 20 marks
Attempt ALL questions

1. A new material is being tested for use in the manufacture of ships.



The results of a tensile test on the material are shown in **Figure 1**.
The range of 0 to A is shown magnified in **Figure 2**.

Figure 1

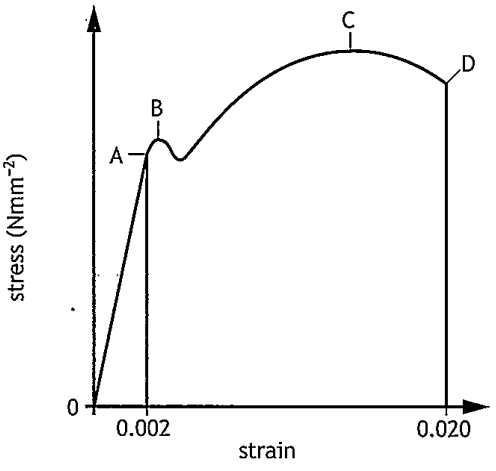
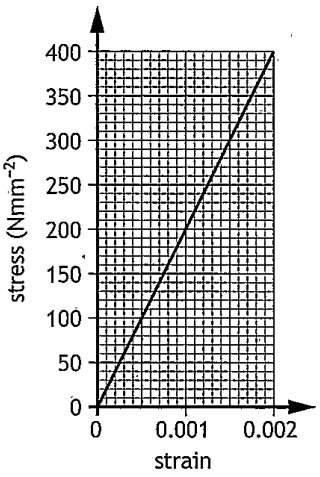


Figure 2



MARKS

1. **(continued)**

(a) (i) State the name of the range 0 to A. 1

elastic range

(ii) State the name of the range A to D. 1

plastic range

(b) (i) Calculate, using the information from **Figure 2**, Young's Modulus for this material. 1

$E = \frac{\sigma}{\epsilon} = \frac{400}{0.002}$

$E = 20,000\ N mm^{-2}$

$E = 20\ kN mm^{-2}$

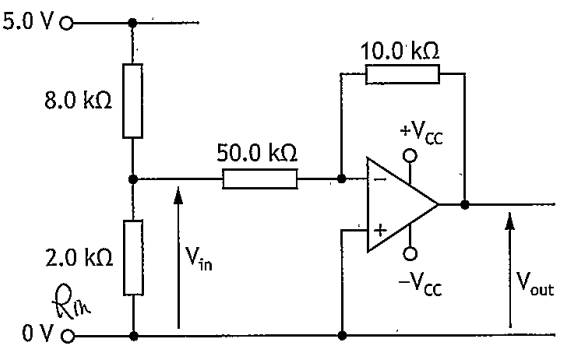
(ii) State the property identified by point C on **Figure 1**. 1

ultimate tensile stress

[Turn over

MARKS

2. Part of an electronic circuit is shown.



(a) Calculate V_{out}. 2

$V_{in} = \frac{2000}{10\,000} \times 5 = 1V$

$V_o = -\frac{R_f}{R_i} \times V_i$

$= -\frac{10,000}{20,000} \times 1$

$= -0.2V$

0

(b) Describe how the gain of this op-amp circuit could be decreased. 1

by decreasing the Resistance of the reference Resistor, by decreasing resistance of Rin resistor

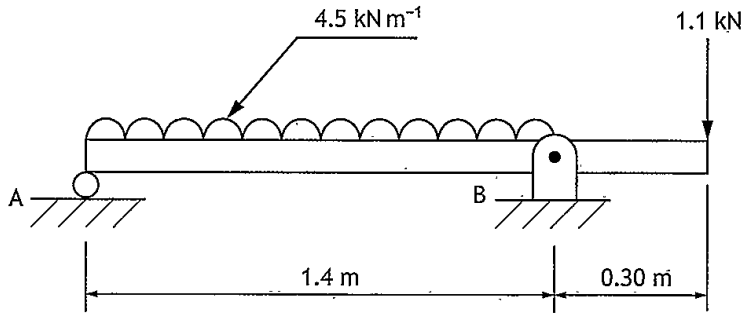
After testing, it was decided to add an additional op-amp configuration to change the polarity of V_{out}.

(c) State the name of the op-amp configuration required to perform this task. 1

inverting amplifier

MARKS

3. A beam used in the construction of a covered walkway is shown.



Calculate by taking moments about B, the vertical reaction at A. 3

$\Sigma M_B = 0$

UDL $= 4.5 \times 1.4$
$= 6.3$ kN @ 0.7 m

$R_A \times 1.4 = (6.3 \times 0.7) + (1.1 \times 0.3)$

$R_A \times 1.4 = 4.41 + 0.33$

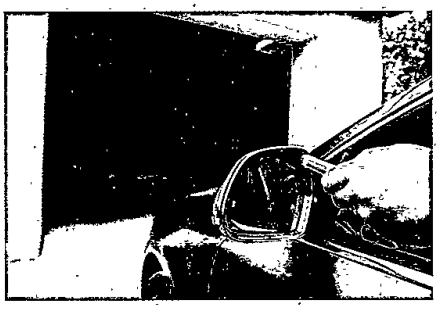
4.74

$R_A = 3.3857...$ kN

$R_A = 3.4$ kN

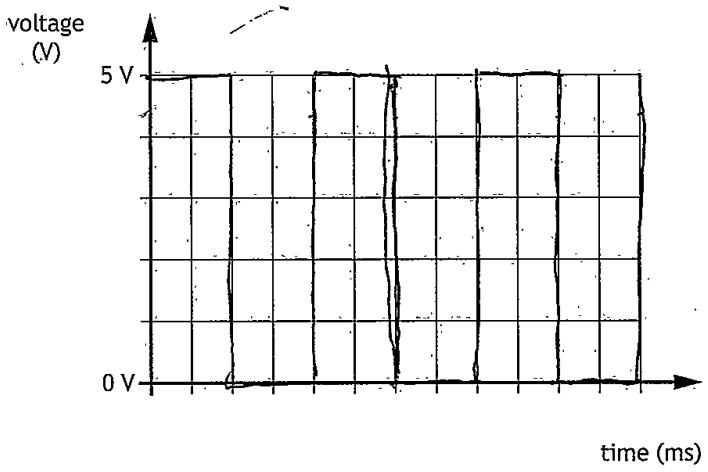
MARKS

4. The speed at which an automatic garage door opens is controlled by a motor using pulse-width modulation (PWM).



(a) Complete the graph below to show how PWM could be used to make the motor rotate at half speed.

You should include at least three pulses. 2



(b) Describe how the speed of this motor could be decreased using PWM. 1

Motor speed can be decreased by decreasing length of pulses (length of time of pulses

MARKS

4. (continued)

An alternative method of speed control involves varying the size of the DC voltage supplied to the motor.

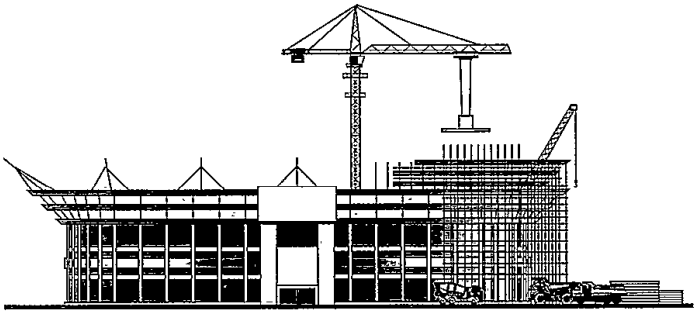
(c) Describe one advantage of using PWM in comparison to varying the size of the voltage supply. 1

more accurate and less wasted energy.

[Turn over

MARKS

5. The capacity of a sports stadium is being increased. This needs an additional stand to be built on top of the existing structure.



A structural engineer is involved in the design of this new structure.

Describe two examples of how the structural engineer will use their knowledge of materials in the design of the new structure. 2

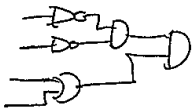
Example 1 Stresses and strains of preexisting materials to ensure that the stadium is not damaged or destroyed.

Example 2 Factor of safety is high enough to account for poor workmanship, material anomolies and UV, weather etc

MARKS

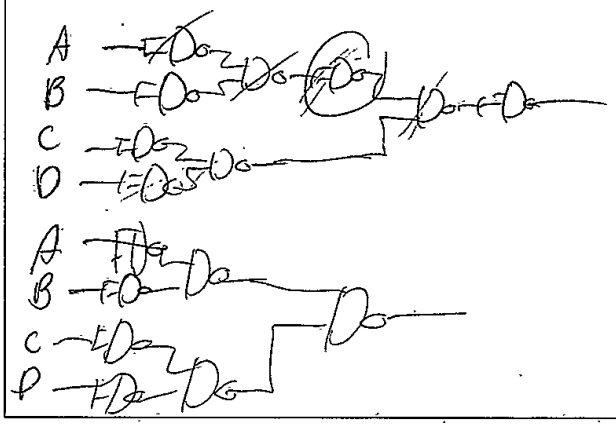
6. An electronic engineer has designed a combinational logic circuit according to the Boolean equation, shown below.

$$Z = \left(\overline{A \bullet B}\right) \bullet (C + D)$$

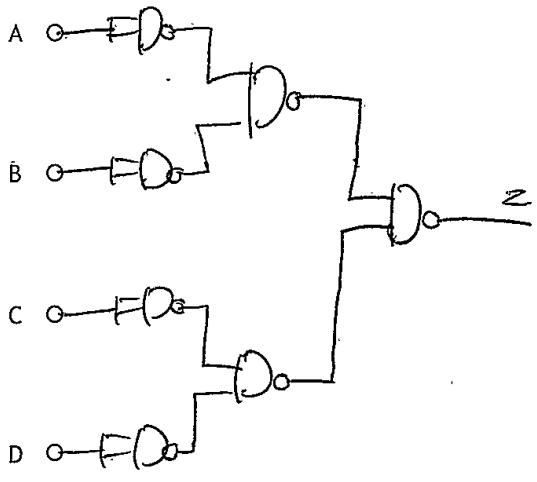


Draw a NAND equivalent circuit for this Boolean equation. 3

Space for working



Final answer

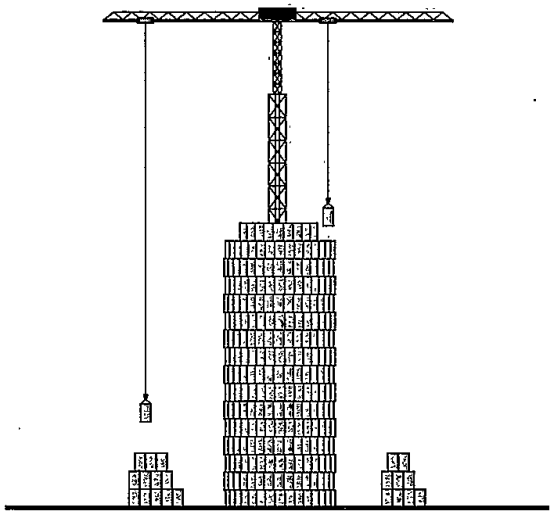


MARKS

SECTION 2 — 90 marks

Attempt ALL questions

7. An engineering team has produced a prototype system to store excess energy from power plants.



When electricity production exceeds demand, electric motors are used to lift concrete blocks and place them in 'towers'. When the blocks are returned to ground level electricity is reclaimed by generators.

The first block has a mass of 10,000.0 kg. The system that raises this block is 92% efficient.

(a) Calculate the energy required to raise this block 32 m. 2

$E_p = mgh$

$= (10,000) \times (9.8) \times 32$

$= 3136000$

$8136000 - 250880$

$= 2885120$

$E = 2.885\ MJ$

$E = 3\ MJ$

250880

2885120

0.08×3136000

$= 250880$

MARKS

7. (continued)

A second block applies a force of 80.0 kN to the supporting wire rope.

As this block is returned to ground level (at constant speed) its supporting wire rope turns a generator and electricity is reclaimed. This part of the system is 87% efficient.

(b) Calculate the power output from the generator if this block descends 15 m in 11 seconds. 3

$E = Fd$

$= 80\,000 \times 15$

$= 1.2\,MJ$

$P = \frac{E}{t}$

$E = Fd$

$P = \frac{E}{t}$

$= \frac{1\,200\,000}{11}$

$= 109090$

$P = 109.09 \times 10^3$

$P = 110\,kW$

The wire rope holding the 80.0 kN block as it is lifted is made from mild steel and has a diameter of 48 mm.

(c) Calculate the factor of safety in the wire rope when it raises this block at a steady speed. 4

1809.557368 28cc

$FOS = \frac{UTS}{SWS}$

$FOS = \frac{430}{\sigma}$

$FOS = 9.7263$

$FOS = 9.7$

$= 10$

$E = \frac{\sigma}{\varepsilon}$

$E = 196\,kNmm^{-2}$

$UTS = 430$

$\sigma = \frac{F}{a} = \frac{80{,}000}{1809.557..}$

$\sigma = 44.209786\,63$

$\sigma = 444.2\,N/mm^2$

7. (continued) MARKS

(d) Describe two economic and two environmental impacts that this system would have. 4

Economic impact 1 if more excess energy is storable then less money will be wasted producing energy that will not be used.

Economic impact 2 lower prices of energy if storage is more efficient

Environmental impact 1 often to less waste energy produced then less harm done to the environment when disposing of it.

Environmental impact 2

(e) Describe two advantages that this system has over a chemical battery storage system for excess electrical energy. 2

Advantage 1 No accidents and chemicals leak so chemical batteries are easily damaged

Advantage 2

8. An anti-lock braking system is used to control the speed of an elevator as it descends. This uses a form of pulse-width modulation operated by a microcontroller.

If the speed of the elevator is too fast, the brakes will increase the proportion of operating time.

The table below identifies the connections to the microcontroller.

Input	Pin	Output
	7	brake
ground level sensor	1	
speed sensor (analogue)	0	

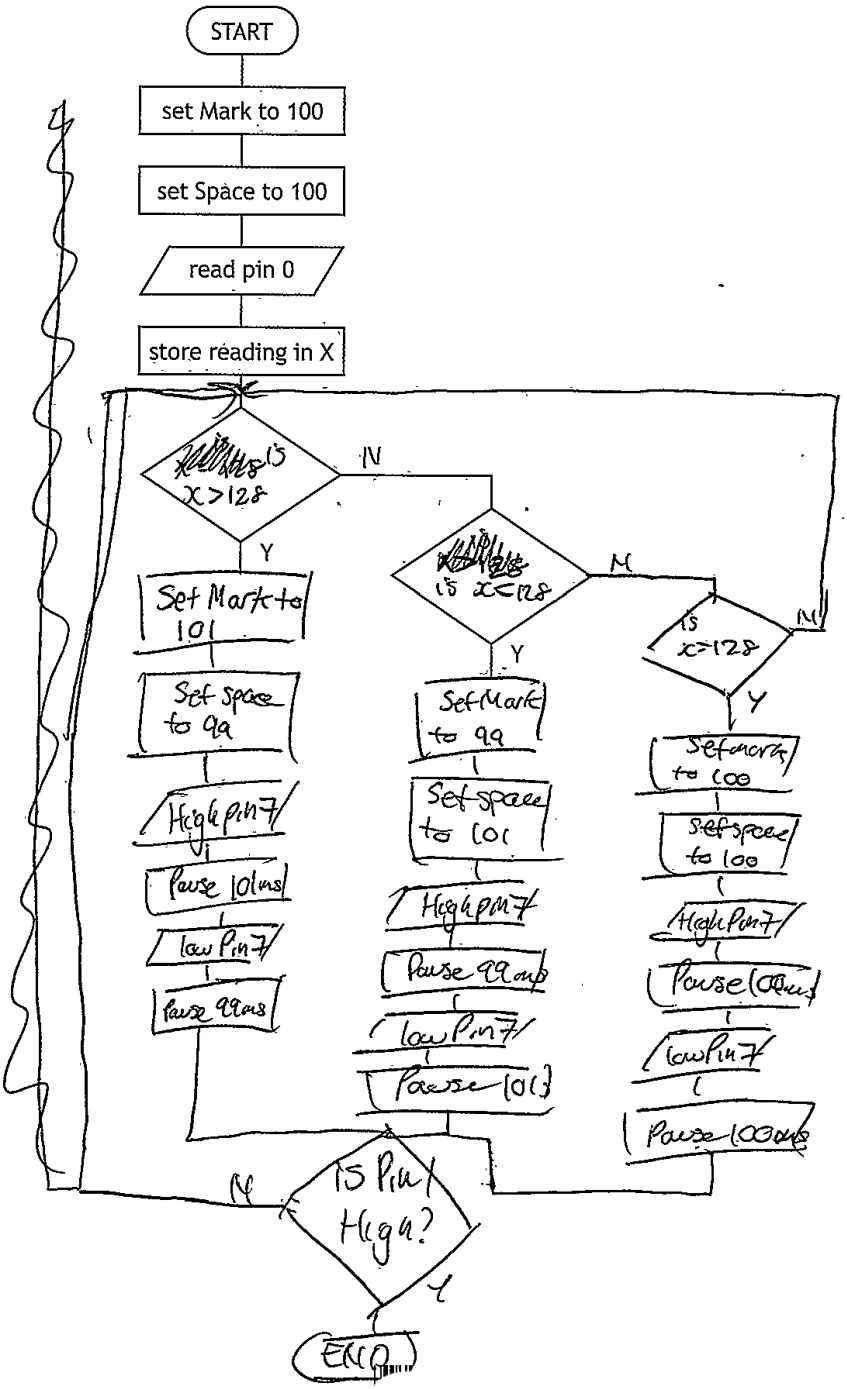
The system must perform the following steps.

- Values for **mark** and **space** both need to be initially set to a value of 100
- A reading must be taken from a speed sensor and its value stored in variable X
- If the value of X is greater than 128 then **mark** increases by 1 and **space** decreases by 1
- If the value of X is smaller than 128 then **mark** decreases by 1 and **space** increases by 1
- If the value of X is 128 then **mark** and **space** do not change
- The brake must be switched on and off for the times specified **mark** and **space** (this will be in milliseconds)
- The process must continue until the ground level sensor is activated

MARKS

8. **(continued)**

(a) Complete, with reference to the specification and the input/output table, this flow chart for the control of the system. **8**



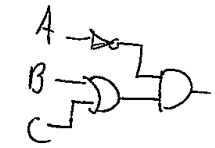
MARKS

8. (continued)

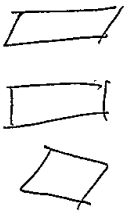
An alarm (Z) is part of the elevator's operating system and needs to be activated under the conditions given by the following Boolean equation.

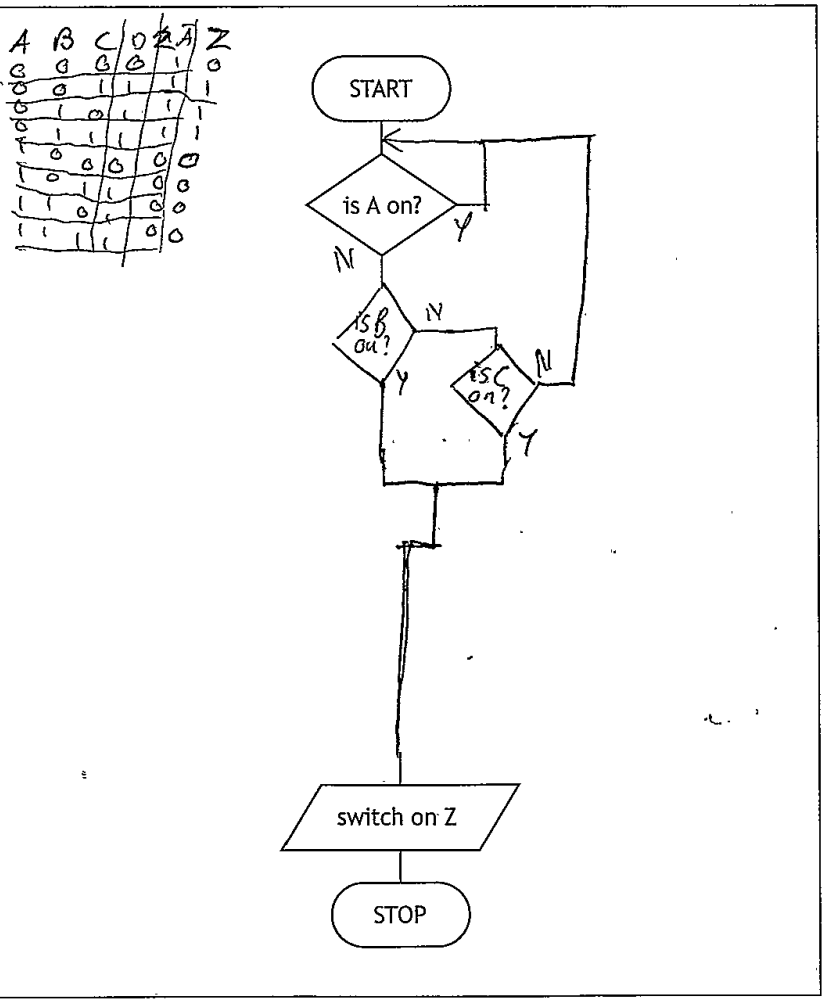
$$Z = \overline{A} \bullet (B+C)$$

(b) Complete the following flowchart to perform the function described above. 3



a needs to be 0 for 2 to be 1

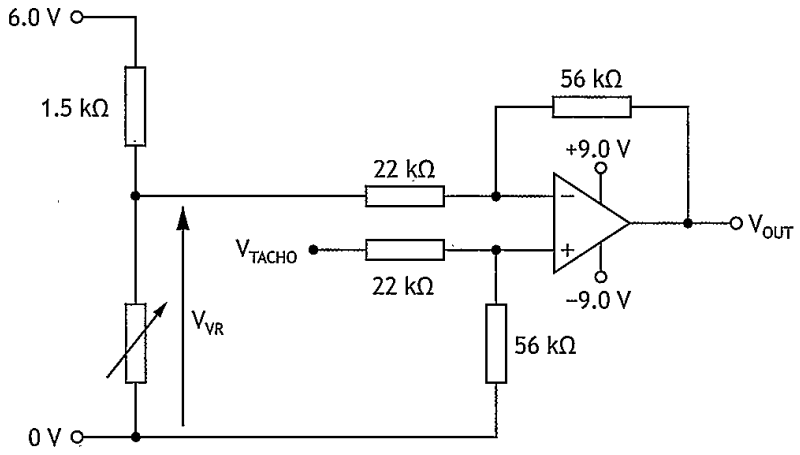




MARKS

8. (continued)

An alternative system to control the force applied by the brake is also tested. As the speed of the elevator varies from a reference value the output of the circuit changes proportionately. The speed of the elevator is monitored by a tachogenerator.



When testing the circuit, the voltage from the tachogenerator (V_{TACHO}) was found to be 2.3 V.

(c) (i) Calculate the resistance of the variable resistor in the circuit shown above when the output voltage of the op-amp is +4.5 V. 4

$V_O = \frac{R_f}{R_i}(V_2 - V_1)$

$4.5 = \frac{56k}{22k}(2.3 - V_{VR})$

$2.3 - V_{VR} = \frac{4.5 \times 22k}{56k}$

$V_{VR} = 2.3 - 1.76785$

$= 0.53V$

$R_{VR} = 165.2\Omega$

$V_2 = 2.3V$

$V_1 = V_{VR}$

$R_f = 56k\Omega$

$R_i = 22k\Omega$

$V_O = 4.5V$

$\frac{R_1}{R_2} = \frac{V_1}{V_2}$ $R_1V_2 = V_1R_2$

$R_2 = \frac{R_1V_2}{V_1}$

$R_{VR} =$

$=$

$V = IR$ $3.65mA$

$I = \frac{V}{R} = \frac{5.47}{1500}$

$V = IR$

$R = \frac{V}{I} = \frac{0.53}{3.65mA}$

$R = 165\Omega$

$2.3 - 0.51$

MARKS

8. (c) (continued)

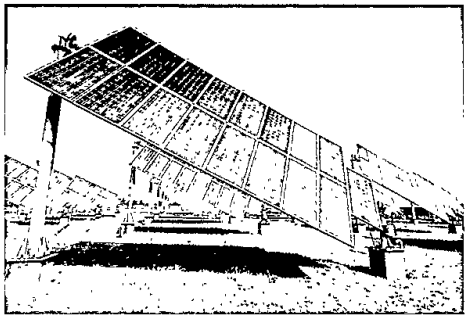
(ii) Describe, with reference to the circuit, how the reference speed of the elevator could be increased. 1

Increasing the value of

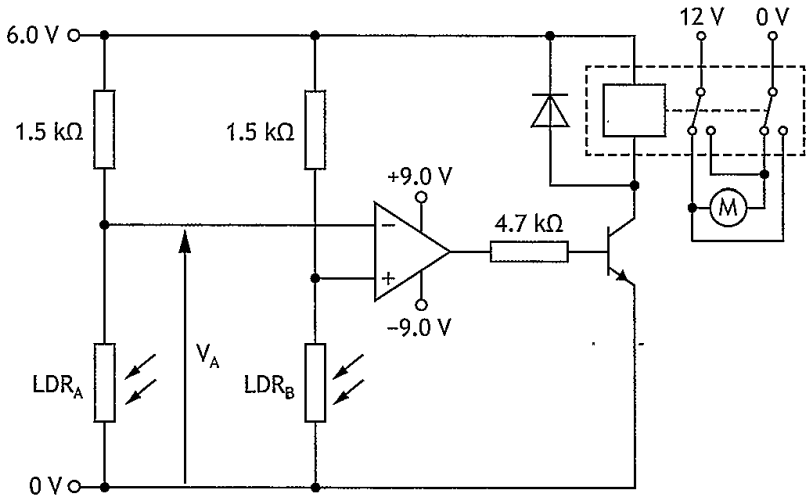
decreasing the value of the variable resistor decreases V_{VR} which increases the difference between V_{TACHO} and V_{VR}, increasing V_{OUT} and the speed of the elevator

[Turn over

9. A system is needed to alter the position of a solar panel so that it is constantly facing the sun during daylight hours. If one sensor gives a higher reading than the other, a motor wil turn the panel in the brighter direction.



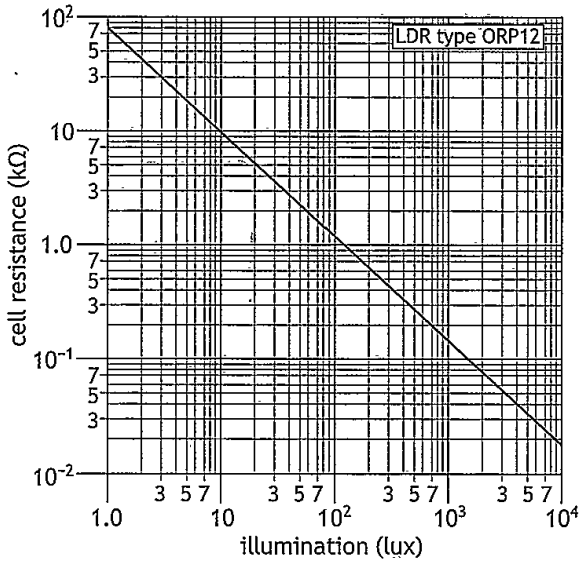
A preliminary design of the control circuit is shown below.



MARKS

9. (continued)

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



(a) Calculate V_A if the light level on LDR_A is 20 lux. **2**

5kΩ

$V_A = 4.6V$

$V_G = \frac{5000}{6500} \times 6$

$V_A = 4.6V$

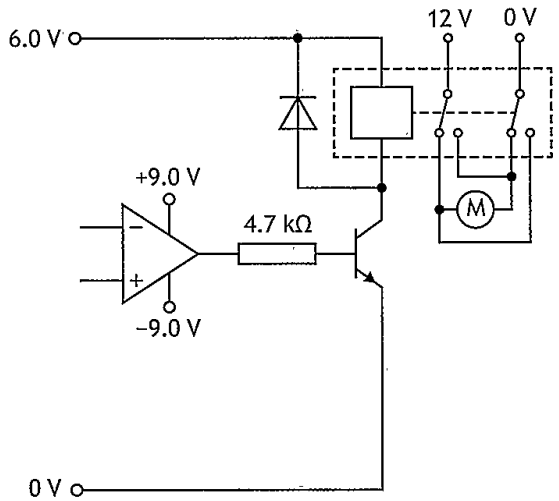
$I = \frac{V}{R}$

$0.93mA$

MARKS

9. (continued)

Part of the control circuit is shown below.



(b) (i) Calculate the base current to the transistor when the op-amp saturates positively.

Assume V_{be} is 0.70 V. The op-amp output saturates at 75% of the supply voltage. 3

$V = IR$

$I = \frac{V}{R} = \frac{(6{\cdot}75 - 0{\cdot}7)}{4700}$

$0{\cdot}75 \times 9 = 6{\cdot}75\text{V}$

$I = 1{\cdot}287 \times 10^{-3}$

$I_b = 1{\cdot}3\text{mA}$

$6{\cdot}13 \times 10^{-2}$

$6{\cdot}013$ kΩ

$0{\cdot}1001\text{A}$

MARKS

9. (b) (continued)

The relay has a resistance of 5.0 Ω.

(ii) Calculate the minimum current gain of the transistor to ensure it is fully saturated when the op-amp is saturated positively. 2

$h_{fe} = \frac{I_c}{I_b}$

$= \frac{1.24}{0.00134}$

$= 923.07$

$h_{fe} = 920$

$V = IR$

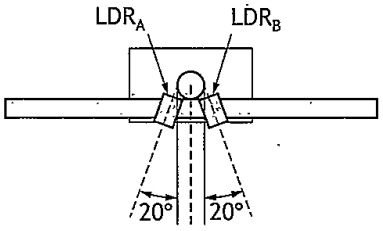
$I_c = \frac{V}{R} = \frac{6}{5}$

$I_c = 1.24$

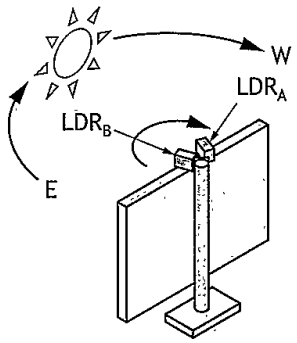
[Turn over

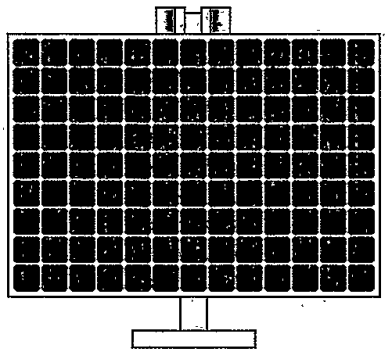
9. (continued)

While testing the circuit, V_A was found to be less than V_B and the motor rotated, moving the solar panel towards the sun's position.

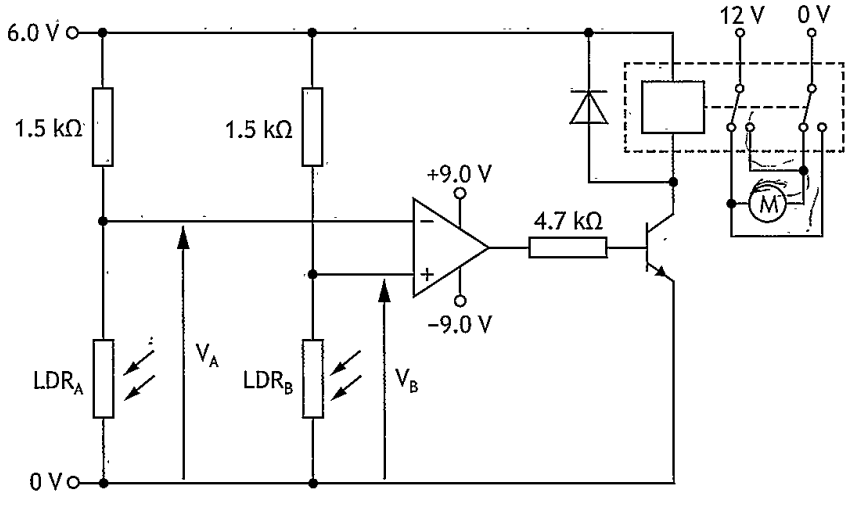


TOP VIEW





FRONT VIEW



MARKS

9. (continued)

(c) Describe, referring to the circuit on the opposite page, what will happen as the solar panel moves.

Your answer must refer to the input voltage dividers, the op-amp and transistor, and the relay and motor. 6

Input voltage dividers as light levels decrease, resistance of LDRs increases, which increases Voltage output. depending on which side is darker, then a larger output is given and motor. if Va < Vb then the op amp saturates positively conditions if Va > Vb then the op amp saturates negatively

Op-amp and transistor if output Voltages of Va and Vb are equal or close enough that an output is put out that is less than 0.7V but larger than -0.7V then the motor will not turn

Relay and motor depending on State Saturation State of the op amp Switch a DPDT is switched depending on polarity of electromagnetic field produced by relay

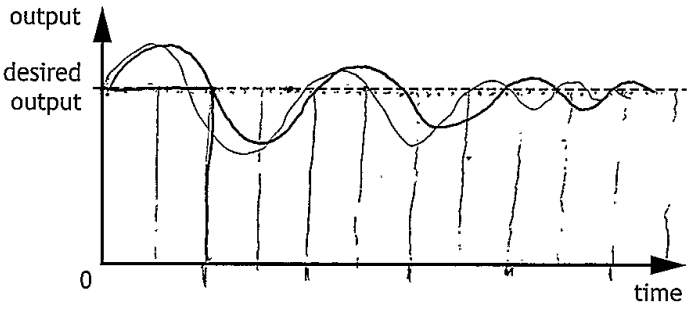
[Turn over

MARKS |

9. **(continued)**

The op-amp control circuit uses two-state control.

(d) (i) Complete the graph below to show how the output of a two-state control system changes as it approaches the desired output. **2**



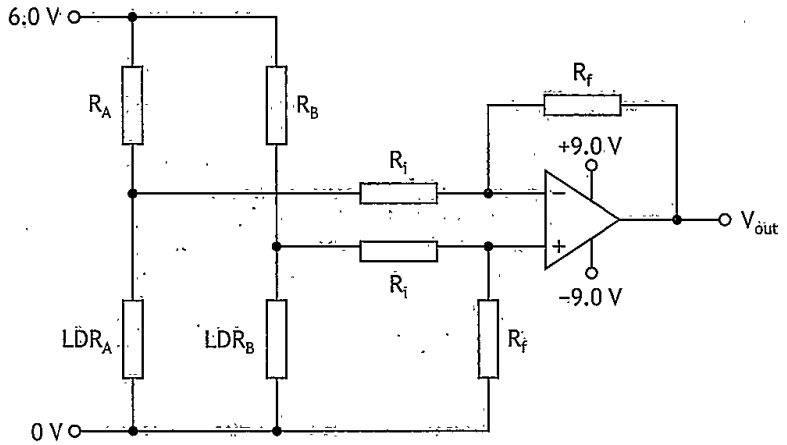
(ii) Describe the impact that this type of control would have on the mechanical output of the system. **1**

output change output would change less and less as it gets closer to desired output.

MARKS

9. (continued)

An alternative control circuit is also tested.



(e) (i) State the type of control produced by this type of circuit. 1

closed loop feedback

(ii) Describe the difference between the control produced by this circuit and a two-state control system. You can use diagrams or graphs to illustrate your answer. 3

[Turn over

MARKS

10. An engineering team is experimenting with different control systems to operate a number of pneumatic cylinders. The following truth table shows the conditions under which one of the cylinders must outstroke.

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

(a) Write a Boolean equation for the output Z. 2

Z = _____

_____

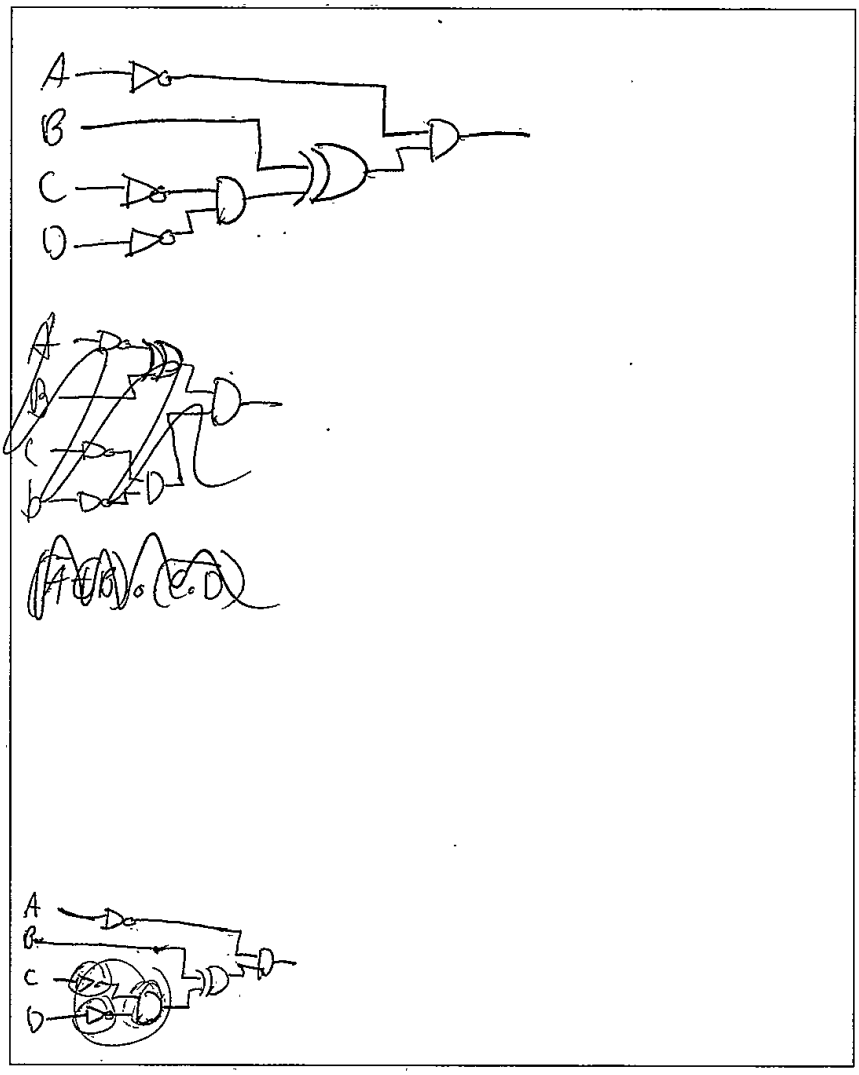
MARKS

10. (continued)

A second cylinder operates under the following conditions.

$$X = \overline{A} \cdot B \oplus (\overline{C \cdot D})$$

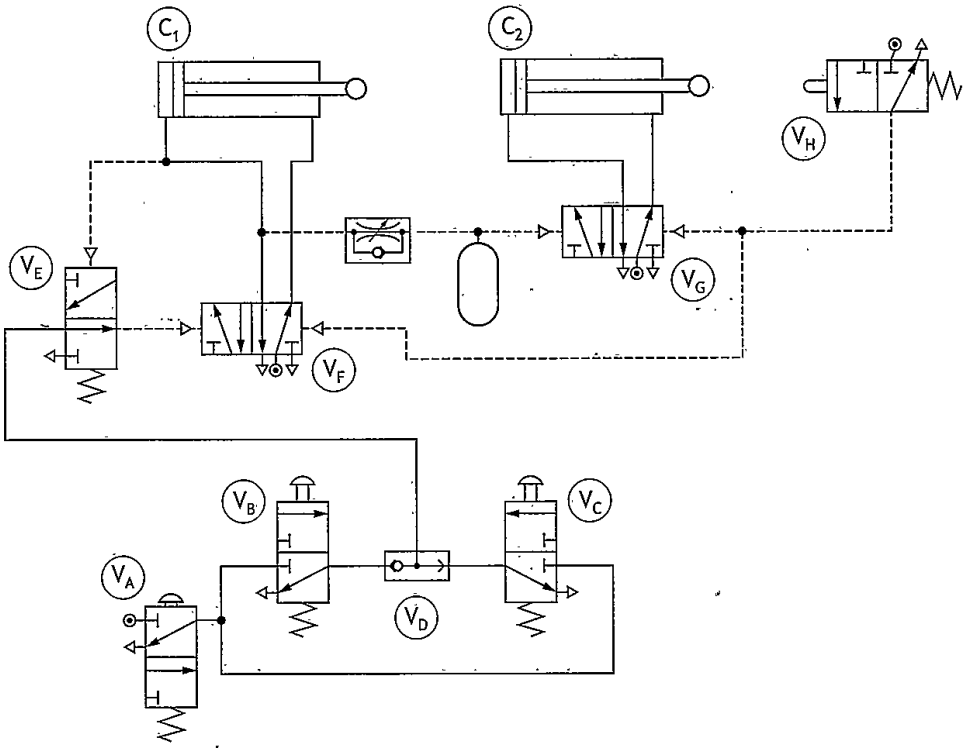
(b) Draw a logic diagram to perform this function. 4



[Turn over

10. (continued)

Two further cylinders are to be controlled by the following circuit.



MARKS

10. (continued)

(c) (i) Describe the operation of this circuit, highlighting the function of each component and the conditions that will cause the cylinders to instroke and outstroke. 6

When V_A... is in its ~~bottom~~ Top State and V_B is in its bottom state then the V_D is pushed right. ~~Air~~ flows through VE putting VF into its left hand state, causing C to outstroke. air flows through the ~~UPPER~~ VDFR and reservoir causing a time delay, then VG is put into its left hand state, causing C to ~~instroke~~ and outstroke and activate VH which then puts VG and VF back into their right hand states. ~~VB and VC~~ V_B, V_C and V_D act as an XOR gate, if one is actuated then air flows in none or both are actuated then air doesn't flow

The engineering team are considering changing the circuit shown opposite to one that is operated by a microcontroller.

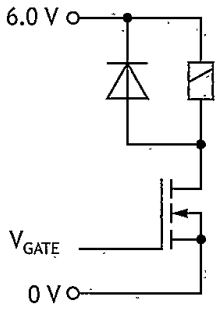
(ii) Describe two reasons why using a microcontroller-based system is preferred to a fully pneumatic system. 2

~~allows for more accurate controlling~~ ~~of cycles~~ easier to control and make alterations

MARKS

10. (continued)

In order to use a microcontroller-based system, solenoid valves need to be used. The following circuit has been designed to actuate one of the solenoids.



The solenoid is rated 12 W at 6.0 V. The MOSFET has a resistance of 0.70 Ω when switched on.

(d) (i) Calculate the resistance of the solenoid. 1

$P = IV$ $I = U^2$

$P = \frac{V^2}{R}$ $R = \frac{V^2}{P} = \frac{36}{12}$ $V = IR$

$R = 3\Omega$ $V = IR$

$R = \frac{U}{I} = \frac{6}{2}$

$= 3\Omega$

$I = \frac{P}{V} = \frac{12}{6}$

$= 2A$

3.7Ω

0.3Ω

(ii) Calculate the current through the MOSFET when it is fully switched on. 1

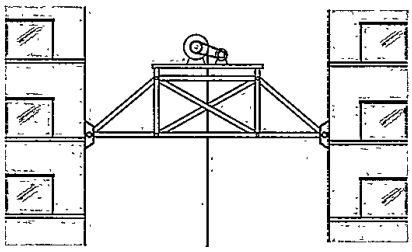
$I = \frac{V_s}{R}$ $R_{MOSFET} = 3 - 0.7$

$V = IR$ $= 2.3$

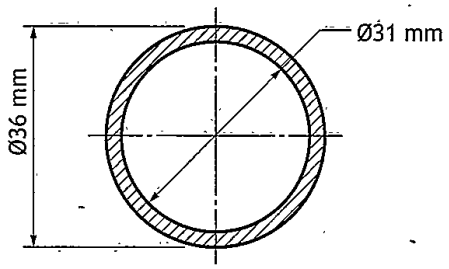
$I = \frac{V}{R} = \frac{6}{2.3} = 2.6A$

MARKS

11. During a construction project in a city centre location, a lifting platform is installed between two high rise buildings.



One of the members in the structure has a cross-section as shown below, with an internal diameter of 31 mm, and an external diameter of 36 mm.



$\varepsilon =$ 1296 / 754.767635

This mild steel member has a strain of 4.6×10^{-5} when subjected to a load.

(a) Calculate the load carried by this member. 99 1017.87602 4

$E = \frac{\sigma}{\varepsilon}$

$\sigma = E \times \varepsilon$

$= 196000 \times 4.6 \times 10^{-5}$

$\sigma = 9.016$

$A = \frac{\pi d^2}{4} - \frac{\pi d^2}{4}$

$A = 1017.87602 - 754.767635$

$A = 263.108385$

$A = 236.1 mm^2$

$E = 196 kN mm^{-2}$

$\sigma = \frac{f}{a}$ $F = \sigma \times a$

$F = 9.016 \times 236.1$

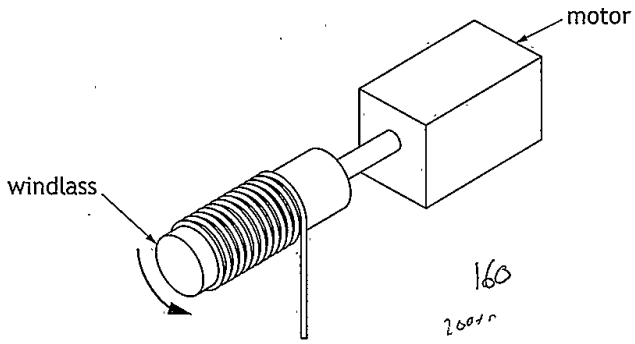
$F = 2128.6776$

$F = 2.13 kN$

MARKS

11. (continued)

A motor-driven winch system is used for lifting construction materials with up to 12,000 kg of mass. The windlass, with 320 mm diameter, rotates at 12 revolutions per minute.



(b) Calculate the mechanical power required by this motor. **5**

$P = 2\pi nt$

$P = 2 \times \pi \times 0{\cdot}2 \times T$

$P = 42826{\cdot}9105$

$P = 42826 \times 10^3$

$P = 430\ kW$

$n = \frac{12}{60} = 0{\cdot}2$ rev s^{-1}

$m = 12\,000$ kg

$d = 320$ mm

$T = F \times r$

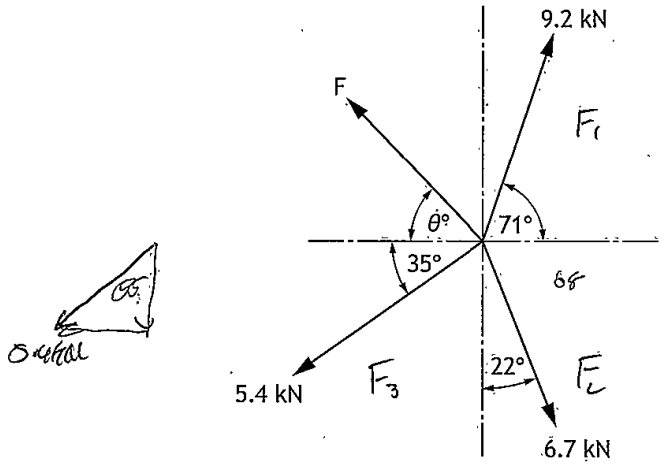
$= 360800$

MARKS

11. (continued)

Later in the construction project, the lifting platform supports cables used to suspend a concrete beam above the site until it is ready for positioning.

The diagram below represents the concurrent force system while the beam is in suspension.



(c) Calculate the magnitude and angle of the force F, required to maintain equilibrium. **6**

$\Sigma \uparrow F = \Sigma \downarrow F$

$F_V + 9.2\sin 71 = 5.4\sin 35 + 6.7\sin 22$ 5.6071

$F_V + 8.69877 = 3.0973 + 2.5098$

$\Sigma \uparrow F = \Sigma \downarrow F$

$F_V + 9.2\sin 71 = 5.4\sin 35 + 6.7\sin 68$

$F_V + 8.69877 = 3.0973 + 6.212$

$F_V = 9.3093 - 8.69877$

$F_V = 0.61053$

$F_V = 0.61\text{kN}$

$\Sigma \rightarrow F = \Sigma \leftarrow F$

$F_H + 5.4\cos 35 = 6.7\cos 68 + 9.2\cos 71$

$F_H + 4.4423 = 2.50986 + 2.995$

$F_H = 5.50486 - 4.4423$

$F_H = 1.082\text{kN}$

$|F| = \sqrt{F_H^2 + F_V^2}$

$F = 1.2\text{kN}$

$F = 1.2\text{kN}$

$\tan\theta = \frac{V}{H}$

$\theta = 29.4°$

60

1082

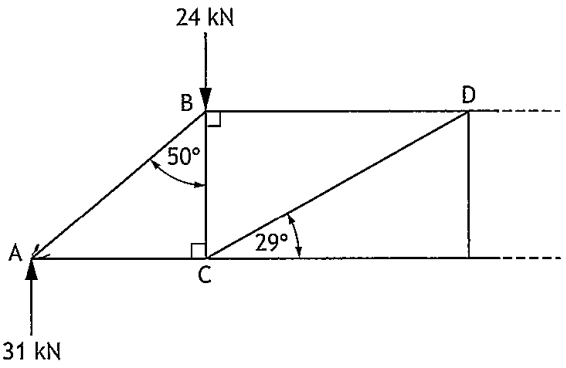
1170724

372600

1542824

MARKS

12. The free-body diagram for part of a structure and its loading is shown below.



Calculate, using nodal analysis, the magnitude and nature of forces in members AB, AC, BC, BD and CD.

Show all working and final units on the page opposite.

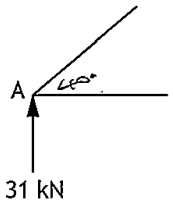
Complete the table below. **8**

Member	Magnitude	Nature
AB	68.2kN	strut
AC	36.9kN	tie
BC	24kN	strut
BD	36.9kN/31kN	
CD	27.6kN/	TIE

12. (continued)

Space for working

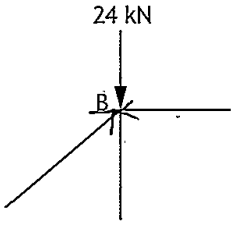
node A



$\Sigma \uparrow F = \Sigma \downarrow F$
$31kN = F_{AB}v$
$F_{AB} \sin 40 = 31$
$F_{AB} = 48.227$
$F_{AB} = 48.2kN$
(STRUT)

$\Sigma \rightarrow F = \Sigma \leftarrow F$
$F_{ABH} = F_{AC}$
$F_{AC} = 48.2 \cos 40$
$F_{AC} = 36.923$
$F_{AC} = 36.9kN$
(TIE)

node B

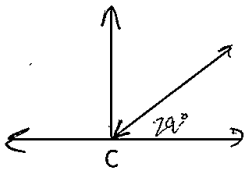


$\Sigma \uparrow F = \Sigma \downarrow F$
$F_{BC} = 24kN$
(STRUT)

$\Sigma \rightarrow F = \Sigma \leftarrow F$
$F_{ABH} = F_{BD}$
$F_{BD} = 48.2 \cos 50$
$F_{BD} = 36.9kN$

$F_{BD} = 48.2 \cos 50$
$F_{BD} = 30.98$
$F_{BD} = 31kN$

node C



$\Sigma \uparrow F = \Sigma \downarrow F$
$F_{BC} = F_{CD}v$
$F_{CD} \sin 29 = 24$
$F_{CD} = 49.5kN?$

$\Sigma \uparrow F = \Sigma \downarrow F$
$F_{BC} = F_{CD}v$
$F_{CD} \sin 61 = 24$
$F_{CD} = 27.4kN$

[END OF QUESTION PAPER]

ENTER NUMBER OF QUESTION

and the use of ram counter would need to be adapted as ~~this is only goin~~ it currently only works for integers, perhaps if the program was upscaled so it checked over more than 35, then an accurate reading could then be made by incrementing with smaller decimal values.