



FOR OFFICIAL USE

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National
Qualifications
2025

Mark

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X823/75/01**Engineering Science**

FRIDAY, 16 MAY

1:00 PM – 2:50 PM



* X 8 2 3 7 5 0 1 *

Fill in these boxes and read what is printed below.

Full name of centre

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Town

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Forename(s)

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Surname

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Number of seat

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Date of birth

Day

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Month

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Year

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Scottish candidate number

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Total marks — 110**SECTION 1 — 20 marks**

Attempt ALL questions.

SECTION 2 — 90 marks

Attempt ALL questions.

Show all working and units where appropriate.

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

The number of significant figures expressed in a final answer should be equivalent to the least significant data value given in the question. Answers that have two more figures or one less figure than this will be accepted.

Write your answers clearly in the spaces provided in this booklet. Additional space for answers is provided at the end of this booklet. If you use this space you must clearly identify the question number you are attempting.

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

Before leaving the examination room you must give this booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

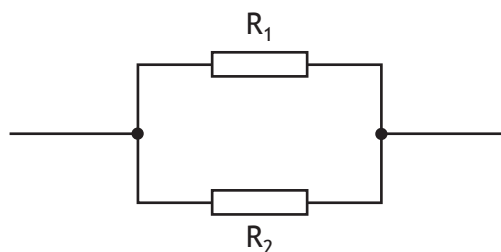


* X 8 2 3 7 5 0 1 0 1 *

SECTION 1 — 20 marks

Attempt ALL questions

1. Two resistors connected in a circuit are shown.



- (a) State the name given to this resistor arrangement.

1

The current flowing through resistor R_2 is measured using an ammeter.

- (b) (i) Draw the symbol for an ammeter.

1

- (ii) Indicate, with an X on the circuit shown above, where the ammeter would be connected to measure the current flowing through resistor R_2 .

1



2. A microcontroller program is shown.

line	program
1	main: if input1 is on then label_1
2	goto main
3	label_1: let count = 0
4	label_2: switch on pin 7
5	pause 500
6	switch off pin 7
7	pause 500
8	let count = count + 1
9	if count = 15 then label_3
10	goto label_2
11	label_3: end

(a) State a line number that contains a time delay.

1

Line number _____

(b) State the number of times that pin 7 will turn on and then off.

1

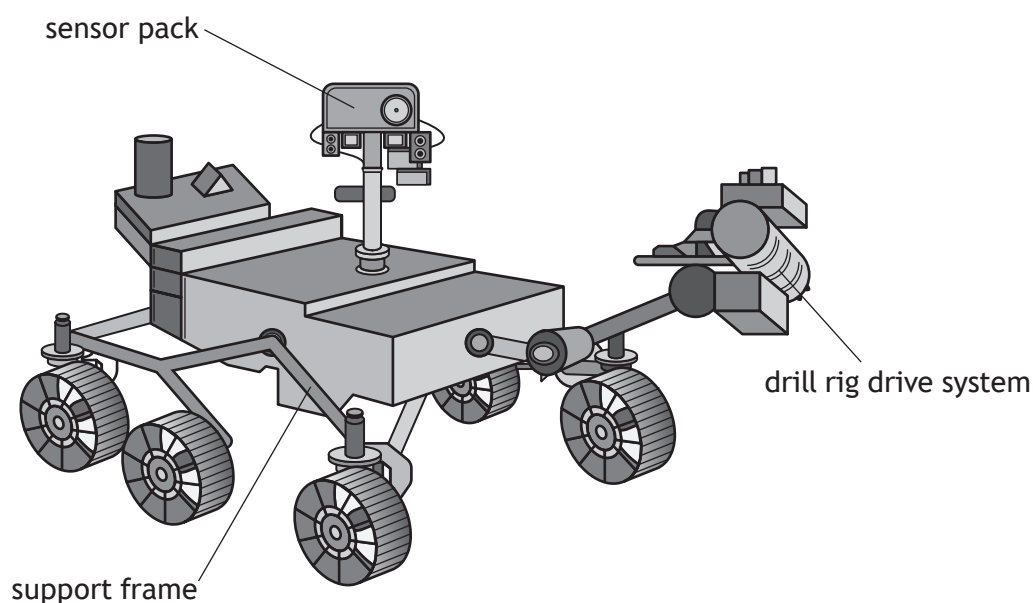
(c) State the name of the type of loop used to control the number of times pin 7 turns on and off.

1

[Turn over



3. A rover used to collect rock samples on Mars is shown.



Several different engineers were involved in the design of the rover.

State which branch of engineering would be responsible for the design of the:

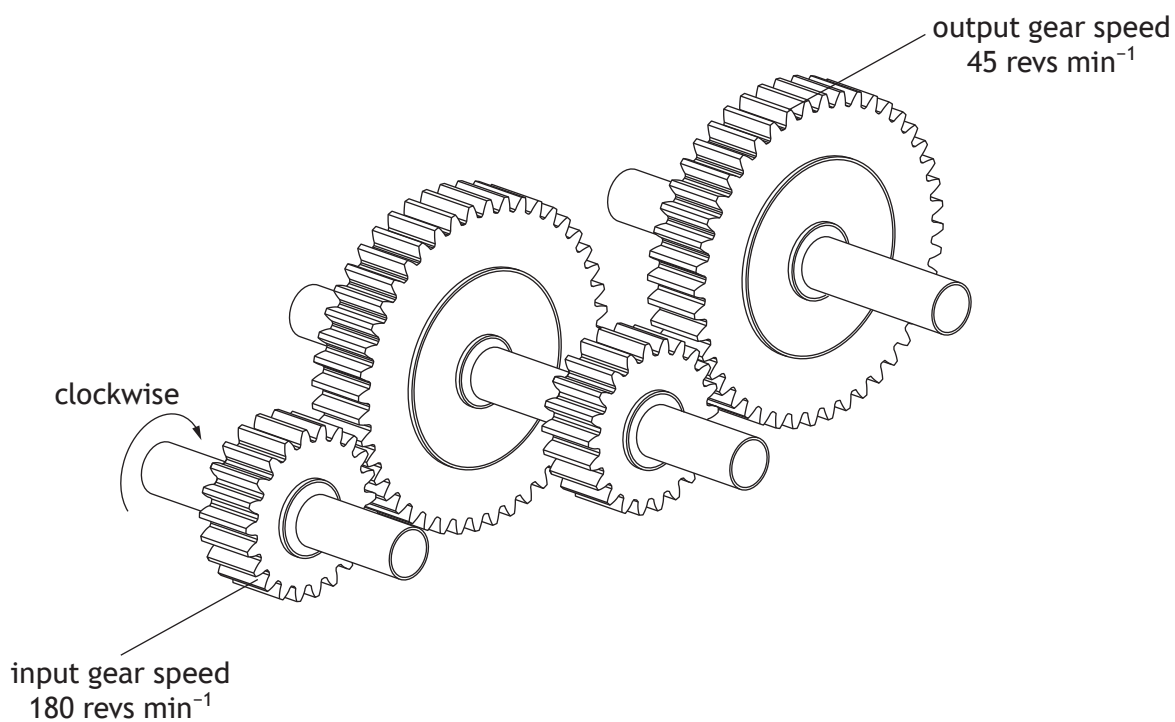
(a) support frame 1

(b) sensor pack 1

(c) drill rig drive system. 1



4. A gear train is shown.



(a) State the name of this type of gear train.

1

The input gear rotates clockwise.

(b) State the direction of rotation of the output gear.

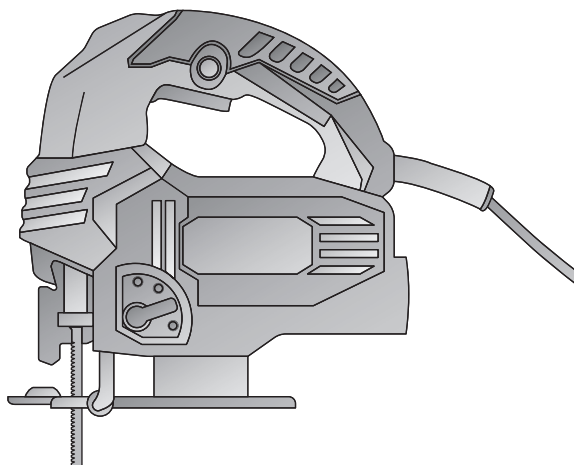
1

(c) Calculate the velocity ratio of the gear train.

2



5. A jigsaw used to cut wood is shown.



The jigsaw uses a motor and saw blade in its operation.

Complete the table below for the motion of the motor and saw blade.

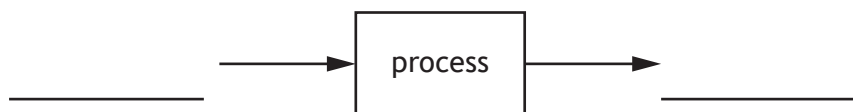
2

Part	Motion symbol	Motion name
motor		
saw blade		reciprocating



6. (a) Complete the **universal** system diagram below.

2



Many systems use control.

- (b) State the type of control that does **not** use feedback.

1

7. Hydropower uses water from a reservoir to produce electricity.



Describe two **environmental** impacts of hydropower as a source of energy.

2

1 _____

2 _____

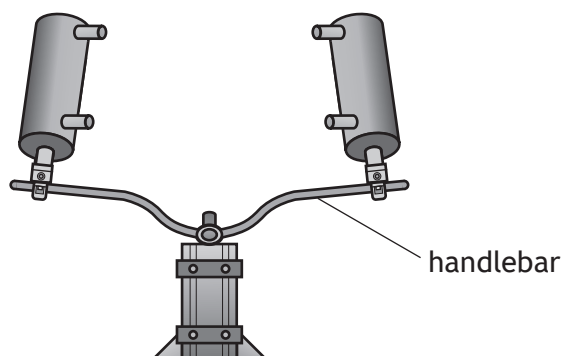
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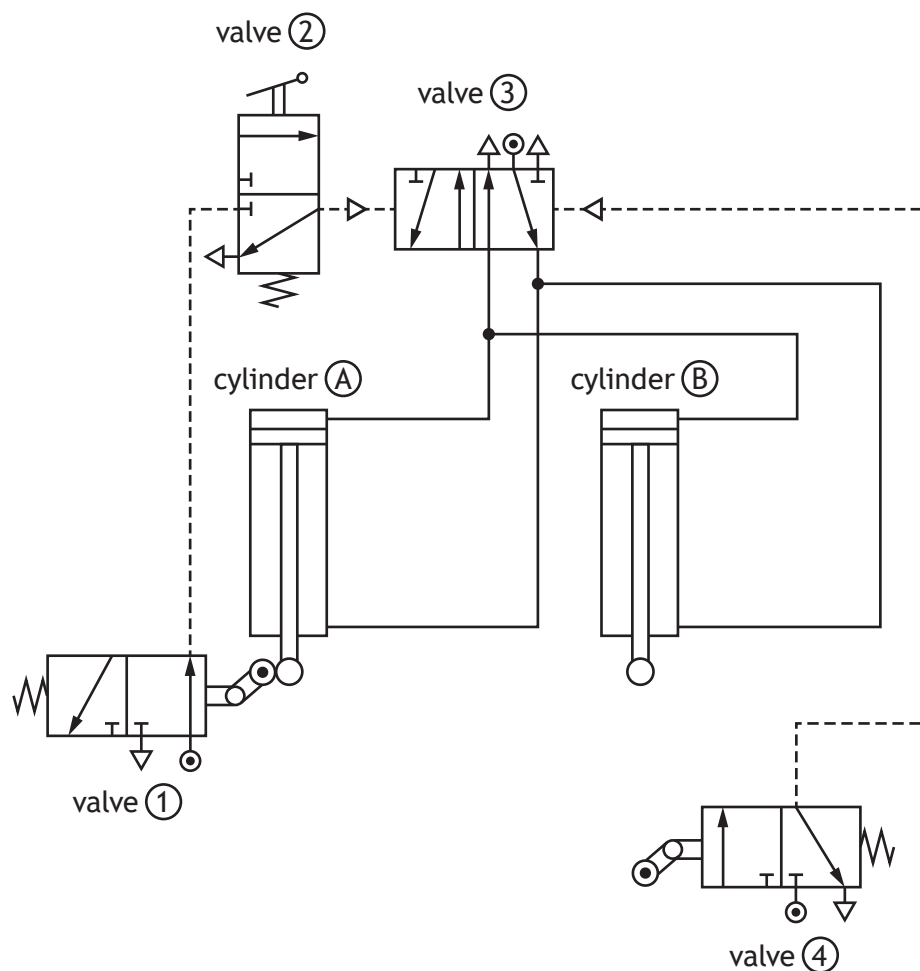
SECTION 2 — 90 marks

Attempt ALL questions

8. A pneumatic test rig used to simulate the forces acting on the handlebar of a bike is shown below.



The pneumatic circuit used in the test rig is shown below.



8. (continued)

- (a) State the type of control created by the piping of valves ① and ②.

1

- (b) Describe the operation of the circuit shown.

4

When valve ② is actuated . . .

The pneumatic circuit is modified to be operated by a microcontroller.

- (c) Explain why the use of a microcontroller is advantageous in this situation.

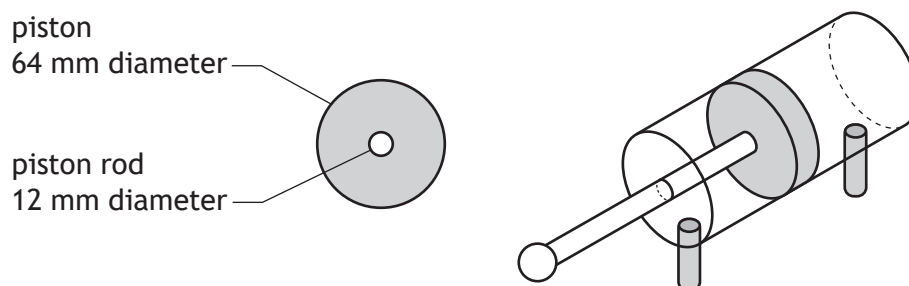
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8. (continued)

Cylinder A used in the test rig is shown.



- (d) (i) Calculate the effective area of the piston when it **instrokes**.

3

- (ii) Calculate the air pressure supplied to the cylinder when the piston **instrokes** with a force of 680 N.

2



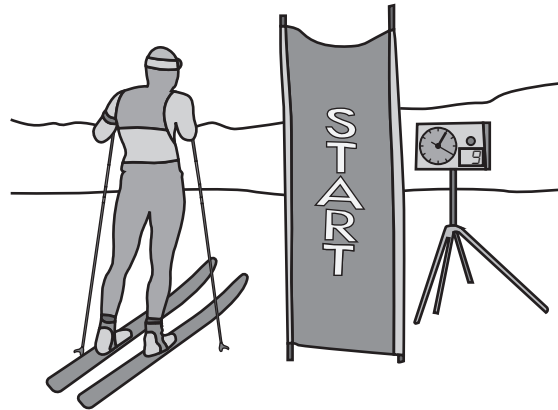
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* X 8 2 3 7 5 0 1 1 1 *

9. A skiing competition has each competitor starting the race with 1 minute intervals between them.



A microcontroller is used to control the starting signal for each competitor.
The sequence used is shown below.

1. A red lamp is turned on.
2. A start switch is activated.
3. The red lamp turns off and a buzzer turns on.
4. After a 0.5 second delay, the buzzer turns off and the red lamp turns on.
5. There is a 1 minute delay.
6. Steps 3 to 5 are repeated 50 times.
7. The red lamp turns off and the sequence ends.

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

Input connection	Pin	Output connection
	7	red lamp
	6	buzzer
start switch	1	



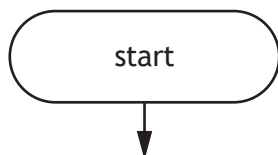
* X 8 2 3 7 5 0 1 1 2 *

9. (continued)

- (a) Complete the flowchart for this sequence, with reference to the data booklet and input/output connections shown opposite.

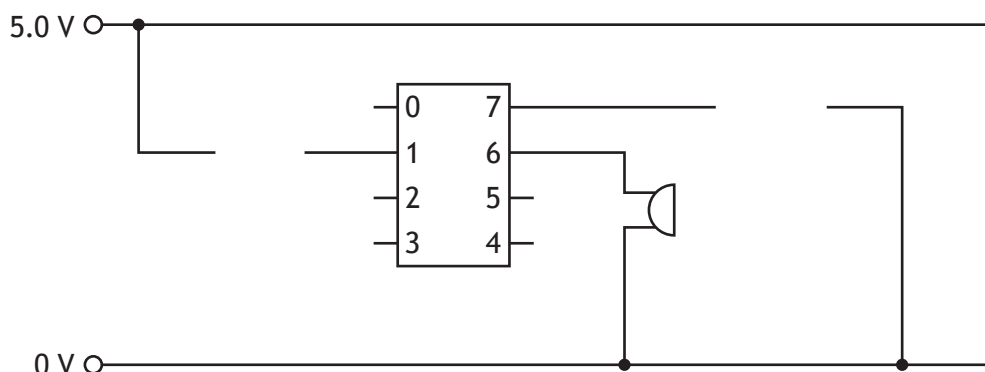
Include **all** pin numbers and the delay units in your flowchart.

10



9. (continued)

An incomplete microcontroller wiring diagram used to test the sequence is shown below.



- (b) Complete the wiring diagram with reference to the input/output table shown below.

2

Input connection	Pin	Output connection
	7	red lamp
	6	buzzer
start switch	1	

During testing it was found that the lamp was not bright enough.

- (c) State the name of an electronic component that could be added to cause the lamp to turn on brightly when the pin is switched on.

1



10. A lifeboat and slipway are shown.

lifeboat

slipway



A team of engineers was involved in the design of the slipway.

- (a) Describe one task an environmental engineer would carry out during the **design** of the slipway.

1

A structural engineer used computer simulation in the design of the slipway.

- (b) Explain why computer simulation was used during the design of the slipway.

2

[Turn over

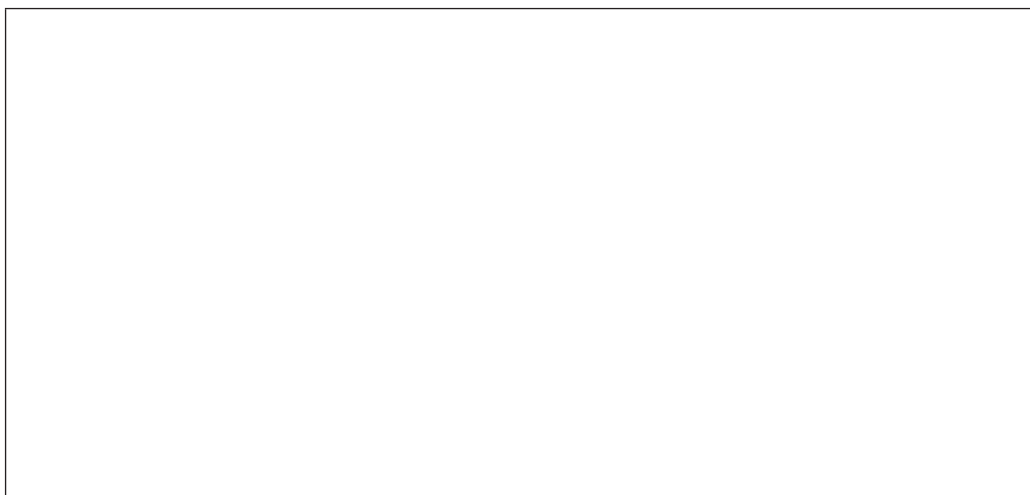


10. (continued)

The lifeboat has a mass of 27 000 kg and a potential energy of 2.2 MJ at its starting position on the slipway.

- (c) Calculate the height of the lifeboat's starting position.

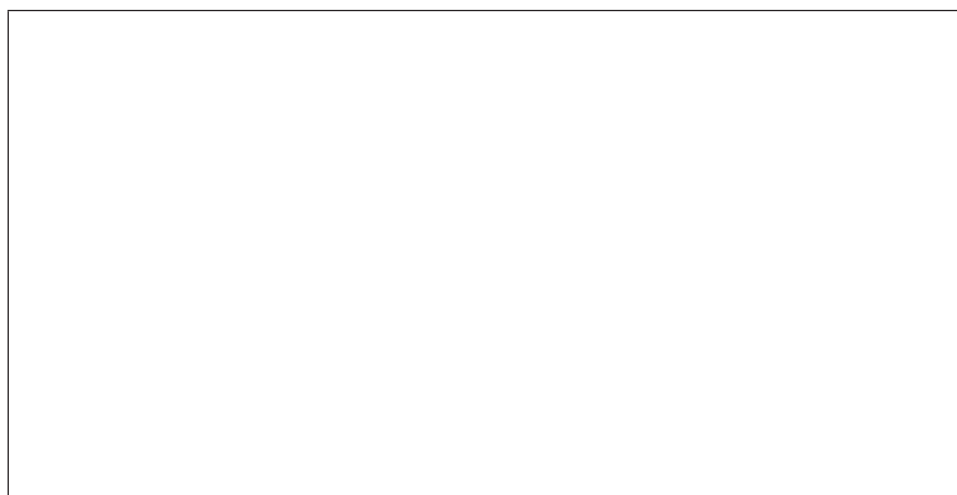
3



As the lifeboat enters the water 0.64 (64%) of the potential energy is transferred to kinetic energy.

- (d) (i) Calculate the kinetic energy as the lifeboat enters the water.

3



- (ii) Explain how the efficiency of the lifeboat moving down the slipway could be increased.

2



10. (continued)

A cable with a cross-sectional area of 710 mm^2 is used to pull the lifeboat to the top of the slipway.

- (e) Calculate the stress in the cable when a force of 26 kN is applied.

2

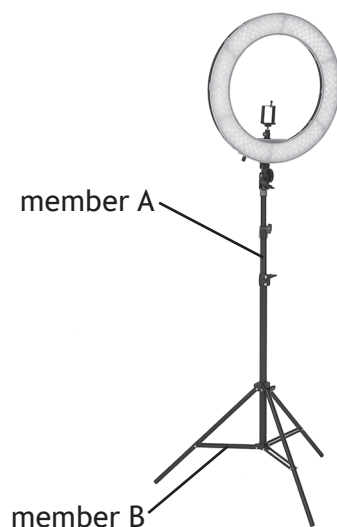
- (f) Describe the effect on the stress if the force remains the same and a cable with a **smaller** cross-sectional area is used.

1

[Turn over



11. A ring light and stand used while taking selfies are shown.



(a) State the nature of the force in:

2

member A _____

member B _____

Member B has a strain of 0.00036 and an original length of 120 mm.

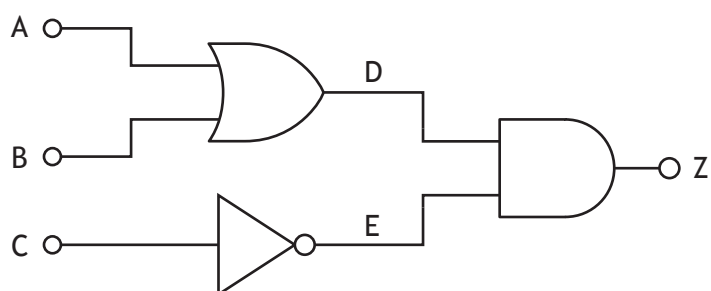
(b) Calculate the change in length of member B.

3



11. (continued)

Part of a logic diagram used in the control circuit of the ring light is shown below.



(c) Complete the truth table for the logic diagram shown above.

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			

[Turn over



11. (continued)

The Boolean equation for a second part of the control circuit is shown.

$$Y = (\bar{K} \cdot L) + M$$

(d) Complete the logic diagram for the Boolean equation shown above.

3

K ○—

L ○—

—○ Y

M ○—

The ring light has a resistance of 470Ω and operates from a 5.0 V supply.

(e) Calculate the power used by the ring light.

2



12. An air fryer is shown.



The air fryer is a more energy efficient method of cooking food than a conventional oven.

(a) Explain why **using** an air fryer can have a positive economic impact.

2

The air fryer is used to cook 0.75 kg of potatoes which have a specific heat capacity of $3400 \text{ J kg}^{-1} \text{ K}^{-1}$.

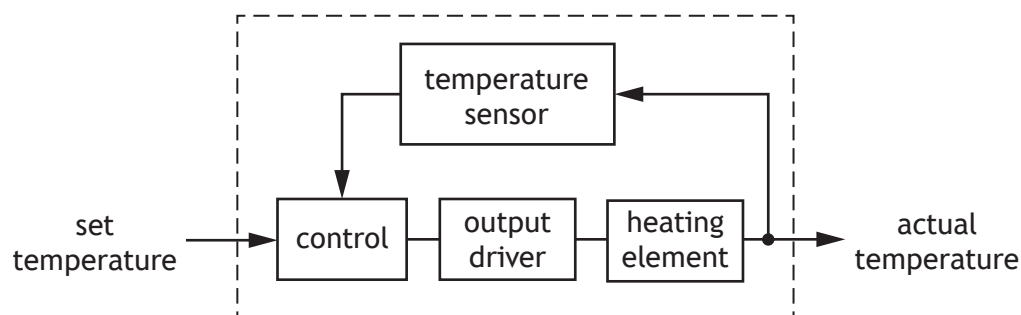
(b) Calculate the energy used to cook the potatoes when the change in temperature is 82°C .

2



12. (continued)

A sub-system diagram for the air fryer is shown below.



- (c) Describe, with reference to the sub-system diagram above, the operation of the system.

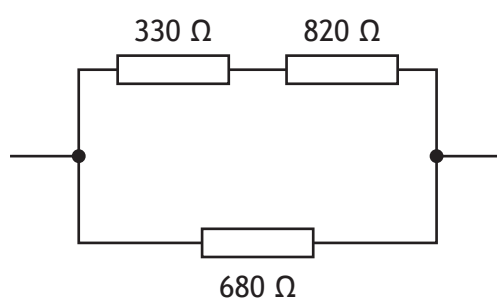
3

The user sets the temperature . . . _____

[illegible]

12. (continued)

Part of a circuit used in the air fryer is shown below.



(d) Calculate the total resistance of the circuit above.

3

When the circuit was tested, 12 V was measured across the $680\ \Omega$ resistor.

(e) Calculate the current flowing through the $680\ \Omega$ resistor.

3



12. (continued)

The air fryer uses an established technology.

An **emerging technology** is one that is being developed and still to be tried commercially within a product or system.

- (f) Explain a possible impact of an emerging technology which you are familiar with.

2

Name of emerging technology _____

Impact _____



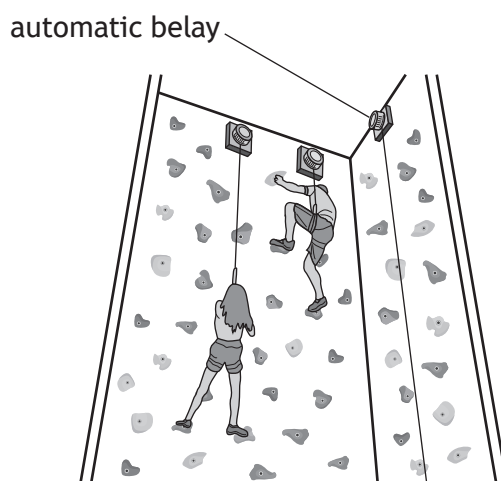
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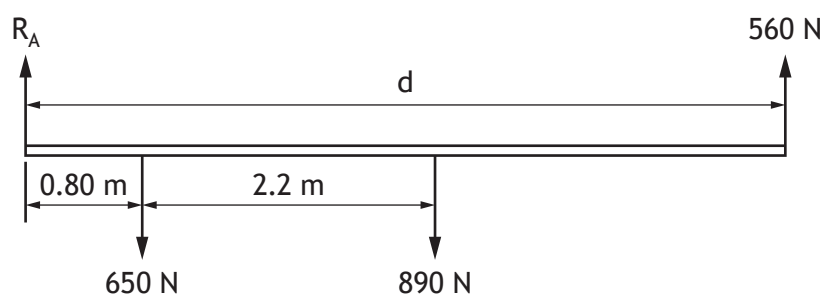


* X 8 2 3 7 5 0 1 2 5 *

13. Automatic belays on a climbing wall are used to safely lower climbers back to the ground as shown.



A simplified diagram of a beam that is used to support two automatic belays as two climbers are lowered is shown below.



- (a) State the name of the diagram shown above.

1

- (b) Calculate the **length d** by taking moments about R_A .

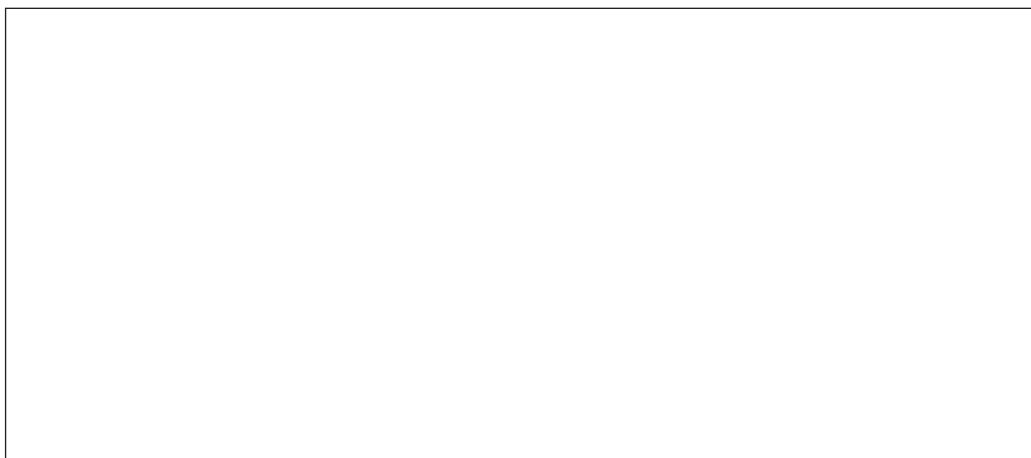
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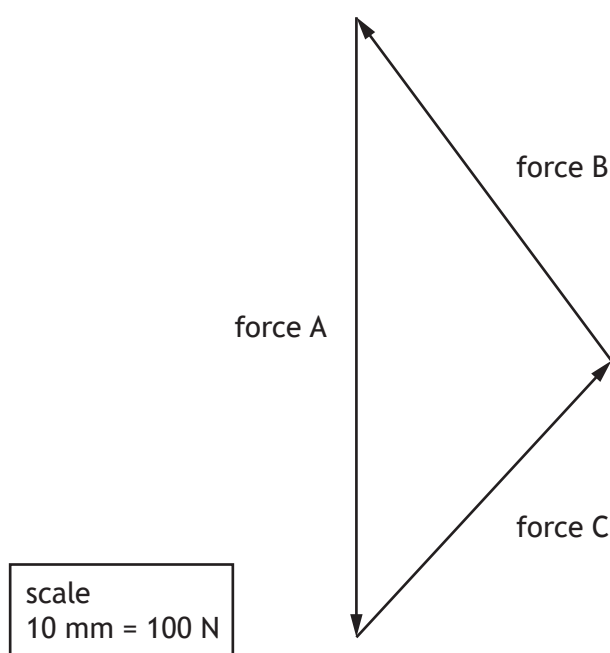
13. (continued)

(c) Calculate the force R_A .

2



A different belay system has three forces acting on it in equilibrium. The forces are analysed using the scale drawing shown.



(d) Determine, with reference to the scale drawing shown above, the size of force A.

1

Force A = _____ N

[Turn over



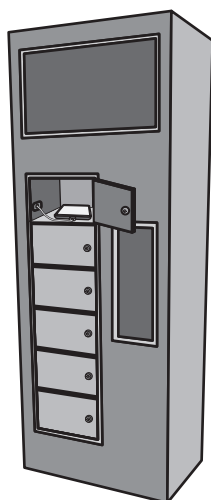
13. (continued)

An engineer used the formula $\Sigma F_h = 0$ when calculating forces at a single point.

- (e) State, with reference to the data booklet, the other condition of equilibrium which can be considered when calculating forces acting at a **single point**.

1

A charging station which allows climbers to charge their electrical devices is shown.



- (f) Describe a task an electrical engineer would carry out during the design of the charging station.

1



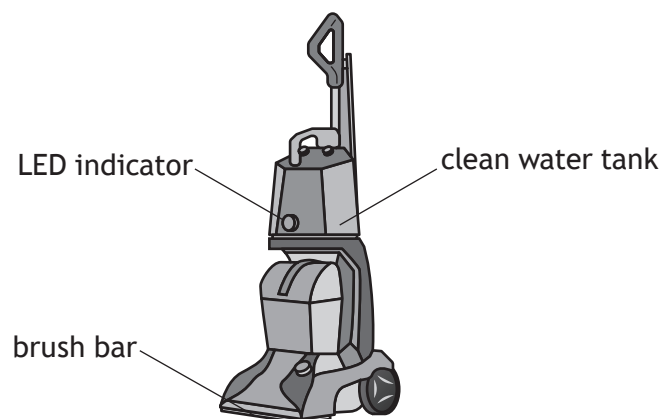
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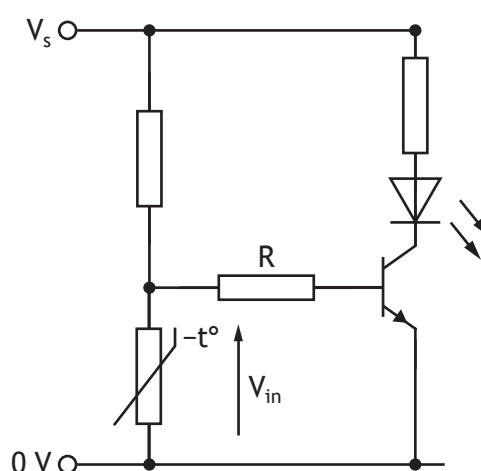
* X 8 2 3 7 5 0 1 2 9 *

14. A carpet cleaner is shown below.



The carpet cleaner uses a heater to maintain the temperature of the water in a clean water tank.

A simplified circuit, used to indicate when the water is too cold, is shown below.



- (a) Describe the operation of the circuit as the water temperature increases. Include reference to the resistance of the thermistor and the voltage V_{in} .

4

As the water temperature increases . . .

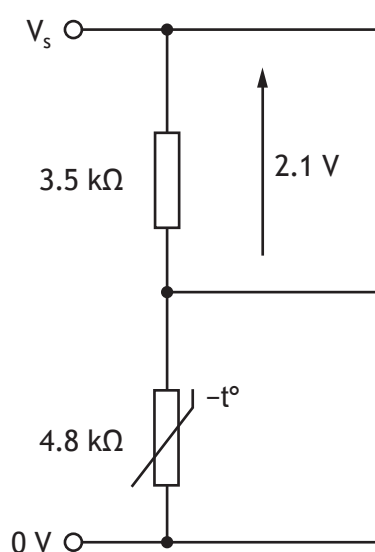


14. (continued)

(b) Explain the purpose of resistor R in the circuit shown opposite.

2

The sensing part of the circuit is shown below.



(c) Calculate the supply voltage V_s in the circuit shown above.

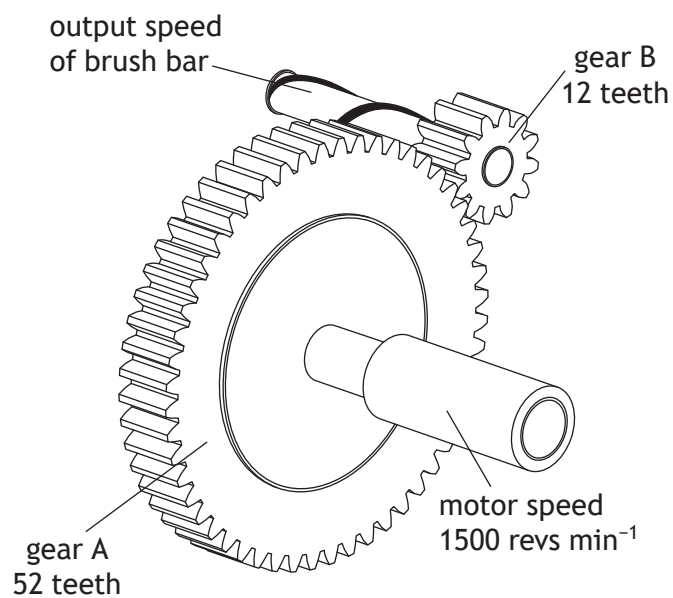
4



14. (continued)

The carpet cleaner has a brush bar to help collect dirt.

A possible drive system to operate the brush bar is shown below.



(d) Calculate the output speed of the brush bar.

3



14. (continued)

During testing it was found that the brush bar did not rotate in the same direction as the motor.

- (e) Describe a modification to the drive system that would cause the brush bar to rotate in the same direction as the motor.

1

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ADDITIONAL SPACE FOR ANSWERS



ADDITIONAL SPACE FOR ANSWERS



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