National 5 Engineering Science Past Papers

Mr McDonald

April 2024

How to Use:

The table on the next page contains links to questions sorted by topic and year. Clicking on a link will take you to that question. The marking instructions for Section 1 questions can be found at the end of the section. The marking instructions for Section 2 questions follow directly after each question. To return to the table click on Back to Table at the top or bottom of any page. Trying to navigate the document without doing this is difficult.

You should have a copy of the N4/5 Engineering Science Data Booklet to hand when answering these questions.

Back to Table

	2014		2015		2016		2017		SQP		2018		2019		2022		2023	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
Disciplines and Roles	3	15(e)	8	13(a)(b)	9	10(a), 14(d)		10(b), 13(a)		11(a), 18(a)	1	13(b)	5(a)	11(d)	6			10(a), 11(a)
Impacts		11(c), 14(d)		10(a), 15(d)		11(a), 13(c), 16(d)		10(c), 13(b), 14(c)	6	11(c), 17(c), 18(e)(f)		16(a) (d)	5(b), 7	8(c), 14(a)	8	11(b), 13(d), 14(e)		10(b)(c), 12(d), 13(d)
Systems Approach	1	11(a)(b)	3	10(b)	1	11(b)(c)	1	13(c)	1	17(a)	4	17(c)	1(a)(b)	9(a)(b)	2	14(a)	1	12(a)(b)
Energy		11(d), 15(a)(b)		11(a)(b)(c)		14(a)(b)(c)	4	10(a),		11(b), 17(b)		11(b), 17(a)(b)	2	12(a)(b)	3	11(c), 13(c), 14(d)	6	10(e), 11(b), 12(e)
Analogue Electronics	2, 4	14(a)(b)(c), 16(a)(b)	1, 2, 7	12, 14(c)(d)	8	10(b)(c), 15	3	8(a)(b)(c), 13(d)(e), 14(d)	3, 5, 10	12(b)(c), 15, 19	2, 5	14(a)(b)(c)(d), 16(b)(c), 17(d)	1(c)	8(a)(b), 9(c), 13, 15(b)	4	10, 13(a)(b)	5, 7	9(d), 10(d), 12(c), 14
Digital Electronics	10	17(e)		13(c)(d)	3	13(d)	2	12(a)(b)		12(a), 18(b)(c)(d)	9	12(a)	6	9(d)(e)		12(a)(b)(c)	3	12(f)(g)
Programmable Control	7	13	5	15(a)(b)	2	12(c)		9		13(a), 14(d)		10(a), 12(b)		10(d), 15(a)		9, 14(c)		8(a), 9(c)
Mechanisms	8	16(c)(d)(e)	4	10(c)(d)	6	11(d)	7	12(c)(d)	4	13(b)	8	11(a), 15(a)(b)	4	10(a), 14(b)	1	10(e), 14(b)	2	13(a) 13(c), 14(f)
Pneumatics	6	12	6	14(a)(b)	4	12(a)(b)	6	11		12(d), 16	7	14(e), 15(c)(d)(e)	3	10(b)(c)(e)		15		9(a)(b)
Structures	9	17(a)(b)(c)	9	13(e), 15(c)	5	13(a), 16(a)(b)(c)	5	8(d), 14(a)	2, 7, 9	11(d), 14(c)	3, 6	11(c), 13(a)		11(a)(b), 12(c)	7	11(a)	4(a)	11(c), 13(b)
Materials	5	15(c)(d), 17(d)		11(d)	7	10(d), 13(b)		14(b)	8	14(a)(b)		10(b), 11(d)		11(c), 12(d)	5	12(d)(e)	4(b)	8(b), 11(d)

Back to Table

Back to Table

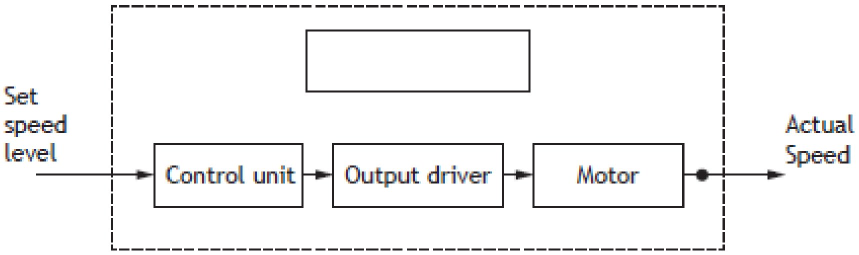
MARKS | DO NOT WRITE IN THIS MARGIN

SECTION 1 — 20 marks

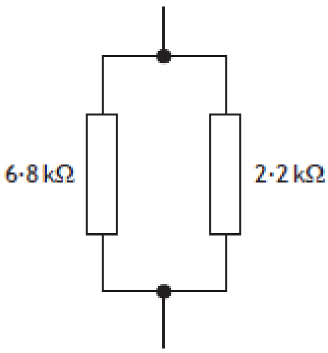
Attempt ALL questions

1. A closed loop system is used to control the speed of a motor.

   Complete the sub-system diagram shown below. 2



2. Two resistors are connected in parallel as shown in the diagram below.



   Calculate their combined resistance. 2

   Show all working and final unit.

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

3. New cars are manufactured in a factory.

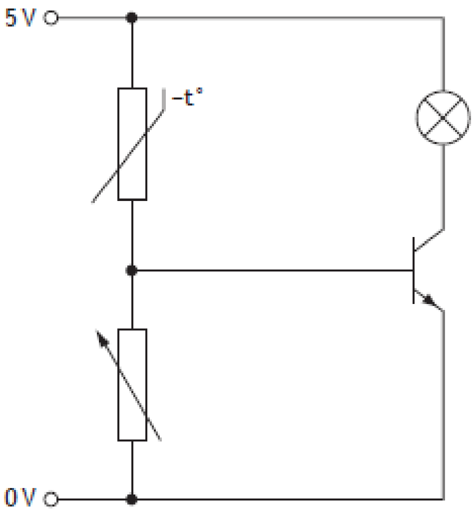
State what type of engineer would be responsible for developing:

(a) the gear box; 1

(b) the lubricants used in the gear box. 1

Total marks 2

4. A circuit to operate a lamp is shown.



(a) State the function of the transistor in the circuit. 1

(b) Describe the input conditions that will operate the lamp. 1

Total marks 2

Back to Table

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

5. A 2 m long steel bar is stretched by 0·003 m when a tensile force is applied.

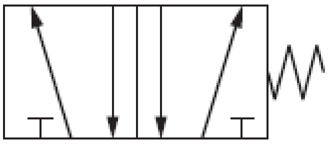
Calculate the strain in the bar. 2

Show all working.

6. Complete the pneumatic symbol below by adding:

(a) main air; 1

(b) a diaphragm actuator. 1



Total marks 2

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

7. Microcontrollers are used in many control systems.

State two reasons why microcontroller based systems are often less expensive to manufacture than hard-wired circuits. 2

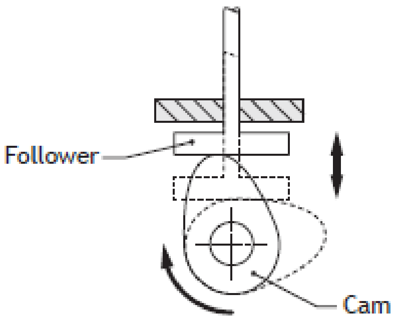
1 ______________________________

____

2 ______________________________

____

8. The cam and follower in the diagram below are used to convert motion.



State the type of motion of:

the cam; ______________________________

the follower. ______________________________ 2

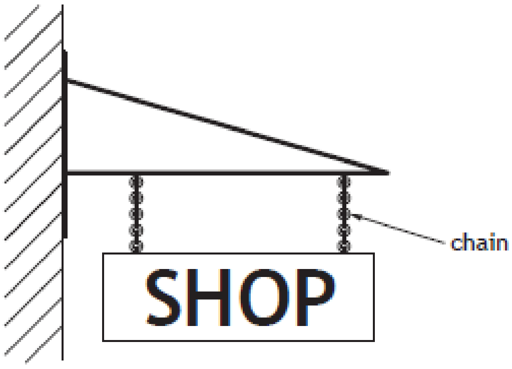
[Turn over

Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

9. A shop sign is hung from a frame structure by two chains.



(a) State the type of force acting on the chain. 1

(b) State a reason for a triangle being used in the frame structure. 1

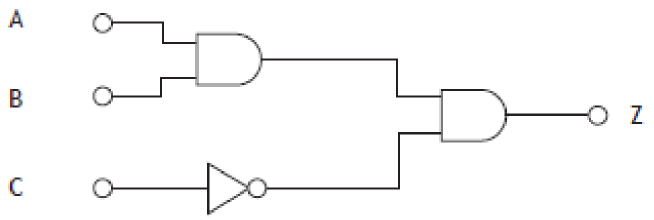
Total marks 2

Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

10. The logic diagram for a security system is shown below.



Complete the truth table for the logic diagram. 2

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

[Turn over

Back to Table

Marking Instructions for each question

Section 1

Question			Expected Answer(s)	Max Mark	Additional Guidance
1.			Feedback loop into control sub-system with arrow Speed sensor (label or specific - tachogenerator or tacho)	2	1 mark 1 mark Not speedometer
2.			$R_t = \frac{R_1 \times R_2}{R_1 + R_2}$ $R_t = \frac{6800 \times 2200}{6800 + 2200}$ $R_t = \frac{14960000}{9000}$ $=1662.22\ \Omega \qquad 1.7\text{k}\Omega$	2	1- substitution 1 - correct answer from working with unit
3.	(a)		Mechanical	1	
	(b)		Chemical	1	
4.	(a)		Switch on lamp/act like a switch	1	Accept amplification
	(b)		High temperature (warm/hot) Temperature above set level Input voltage to transistor = 0.7V	1	Any one in a descriptive response

Question			Expected Answer(s)	Max Mark	Additional Guidance
5.			€ = Δl/l € = 3/2000 = 0.0015	2	1 mark for substitution, 1 mark for correct answer from working (ignore any units)
6.	(a)		main air symbol in correct position (either state)	1	1 mark
	(b)		diaphragm in correct position (both arrows required and pilot line)	1	1 mark
7.			Fewer parts Reduced materials Reduced stock one IC (standard component) used in multiple products Quicker manufacture time	2	1 mark for each economic based valid answer Not easy to repair or cheaper Not smaller/reprogrammable (flexible) without economic reason
8.			Cam: rotary / rotational Follower: reciprocating	2	1 mark for each correct answer
9.	(a)		Tension	1	Named or inferred (downward) Not gravity or strain on its own
	(b)		It is rigid / strong shape / resists forces /support loads / stable	1	Any one for 1 mark
10.			Row 2 - 0 Row 7 - 1	2	1 mark for each correct answer

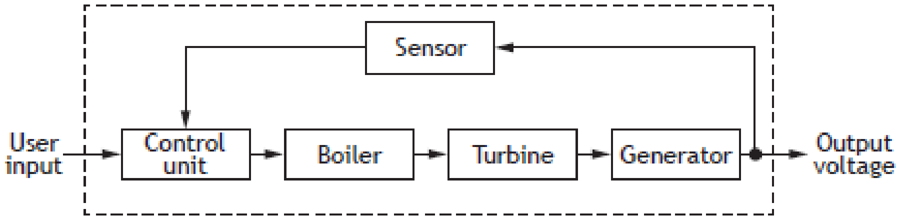
Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

SECTION 2 — 70 marks

Attempt ALL questions

11. A simplified sub-systems diagram of a biomass power station is shown below.



(a) Describe, with reference to the sub-system diagram, the operation of the power station. 4

(b) State the type of control used in this system. 1

Electricity is increasingly being produced from renewable sources rather than using fossil fuels.

(c) Describe two positive environmental impacts renewable energy sources have over fossil fuels. 2

1

2

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

Back to Table

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

11. (continued)

The power station is found to be 44% efficient.

(d) Calculate the output energy produced when 13 MJ is supplied. 2

Show all working and final unit.

Total marks 9

[Turn over

Back to Table

Back to Table

Section 2

Question			Expected Answer(s)	Max Mark	Additional Guidance
11	(a)		The user will set the required output. The control unit will compare the required output with feedback value. The control unit will send signals to the boiler. The boiler will produce steam to power the turbine. The turbine will drive the generator. The generator will produce electricity/output voltage. The sensor monitors the value of the output voltage.	4	1 mark for each valid description of the operation (3 marks max) Not - send a signal between boiler - turbine - generator 1 mark for the description of the closed loop aspect (feedback or comparing by control sub-system) - 2 marks max
	(b)		Closed loop	1	
	(c)		Less pollution/cleaner/less waste gas fewer greenhouse gases/CO2 reduce the causes of climate change	2	1 mark per positive environmental impact described Not - will not run out Not - fossil fuels pollute on its own
	(d)		Eout = Ein x eff = 13MJ x 0.44 = 5.72MJ	2	1 for substitution 1 for answer with unit from given working

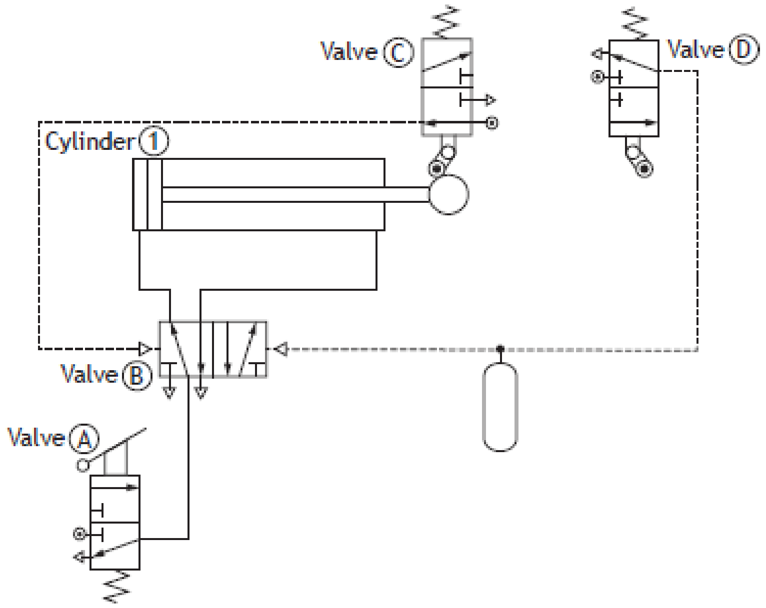
Back to Table

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

12. A pneumatic circuit used to punch holes in steel sheets is shown below.

(a) Draw a uni-directional restrictor in the correct position to form an adjustable time delay. 3



(b) Describe, using appropriate terminology, the operation of the circuit. 3

Back to Table

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

12. (continued)

The piston in cylinder 1 has a diameter of 20 mm and is supplied with air at a pressure of $2\,N\,mm^{-2}$.

(c) Calculate the outstroking force of the cylinder.

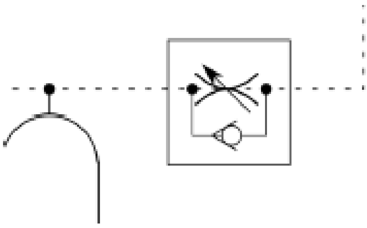
Show all working and final unit. 3

Total marks 9

[Turn over

Back to Table

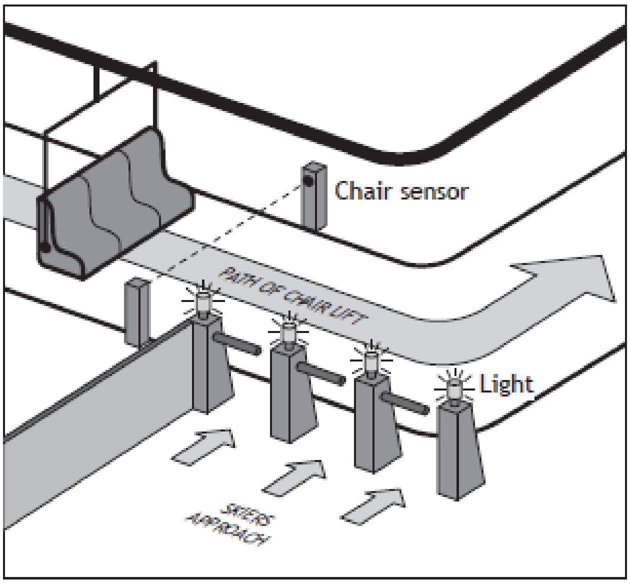
Back to Table

Question			Expected Answer(s)	Max Mark	Additional Guidance
12	(a)			3	1 mark for correct symbol (ignore rectangle) 1 mark for correct position 1 mark for correct orientation
	(b)		1 mark for describing the function of A 1 mark for describing outstroke conditions 1 mark for describing instroke conditions	3	1 mark for each valid descriptive point up to 3
	(c)		$A = \Pi r^2$ $= 3{\cdot}14 \times 10 \times 10$ $= 314 mm^2$ $P = \frac{F}{A}$ $F = PA$ $= 2 \times 314$ $= 628 N$	3	Calculation of area (no units) - 1 Substitution with area value calculated above (FTE) - 1 Answer from given working with unit - 1

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

13. A chair lift system at a ski resort is operated by a microcontroller.



The system must perform the following sequence.

- When the chair sensor is triggered warning lights flash 4 times over a 2 second period.
- The barriers will then open.
- The system will pause for 3 seconds to allow the skiers through.
- The barriers will then close.
- The sequence will repeat.

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

Input Connection	Pin	Output Connection
	2	Barriers (1 = open)
	1	Warning lights
Chair sensor (1 = chair sensed)	0	

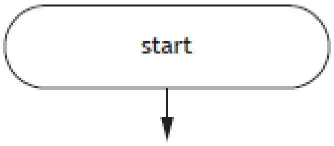
Complete the flowchart opposite for the control sequence with reference to the Data Booklet and input/output connections. 10

Include all pin numbers.

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

13. (continued)

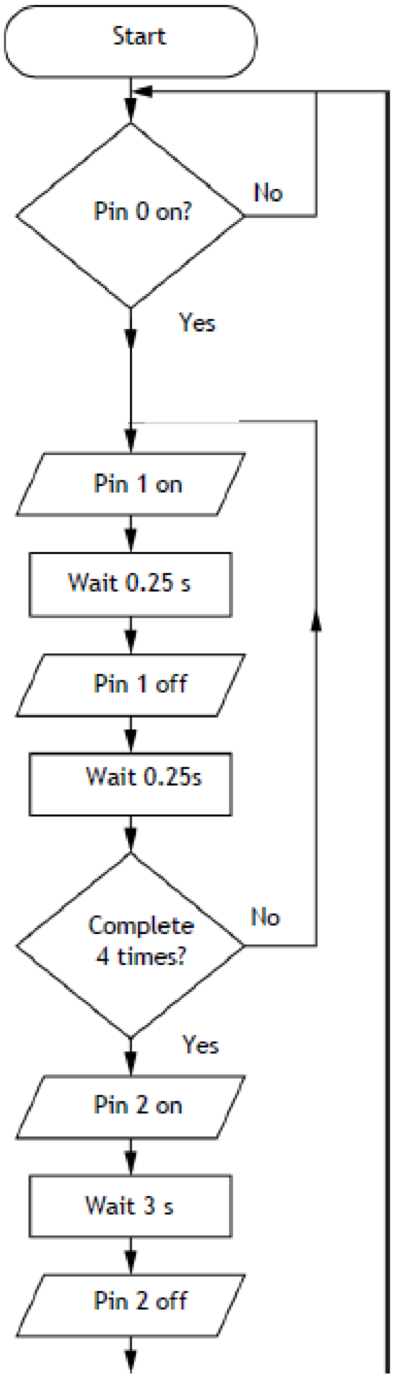


* X 7 2 3 7 5 0 1 1 3 *

[Turn over

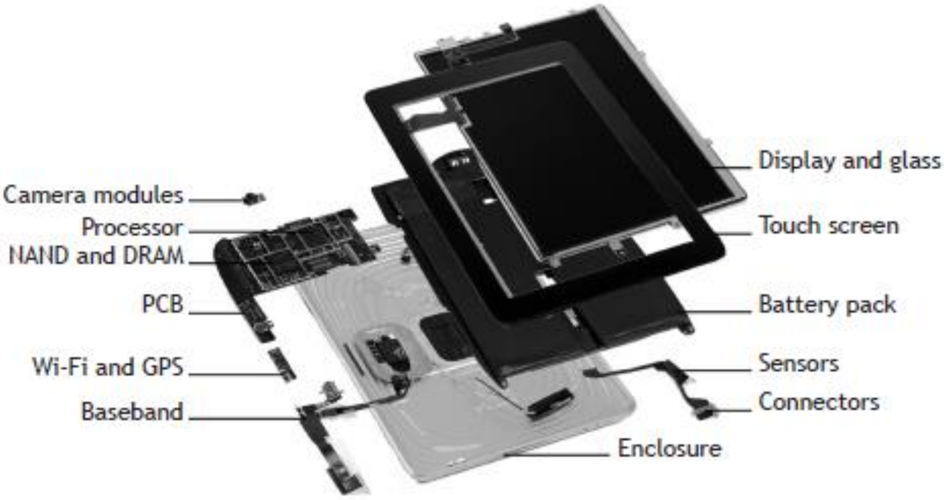
Back to Table

Back to Table

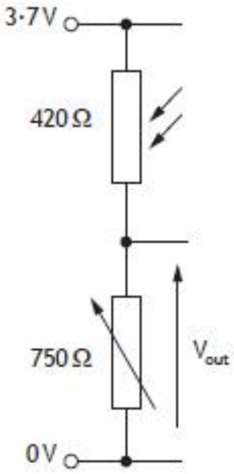
Question	Expected Answer(s)	Max Mark	Additional Guidance
13.		10	Pin number must be correct where applicable Pin 0 on? - 1 mark for decision with y/n and loop Pin1 on/off - 1 mark for both boxes Wait - 1 mark for both - 1 mark both times totalling 0.5 s x 4 decision with y/n - 1 mark decision loop return point - 1 mark Pin2 on/off - 1 mark for both Wait 3s - 1 Continuous loop - 1 All marked symbols correct - 1 (additional boxes ignored) Credit given for a series of flashes done without fixed loop. (1 mark)

MARKS DO NOT WRITE IN THIS MARGIN

14. An electronic engineer is working on the circuitry for a tablet computer.



To sense light levels the following circuit is used.



(a) Draw, on the diagram above, the symbol for a voltmeter connected to measure V_{out}. 2

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

14. (continued)

(b) Calculate V_{out}. 3

Show all working and final unit.

The light level changes and V_{out} becomes 3 V.

(c) Calculate the power used by the 750 Ω variable resistor. 2

Show all working and final unit.

[Turn over

Back to Table

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

14. (continued)

Tablet computers have many advantages over normal desktop computers.

(d) Describe one environmental advantage. 1

____

____

Total marks 8

Back to Table

Back to Table

Question			Expected Answer(s)	Max Mark	Additional Guidance
14	(a)		voltmeter symbol connecting voltmeter in parallel to the variable resistor.	2	1 mark 1 mark
	(b)		$\frac{V_1}{V_2} = \frac{R_1}{R_2}$ = $\frac{V_1}{V_s} = \frac{R_1}{R_t}$ $\frac{Vout}{3 \cdot 7} = \frac{750}{1170}$ $Vout = 3 \cdot 7 \times 0 \cdot 641$ $= 2 \cdot 37V$ (2.4V) $I = \frac{V}{R}$ $= \frac{3 \cdot 7}{1170}$ $= 3 \cdot 16mA$ $Vout = 0 \cdot 00316 \times 750$ $= 2 \cdot 37V$ (2.4V)	3	Substitution - 1 Transposition - 1 Answer from given working with unit - 1 Alternative method 1 for substitution 1 for answer from working 1 for answer from working with unit
	(c)		$P = V^2/R$ $= 3^2/750$ = 12mW (0.012W)	2	Substitution - 1 Answer from given working with unit - 1
	(d)		Use less material in their construction. Lower power/energy used to run. Smaller size/weight means less fossil fuel burned during transportation.	1	1 mark for any acceptable environmental descriptive answer Not – easier to recycle

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

15. The bicycle and rider shown below have a combined mass of 80 kg and are travelling at a velocity of $8\,\mathrm{m\,s^{-1}}$.

(a) Calculate the kinetic energy of the rider and bicycle. 2

Show all working and final unit.

The brakes have an initial temperature of 10 °C and a mass of 0·4 kg.

(b) Calculate the final temperature of the brakes when the bicycle and rider stop. The brakes have a specific heat capacity (c) of $900\,\mathrm{J\,kg^{-1}\,K^{-1}}$. 4

Assume all kinetic energy from Q15(a) will be converted into heat energy in the brakes.

Show all working and final unit.

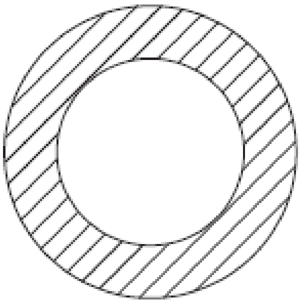
Back to Table

[Back to Table]

MARKS DO NOT WRITE IN THIS MARGIN

15. (continued)

The illustration below shows the cross-section of member A.



Area = 200 mm^2

(c) Calculate the stress in member A when a tensile load of 1200 N is applied. Show all working and final unit. 2

(d) Describe, for the same load, how the stress in member A could be reduced. 1

A number of engineers were involved in the design of the bicycle.

(e) Describe the role that a mechanical engineer may have had in the development of the bicycle. 2

Total marks 11

[Back to Table]

Back to Table

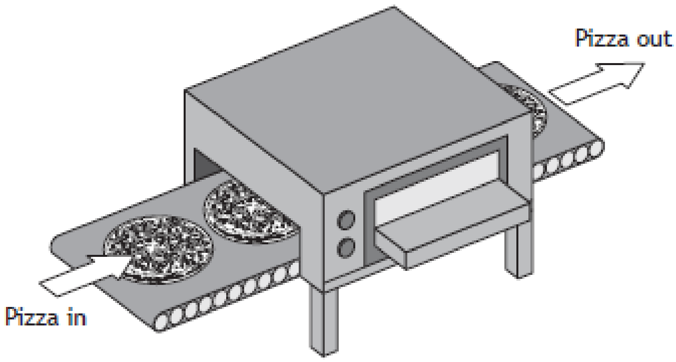
Question			Expected Answer(s)	Max Mark	Additional Guidance
15	(a)		$Ek = 0{\cdot}5mv^2$ $= 0{\cdot}5 \times 80 \times 8^2$ $= 2560J$ (2.6kJ)	2	Substitution - 1 mark Answer from given working with unit - 1 mark
	(b)		$E_h = mc\Delta T$ $\Delta T = \frac{E_h}{mc}$ $= \frac{2560}{0{\cdot}4 \times 900}$ $= 7{\cdot}1°C$ Final temp $= 10 + 7{\cdot}1 = 17{\cdot}1°C$	4	Transposition - 1mark Substitution {FTE from (a)} - 1 mark Answer from given working - 1 mark Final answer and unit - 1 mark
	(c)		$\sigma = \frac{F}{A}$ $= \frac{1200}{200}$ $= 6Nmm^{-2}$ (6MPa)	2	Substitution - 1 mark Answer from given working and unit - 1 mark Not Pa unless m^2 used
	(d)		Increase (cross sectional) area Increase thickness/use solid bar the same diameter/outside diameter larger	1	1 mark for a correct descriptive response. Not - Make A bigger, change material
	(e)		Design/testing the… Mechanical aspect: Gears, sprocket, chain, brakes, materials, wheel, bearings, pedals, suspension	2	Descriptive response Activity - 1 mark (max) Not - development Mechanical aspect - 1 mark (max) Not - frame

Back to Table

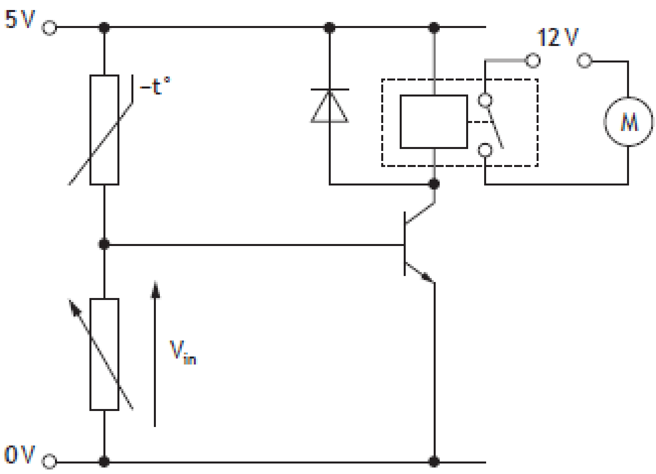
Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

16. Pizzas are cooked when they move through an oven on a motorised conveyor.



An electronic circuit will switch on the conveyor when the oven increases to a set temperature.



(a) Describe, as the temperature increases, the operation of the:

(i) input sub-system; 2

___

___

___

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

16. (a) (continued)

(ii) process and output sub-systems. 2

(b) Describe the function of the following components in the circuit.

(i) relay 1

(ii) diode 1

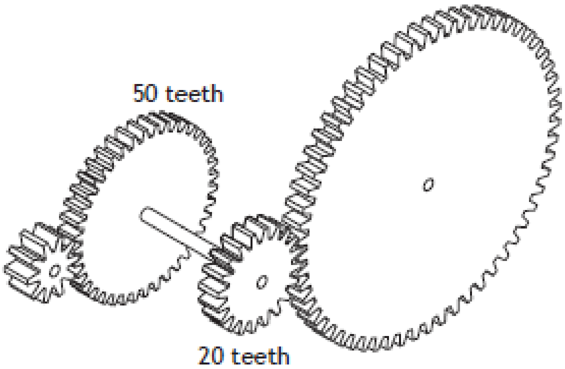
[Turn over

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

16. (continued)

To drive the conveyor, the motor is connected to a compound gear train.



(c) Describe an advantage of a compound gear over a simple gear train. 1

(d) Calculate the speed of the output gear when the input rotates at 250 rev min^{-1}.

Show all working and final unit. 4

(e) Describe how friction in a mechanical system could be reduced. 1

Total marks 12

Back to Table

Back to Table

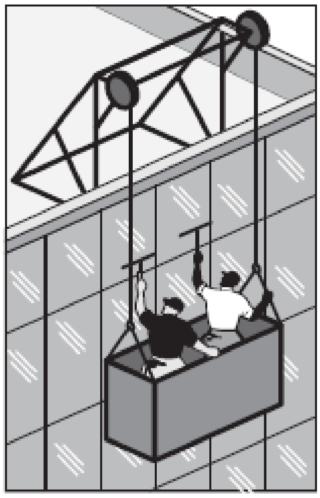
Question			Expected Answer(s)	Max Mark	Additional Guidance
16.	(a)	(i)	*As the temperature increases:* the resistance of the thermistor drops the voltage across the thermistor drops the voltage across the variable resistor (Vin) increases	2	1 mark for each valid descriptive point Change in resistance / voltage must refer to a component / position in circuit
		(ii)	The transistor switches on when the temperature/voltage reaches the set level. The relay switches on when the transistor is on. When the relay is on the motor will spin.	2	1 mark for any valid descriptive point relating to the transistor Not -'transistor switches on' without reference to temperature/voltage 1 any for any valid descriptive point relating to the relay/motor
	(b)	(i)	Allows the 5V/low voltage circuit to control the more powerful circuit.	1	1 mark for any valid descriptive response Not - powers electrical circuit or connects/links electronic to electrical circuit.
		(ii)	Protects the transistor	1	1 mark for any valid descriptive response Not - protect the relay/prevents back emf
	(c)		Allows same gear ratio in a smaller space. Allows large gear ratio with small gears.	1	1 mark for any valid descriptive response Not smaller (compact) or more efficient
	(d)		1st pair; $10 \times 250 = 50 \times T$ $T = 50$ rev min^{-1} 2nd pair; $50 \times 20 = 60 \times T$ $T = 16.7$ rev min^{-1} Alternative using VR; $250 \times (10/50 \times 20/60)$ $= 16.7$ rev min^{-1}	4	Substitution - 1 mark Answer from working - 1 mark Substitution - 1 mark Answer with unit from working - 1 Alternative ; Substitution for individual VRs - 1 mark each Substitution into combined eqn - 1 mark Answer with unit from working - 1
	(e)		Lubricate moving parts. Smoother materials could be used where mechanisms interact. Add bearings to the shaft	1	1 mark for any suitable descriptive response (what and where). No single word answers.

Back to Table

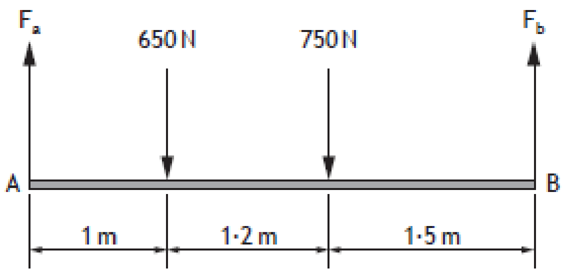
Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

17. A window-cleaning platform is used on an office block.



The diagram below shows the forces acting on it.



(a) State the full name of the type of diagram shown above. 1

Back to Table

17. (continued) MARKS

DO NOT WRITE IN THIS MARGIN

(b) Calculate, by taking moments about A, the force F_b. 3

Show all working and final unit.

(c) Calculate the force F_a. 2

Show all working and final unit.

The maximum strain allowed for a cable is 0·0015.

(d) Calculate the maximum allowable extension in a 2 m length of cable. 2

Show all working and final unit.

[Turn over for Question 17 (e) on *Page twenty-six*

Back to Table

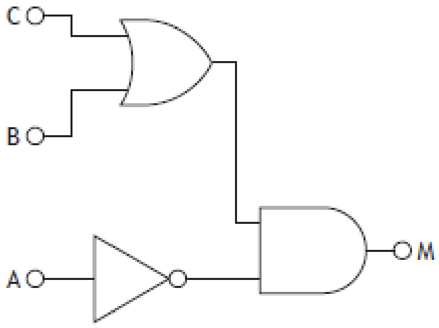
Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

17. (continued)

An electronic circuit is used to operate the movement of the platform.

The logic diagram for the circuit is shown below.



(e) Complete a Boolean equation for the circuit. 3

M = ____

Total marks 11

[END OF QUESTION PAPER]

Back to Table

17.	(a)		Free body	1	Not F.B.D.
	(b)		ΣACWM = ΣCWM Fb x 3.7 = 650x1 + 750x2.2 Fb = 2300/3.7 Fb = 621.6N	3	Substitution - 1 Transposition - 1 Answer from given working with units - 1
	(c)		ΣFv = 0 Fa + 621.6 = 650 + 750 Fa = 1400 - 621.6 =778.4N	2	Substitution - 1 Follow through error from (b) Answer from given working with units - 1
	(d)		$\Delta l = 2 \times 0{\cdot}0015$ $= 0{\cdot}003m$	2	Substitution - 1 Answer from given working with unit -1
	(e)		M = $\bar{A}$·(B+C)	3	1 mark for correct use of • ( ) 1 mark for correct use of + 1 mark for correct use of ¯ Other correct equations are acceptable

Back to Table

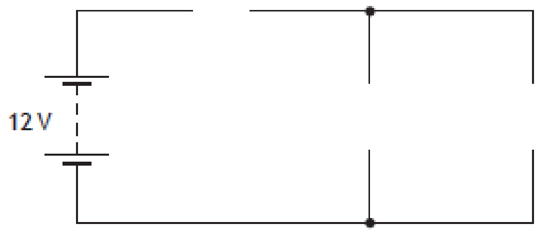
Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

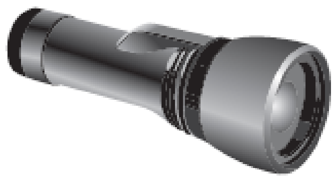
SECTION 1 — 20 marks

Attempt ALL questions

1. Complete the circuit diagram below to show a motor operated when one switch or another switch is pressed. 2



2. An electric torch is shown in the diagram below. The lamp is rated at 7·2 V and 0·7 A.



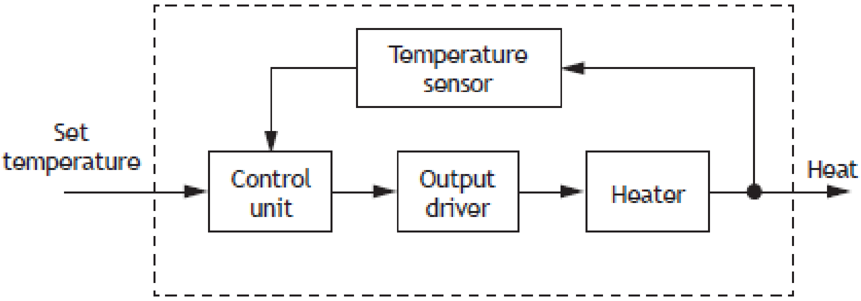
Calculate the resistance of the lamp. 2

Show all working and final unit.

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

3. A diagram for a heating system is shown below.



(a) State the name of this type of diagram. 1

(b) State the function of the output driver. 1

[Turn over

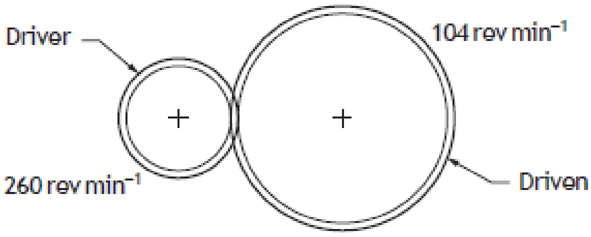
* X 7 2 3 7 5 0 1 0 3 *

Back to Table

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

4. A motorised coffee grinder uses a simple gear train.



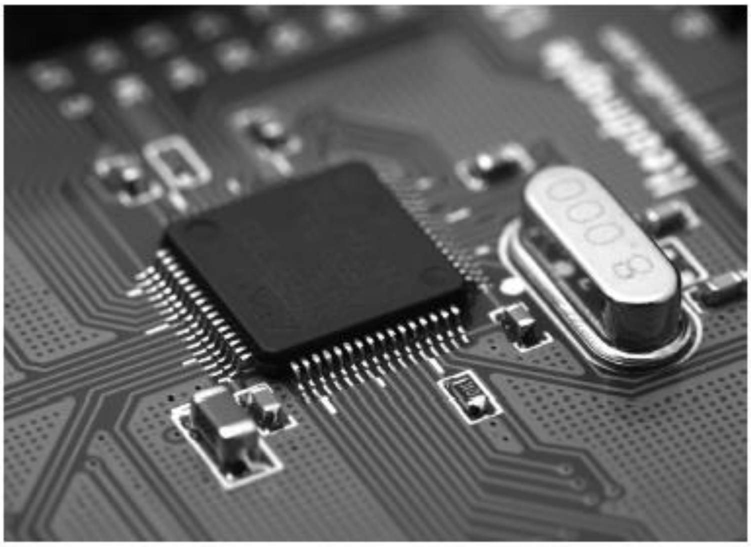
(a) Calculate the velocity ratio of the gear train. 2

Show all working and final unit.

(b) Describe how the simple gear drive could be altered to make the driver and driven gears turn in the same direction. 1

MARKS DO NOT WRITE IN THIS MARGIN

5. Microcontrollers are often used in place of hard wired electronic circuits in control systems.



Describe an advantage of a microcontroller over a hard wired circuit for:

(a) a design engineer; 1

(b) a manufacturer during the production of the control system. 1

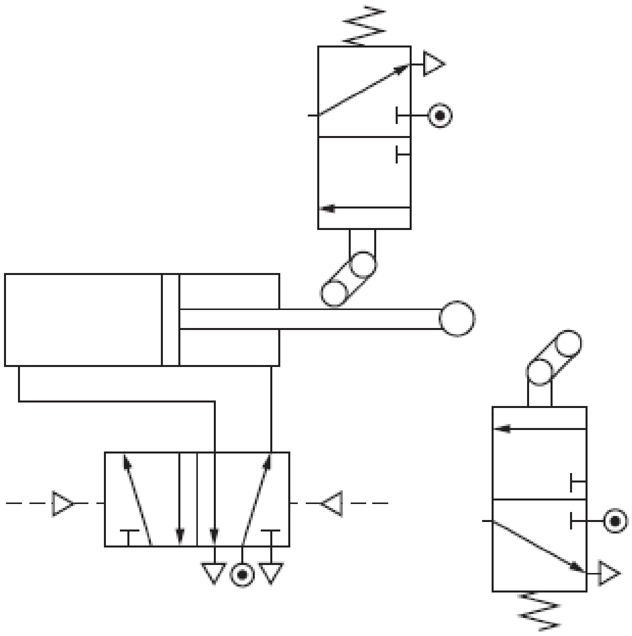
[Turn over

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

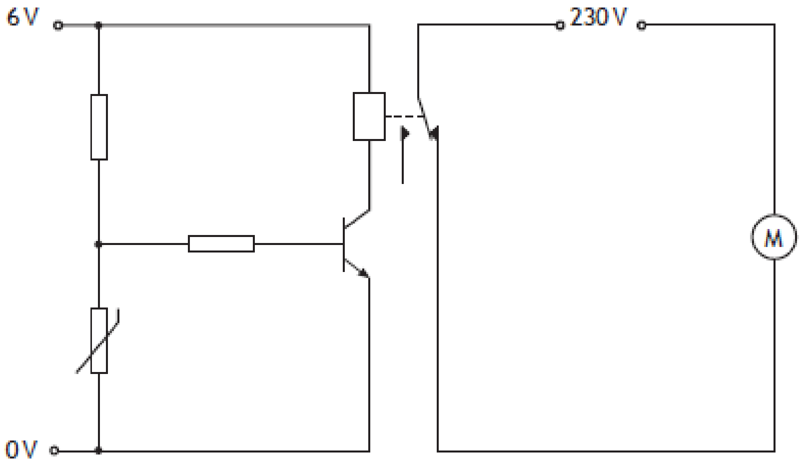
6. An incomplete pneumatic circuit to produce reciprocating motion is shown in the diagram below.

   Complete the diagram by inserting the missing piping. 2



7. An electronic circuit to control the operation of a motor is shown in the diagram below.

   Complete the circuit by adding a diode to protect the transistor. 2



MARKS | DO NOT WRITE IN THIS MARGIN

8. A geothermal power station is shown below.

Describe the role of:

(a) a mechanical engineer during the design of the power station; **1**

(b) a civil engineer during the construction of the power station; **1**

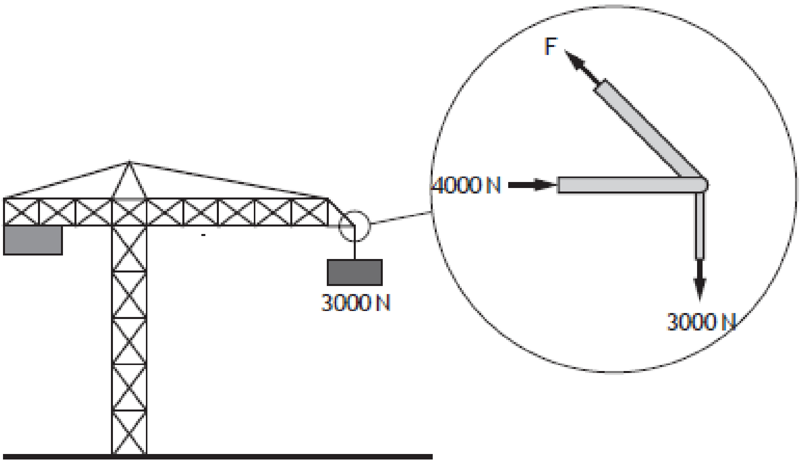
(c) an electrical engineer during the monitoring of the power station. **1**

[Turn over

Back to Table

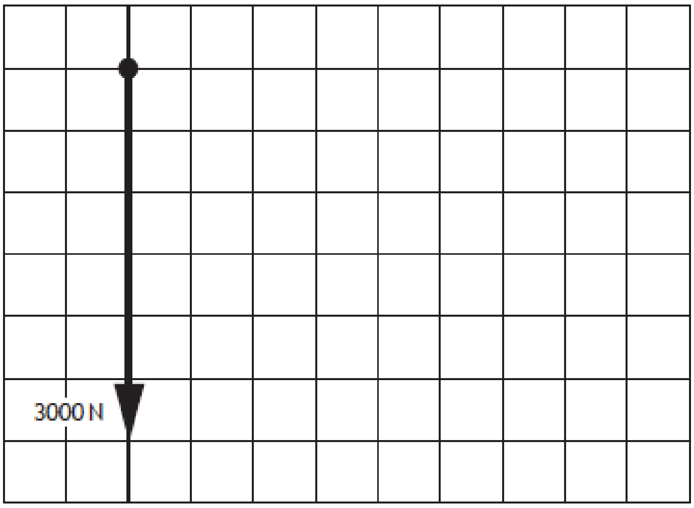
MARKS | DO NOT WRITE IN THIS MARGIN

9. A crane is used to lift a 3000 N load. Detail of the end of the crane is shown below.



With reference to the crane shown above:

(a) complete the triangle of forces scale drawing below; 1



10 mm = 500 N

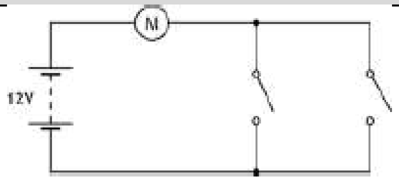
(b) determine, using the given scale, the size of force F. 1

F = ______________________

Back to Table

Detailed Marking Instructions for each question

Section 1

Question			Expected Answer(s)	Max Mark	Additional Guidance
1.				2	1 mark for motor and switch symbol. 1 mark for correct positions of three components. Ignore any additional symbols.

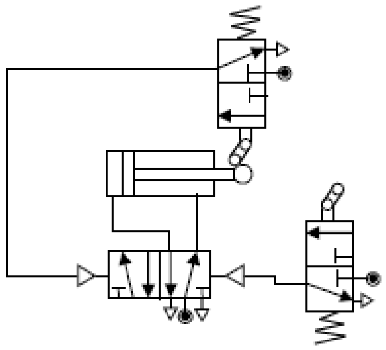
Question			Expected Answer(s)	Max Mark	Additional Guidance
2.			$R = \frac{V}{I}$ $R = \frac{7.2}{0.7}$ (1 mark for substitution) = 10.29Ω (1 mark for correct answer from given working with unit)	2	

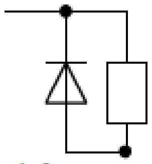
Question			Expected Answer(s)	Max Mark	Additional Guidance
3.	(a)		Sub-system (diagram)	1	
	(b)		To amplify the current (signal) To power the heater/output	1	Not switch on or drive the heater

Question			Expected Answer(s)	Max Mark	Additional Guidance
4.	(a)		VR = 260/104 = 2.5 (2.5:1 5:2 etc)	2	1 mark for substitution 1 mark for correct calculation from given working (ignore any units)
	(b)		An extra gear between the driver and driven / use an idler gear.	1	Descriptive response. Do not accept just 'add another gear' without statement on where it should be added.

Back to Table

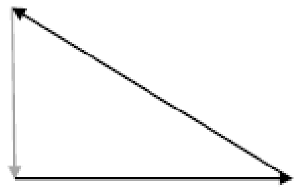
Question			Expected Answer(s)	Max Mark	Additional Guidance
5.	(a)		Easier / quicker / simpler to develop than design a complex electronic circuit. Easier/quicker to update/modify.	1	Easier / quicker / simpler must be qualified. Descriptive responses only. Not smaller.
	(b)		The circuits will be manufactured more quickly and more cheaply due to fewer components/ easier to wire. One controller could be used in a number of products.	1	Smaller/cheaper/reliable/quickly must be qualified. Other suitable descriptive responses with qualifying statements accepted.

Question			Expected Answer(s)	Max Mark	Additional Guidance
6.			 1 mark for piping (Port to port) x2	2	Do not penalise for no pilot lines or extra pipes. 1 mark where 3/2 valves are piped to the incorrect 5/2 pilot ports.

Question			Expected Answer(s)	Max Mark	Additional Guidance
7.			 1 mark for correct symbol 1 mark for correct position & orientation	2	Do not accept LED for symbol. Do not penalise if line through triangle is missing.

Back to Table

Question			Expected Answer(s)	Max Mark	Additional Guidance
8.	(a)		Planning the turbines, valves, pumping systems (moving parts).	1	1 mark for any appropriate descriptive answer (Mechanical Engineering based activity and aspect) - accept design.
	(b)		Checking and monitoring the construction of the roads/station/ chimney, coordinating the drilling of holes to allow water to be pumped under the ground.	1	1 mark for any appropriate descriptive answer (Civil Engineering based activity and aspect).
	(c)		Checking the amount of electricity being output from the station to ensure it meets the demand. Monitoring the operation to see if it is safe /efficient.	1	1 mark for any appropriate descriptive answer (Electrical Engineering based activity and aspect).

Question			Expected Answer(s)	Max Mark	Additional Guidance
9.	(a)			1	1 mark for both correctly drawn vectors. To scale and with both arrows.
	(b)		5000N	1	1 mark for a numerical value with unit. (Ignore nature). Allow follow through error (FTE).

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

SECTION 2 — 70 marks

Attempt ALL questions

10. A wind farm is shown below.

(a) (i) Describe one positive environmental impact of a wind farm. **1**

(ii) Describe one negative environmental impact of a wind farm. **1**

(iii) Explain an economic impact of using a wind farm to produce electricity. **2**

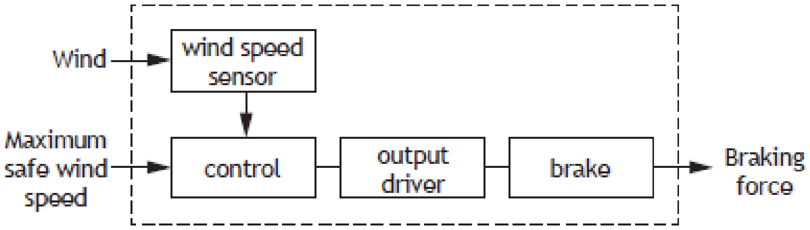
Back to Table

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

10. (continued)

A wind turbine can only be used when the wind speed is below a maximum safe level. A diagram for part of the braking system is shown below.



(b) Describe, using appropriate terminology, the operation of the wind turbine braking system. 3

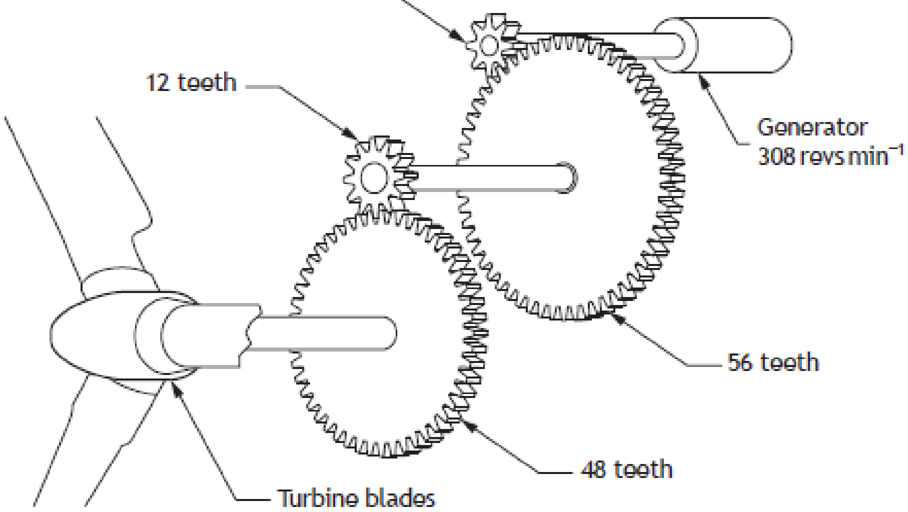
[Turn over

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

10. (continued)

A pupil's model of the wind turbine's compound gear train is shown in the diagram below.



(c) Describe an advantage of using a compound gear train over a simple gear train. 1

____

____

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

10. (continued)

(d) Calculate the speed of the turbine blade. 4

Show all working and final unit.

[Turn over

Back to Table

Section 2

Question			Expected Answer(s)	Max Mark	Additional Guidance
10.	(a)	(i)	No need to remove fossil fuels from the ground. No CO_2 produced during use. Clean source of energy.	1	Descriptive positive environmental response. Not renewable on its own.
		(ii)	Effect on the landscape or wild life or construction issues.	1	Descriptive negative environmental response. Not - uses a lot of space/land.
		(iii)	Installation is expensive. Inexpensive long term electricity because the source is free. Brings money to the area due to job creation. Efficiency not as high as fossil fuel so more expensive.	2	Single economic explanation based response - cause (1) and valid effect (1) - apply FTE.
	(b)		The maximum safe wind speed is set. Set level is compared with the actual wind speed detected by the wind speed sensor. If the wind speed is too fast then the output driver will activate the brake / if the wind speed is within safe levels the brake is not applied.	3	1 mark for each correct descriptive based statement (3)
	(c)		Compact size with a large speed changes possible.	1	Descriptive response
	(d)		Velocity Ratio = $\frac{12}{48} \times \frac{8}{56}$ (1 mark for substitution) Velocity Ratio = $\frac{1}{28}$ Velocity Ratio = 1:28 (1 mark for correct answer from given working) Velocity Ratio = $\frac{\text{Speed of input}}{\text{Speed of output}}$ Input speed = $\frac{1}{28} \times 308$ (1 mark for substitution - allow FTE) Input speed = 11 revs min^{-1} (1 mark for correct answer from candidate's working)	4	Alternative method $In_{speed} \times in_{size} = out_{speed} \times out_{size}$ $In_{speed} \times 56 = 308 \times 8$ - 1 mark $In_{speed} = 44$ (ignore unit) - 1 mark $In_{speed} \times 48 = 44 \times 12$ - 1 mark (allow follow through error) In_{speed} = 11 revs min^{-1} (1 mark for answer from given working with unit) Do not accept rpm.

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

11. A lifeboat winching system on a cruise ship is shown below.

A lifeboat of mass 7750 kg is lowered into the water.

(a) Calculate the kinetic energy of the lifeboat as it enters the water at $3\,ms^{-1}$. 2

Show all working and final unit.

The lifeboat is winched back up to its starting position 15 m above the water level.

(b) Calculate, showing all working and final unit:

(i) the potential energy of the lifeboat; 2

Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

11. (b) (continued)

(ii) the efficiency of the system when the input energy to the winch is 2·50 MJ. 2

(c) Explain why the winching system is not 100% efficient. 2

The rope used to raise the lifeboat has a length of 15 m.

(d) Calculate the change in length of the rope when the resulting strain is 0·00375. 3

Show all working and final unit.

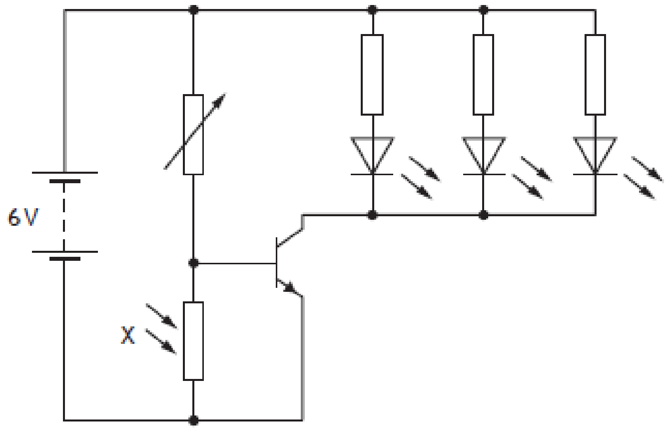
[Turn over

Back to Table

11.	(a)		$E_k = \frac{1}{2} mv^2$ $= \frac{1}{2} \times 7750 \times 3^2$ (1 mark for substitution) = 34875J (1 mark for correct answer from given working with unit)	2	
	(b)	(i)	$E_p = mgh$ = 7750 x 9·8 x 15 (1 mark for substitution) = 1139250J (1 mark for correct answer from given working with unit)	2	
	(b)	(ii)	Efficiency = $\frac{Eout}{Ein}$ = $\frac{1{\cdot}14}{2{\cdot}50}$ (1mark for substitution) = 0·456 (0.46) Or 45·6% (46%) (1 mark for correct answer from given working)	2	Allow FTE from (b) (i)
	(c)		Loss of energy/heat/sound 1 mark due to friction 1 mark	2	Explanation Cause - 1 mark effect - 1 mark
	(d)		$\varepsilon = \Delta l \,/\, l$ $0{\cdot}00375 = \Delta l \,/ 15$ (1 mark for substitution) $\Delta l = 0{\cdot}00375 \times 15$ (1 mark for transposition) = 0·056m (0.06m) (1 mark for correct answer with units from given working)	3	Units required

MARKS DO NOT WRITE IN THIS MARGIN

12. The circuit used in a bicycle light is shown below.



(a) State the full name of component X shown in the circuit. 1

(b) Describe the operation of the circuit. 4

(c) (i) Describe one advantage of wiring the LEDs in parallel rather than in series. 1

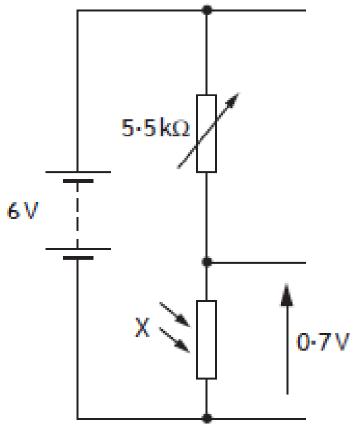
(ii) Describe why LEDs were used in preference to lamps. 1

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

12. (continued)

The sensing sub-system used in the operation of the bicycle light is shown below.



(d) Calculate the resistance of component X. 4

Show all working and final unit.

[Turn over

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

Back to Table

Back to Table

Question			Expected Answer(s)	Max Mark	Additional Guidance
12.	(a)		Light Dependant Resistor	1	Not LDR
	(b)		As the light level decreases the resistance of the LDR increases/ increasing the voltage dropped across it/ sensitivity can be adjusted by the variable resistor. As the voltage across the LDR increases / 0.7V /reaches the correct voltage the transistor will switch on. The LEDs switch on.	4	1 mark for each correct descriptive statement 2 marks Voltage division 1 mark Transistor 1 mark Output No mark for dark sensor without description of voltage divider operation.
	(c)	(i)	They will all have the same brightness/voltage. Overall more light will be produced. If one goes out the rest will stay on. Easy to fault find /repair because damage component can be clearly seen.	1	1 mark for one correct description
		(ii)	LEDs uses less energy - LEDs are more efficient - LEDs longer lasting - LEDs are more robust - LEDs are smaller - LEDs output is brighter	1	1 mark for one correct descriptive response Not cheaper
	(d)		$6 - 0{\cdot}7 = 5{\cdot}3\text{V}$ (1 mark for calculating V across variable resistor) $\frac{V_1}{V_2} = \frac{R_1}{R_2}$ $\frac{0{\cdot}7}{5{\cdot}3} = \frac{R_1}{5{\cdot}5}$ (1 mark for substitution of 3 values - allow FTE for 6V if 5.3V is not determined) $R_1 = 0{\cdot}13 \times 5{\cdot}5$ (1 mark for transposition) $R_1 = 0{\cdot}726\ \text{k}\Omega \quad 726\Omega$ (1 mark for correct answer from given working with unit)	4	

Back to Table

Back to Table

13. A rollercoaster is shown below. MARKS DO NOT WRITE IN THIS MARGIN

(a) Describe two tasks a structural engineer would undertake during the design of the rollercoaster's structure.

1 ______________________________ 1

____

2 ______________________________ 1

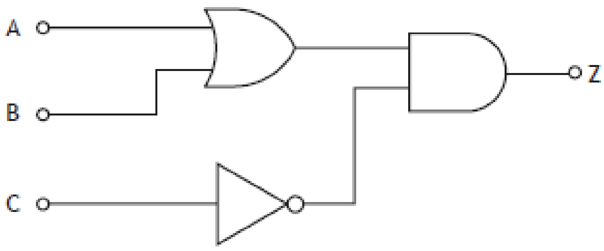
____

An electronic engineer used computer simulation during the design of the rollercoaster.

(b) State one feature of the rollercoaster design that the electronic engineer would simulate. 1

____

The logic diagram for part of the electronic control system used in the rollercoaster is shown below.



(c) Complete the Boolean equation for the logic diagram. 3

Z = ______________________________

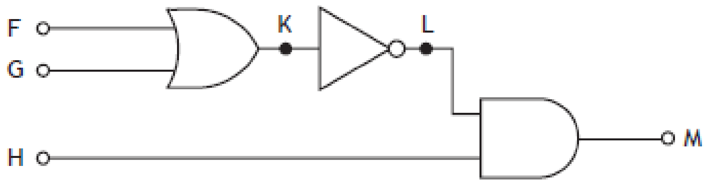
Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

13. (continued)

The logic diagram for a second part of the electronic control system is shown below.



(d) Complete the truth table below for the logic diagram. 3

F	G	H	K	L	M
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

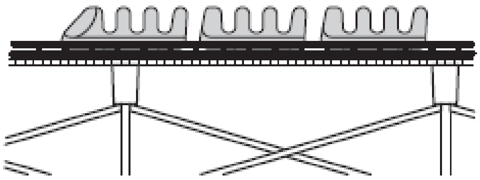
Back to Table

Back to Table

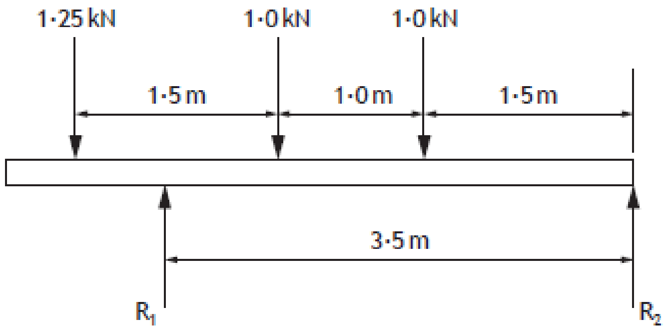
MARKS DO NOT WRITE IN THIS MARGIN

13. (continued)

The rollercoaster carriages sit on the track as shown below.



The forces acting on the system are shown in the diagram below.



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

Show all working and final unit.

Back to Table

<table>
<tr><th colspan="3">Question</th><th>Expected Answer(s)</th><th>Max Mark</th><th>Additional Guidance</th></tr>
<tr><td>13.</td><td>(a)</td><td></td><td>Choosing the correct materials to use.

Designing the supporting structure (specific aspect).

Research loadings (roller coaster and external - wind etc)</td><td>2</td><td>1 mark per correct descriptive response</td></tr>
<tr><td></td><td>(b)</td><td></td><td>To simulate control circuits, safety systems, lighting, braking systems, program/flowchart and test their operation. (1 mark for any relevant answer)</td><td>1</td><td>Statement based response</td></tr>
<tr><td></td><td>(c)</td><td></td><td>(A + B) · $\overline{C}$ = Z</td><td>3</td><td>(1 mark OR with bracket,
1 mark AND,
1 mark NOT)

Other correct Boolean equations are acceptable</td></tr>
<tr><td></td><td>(d)</td><td></td><td><table><tr><th>K</th><th>L</th><th>M</th></tr><tr><td>0</td><td>1</td><td>0</td></tr><tr><td>0</td><td>1</td><td>1</td></tr><tr><td>1</td><td>0</td><td>0</td></tr><tr><td>1</td><td>0</td><td>0</td></tr><tr><td>1</td><td>0</td><td>0</td></tr><tr><td>1</td><td>0</td><td>0</td></tr><tr><td>1</td><td>0</td><td>0</td></tr><tr><td>1</td><td>0</td><td>0</td></tr></table></td><td>3</td><td>1 mark for each correct column

Allow FTE for column L and M;

L = NOT K

M = H AND L</td></tr>
<tr><td></td><td>(e)</td><td></td><td>ΣCWM = ΣACWM

(R_1 x 3·5) = (1·25 x 4.0) +
(1·0 x 2·5)
+ (1·0 x 1·5)

(1 mark for substitution)

R_1 = 9·0/3·5

(1 mark for transposition)

R_1 = 2·57kN (2571 N)

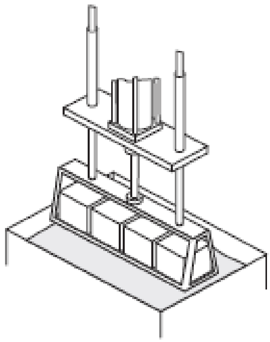
(1 mark for correct answer from given working with unit)</td><td>3</td><td></td></tr>
</table>

Page eleven

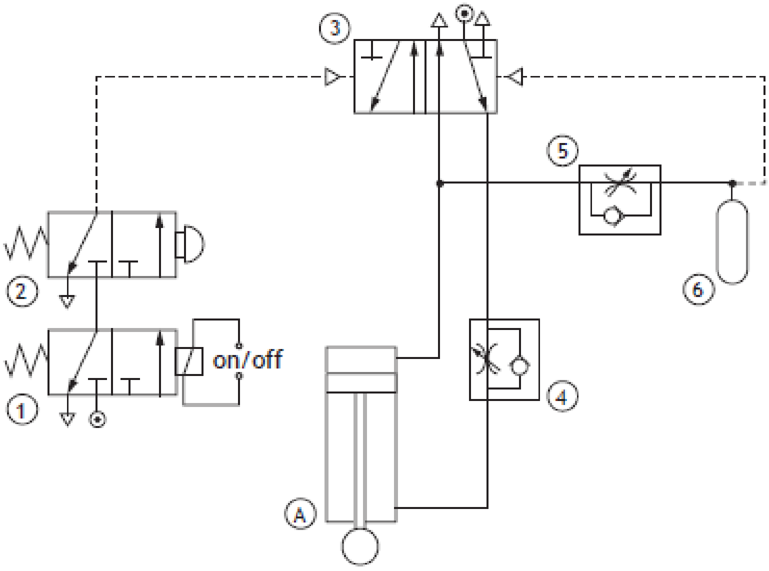
Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

14. A pneumatic system used to lower metal components into an acid bath to be cleaned is shown below.



The pneumatic circuit used is shown below.



(a) Describe the operation of the pneumatic circuit. **4**

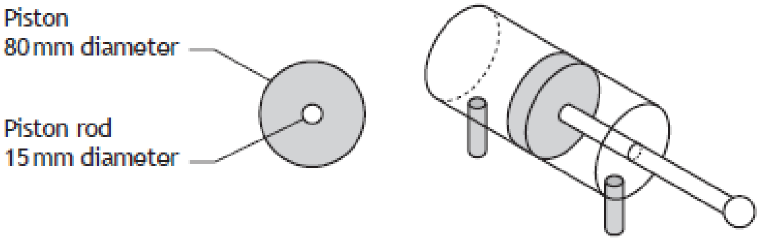
When Valve (1) is actuated . . .

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

14. (continued)

The pneumatic cylinder used is shown in the diagram below.



(b) Calculate the air pressure required to produce an instroking force of 1460 N. 4

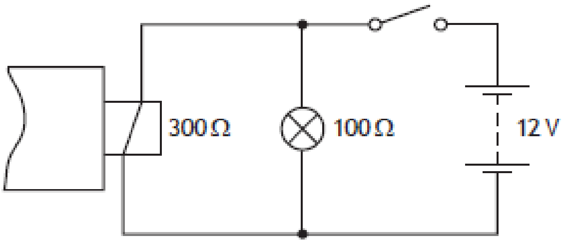
Show all working and final unit.

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

14. (continued)

The solenoid on pneumatic valve (1) is connected to a circuit as shown below.



(c) Calculate the total resistance of the circuit. 2

Show all working and final unit.

An ammeter is used to measure current in the circuit.

(d) (i) Draw the symbol for an ammeter below. 1

(ii) Indicate, with an X, on the circuit above where an ammeter would be connected to measure the current through the solenoid. 1

[Turn over

Back to Table

Back to Table

Question			Expected Answer(s)	Max Mark	Additional Guidance
14.	(a)		When the solenoid and push button are both activated pilot air is sent to Valve 3. (1 Mark) This causes the cylinder to outstroke slowly. (1 Mark) When the cylinder has outstroked air is sent to the reservoir via the uni-directional restrictor creating a time delay. (1 Mark) Pilot air is then sent to valve 3 causing the cylinder to instroke. (1 Mark)	4	1 mark for AND control. 1 mark for speed control when outstroking. 1 mark for Time Delay. 1 mark for instroking.
	(b)		$A_{rod} = \frac{\pi d^2}{4}$ $= \frac{3{\cdot}14 \times 15^2}{4} = 176.6\ (\text{mm}^2)$ A_{piston} $= \frac{3 \cdot 14 \times 80^2}{4} = 5024\ (\text{mm}^2)$ (1 mark for correct calculation of either area - ignore units) $A_{effective} = A_{piston} - A_{rod}$ $= 5024 - 176{\cdot}6$ $= 4847{\cdot}4\ \text{mm}^2$ (1 mark for correct answer from given working - ignore units) P = F/A = 1460/4847·4 (1 mark for substitution) $= 0{\cdot}3\text{Nmm}^{-2}$ (0.3 MPa) (1 mark for correct answer from given working with unit)	4	
	(c)		$R_T = \frac{R_1 \times R_2}{R_1 + R_2}$ $R_T = \frac{300 \times 100}{300 + 100}$ (1 mark for substitution) $R_T = 75\Omega$ (1 mark for correct answer from given working with unit)	2	Apply similar mark allocation if the other version of the formula is used.
	(d)	(i)		1	
		(ii)	X should indicate a wire between solenoid and lamp. Can be top or bottom of branch. Series connection only.	1	

 Back to Table

Back to Table

15. A sign used to display a car's speed is shown below.

The sign is operated by a microcontroller. Input and output connections to the microcontroller are shown in the table below.

Input connections	Pin	Output connections
	7	
	6	speed display
	5	"smiley" face display
	4	
	3	
speed sensor (1 = too fast)	2	
	1	
	0	

The sign operates using the following sequence.

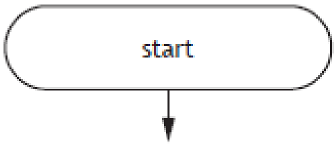
1 The speed sensor measures the speed of the car.
2 If the car is moving too fast, the speed display sign is switched on for 0·5 seconds.
3 If the car is not moving too fast, the "smiley" face display is switched on for 1 second.
4 The sequence then repeats.

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

15. (continued)

(a) Complete the flowchart for the sequence with reference to the Data Booklet and input/output connections. Include all pin numbers in your flowchart. 6



(b) State the type of program loop used in the operation of the sign. 1

[Turn over

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

15. (continued)

The sign applies a load of 88 N onto a supporting pole, resulting in a stress of 0·095 Nmm^{-2}.

(c) Calculate the cross-sectional area of the pole. 3

Show all working and final unit.

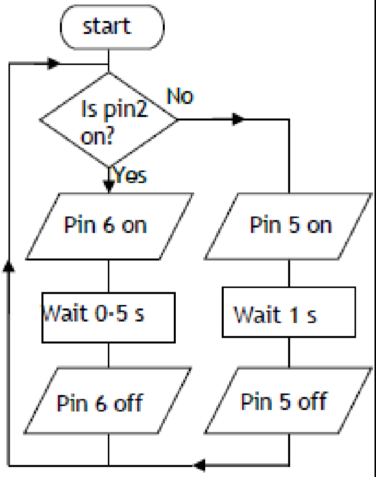
A solar panel is used to provide power for the sign.

(d) Explain how the use of solar panels can contribute towards tackling climate change. 2

[END OF QUESTION PAPER]

Back to Table

Back to Table

Question		Expected Answer(s)	Max Mark	Additional Guidance
15.	(a)	 1 mark for decision -(pin) 2, with Y or N labelled 1 mark for both (pin) 6 on/off 1 mark for both (pin) 5 on/off 1 mark both pauses 1 mark for continuous loop with arrow 1 mark for all symbols correct	6	Allow FTE for incorrect pin being switched on. Ignore any additional steps *Pause 1000* (PBASIC) or *Delay 1000* (C) accepted as wait 1s etc
	(b)	Continuous / infinite loop	1	Named or Described
	(c)	$\sigma = \frac{F}{A}$ $0.095\text{Nmm}^{-2} = \frac{88\text{N}}{A}$ (1 mark for substitution) $A = \frac{88}{0{\cdot}095}$ (1 mark for transposition) $A = 926{\cdot}3\text{mm}^2$ (1 mark for correct answer from given working with unit)	3	
	(d)	Reduces greenhouse gases / CO2 (1 mark). Due to reduced use of fossil fuels (1 mark).	2	Explanation Cause - 1 mark effect - 1 mark Not pollution / gases on own

Back to Table

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

SECTION 1 — 20 marks

Attempt ALL questions

1. An automatic vacuum cleaner uses a proximity sensor to detect when it is getting close to walls or furniture. It will then move to avoid them.

The vacuum cleaner uses closed loop control.

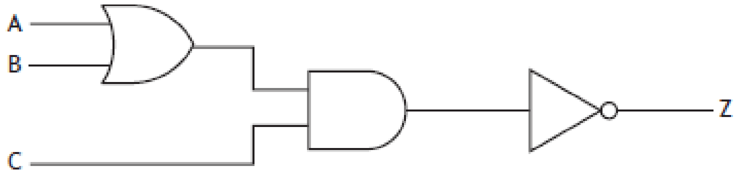
Describe what is meant by closed loop control. 1

2. Describe two advantages of a microcontroller based control system compared to a hard-wired electronic circuit. 2

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

3. The logic diagram shown below forms part of a house alarm.



Complete the truth table for the logic circuit above. 3

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

[Turn over

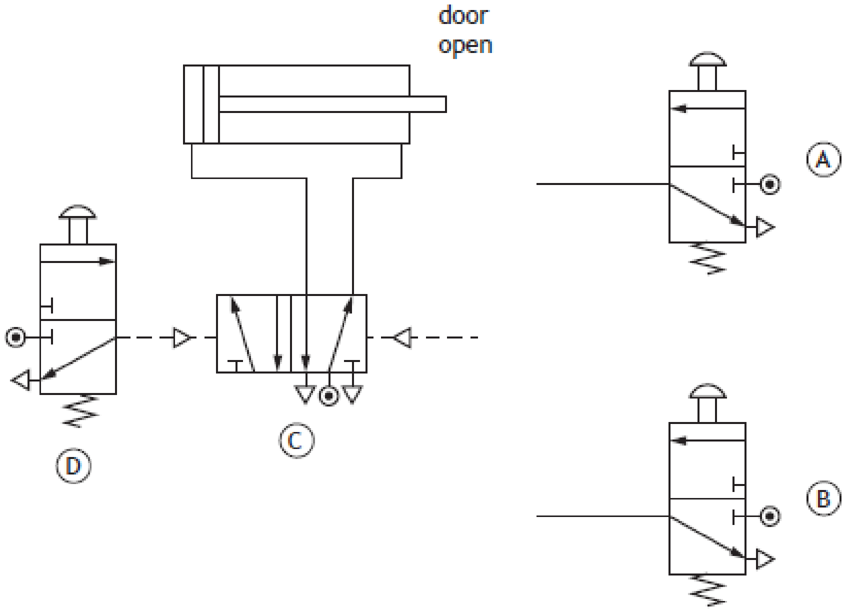
* X 7 2 3 7 5 0 1 0 3 *

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

4. A pneumatic door in a factory is being designed.

(a) Complete the diagram below to allow the door to open when valve A or B is actuated. 2



(b) State the name of the type of actuator used to control valve C. 1

5. State two pieces of information that should be given on a free body diagram. 2

1

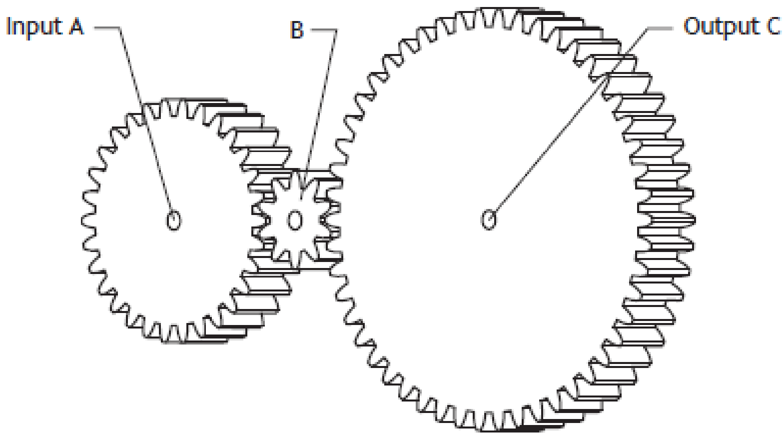
2

Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

6. A diagram of part of a gear mechanism for an electric food mixer is shown below.



(a) (i) State the name of gear B. 1

(ii) Describe the function of gear B. 1

(b) Calculate the velocity ratio when Input A rotates at 1200 revs min^{-1} and Output C has a speed of 720 revs min^{-1}. 2

Show all working.

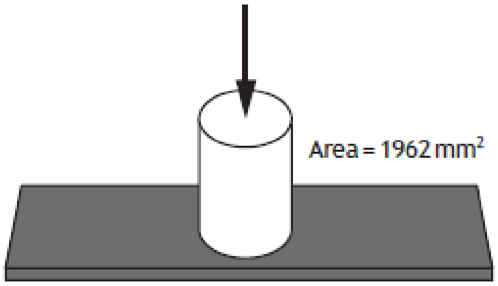
[Turn over

Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

7. A section from a structural member is shown in the diagram below.



Calculate the stress acting on the member if a force of 5·0 kN is applied. 2

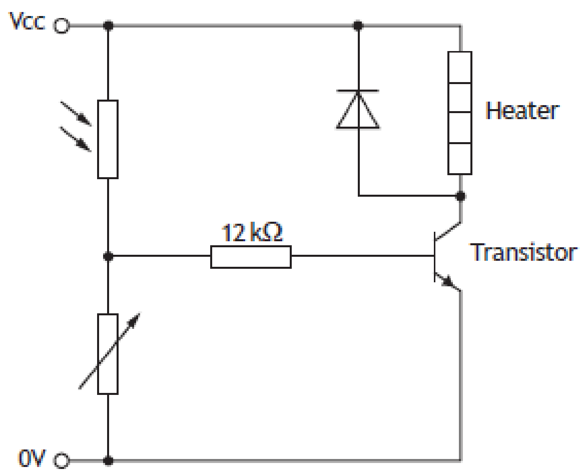
Show all working and final unit.

Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

8. A diagram of part of a heating circuit is shown below.



(a) State the function of the transistor. **1**

____

(b) State the function of the 12 kΩ fixed resistor. **1**

____

9. State what type of engineer would be responsible for developing the lubricants used in a gear drive. **1**

____

[Turn over

Back to Table

Back to Table

Marking Instructions for each question

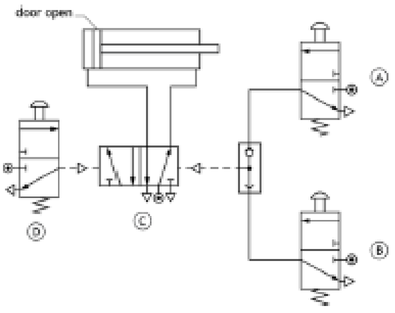
Section 1

Question			Expected Answer(s)	Max Mark	Additional Guidance
1.			Closed loop is self-monitoring and will adjust the output according to changing conditions	1	Descriptive response. Accept: has feedback loop (adjusts itself/checks output)

Question			Expected Answer(s)	Max Mark	Additional Guidance
2.			Fewer parts Increased reliability Simplified/faster assembly Can be reprogrammed Re-usable Upgradable - system's features can be quickly/easily changed Reduced stock inventory (one microcontroller circuit can be repurposed)	2	1 mark per each correct descriptive response. Accept - easier to fix mistakes Not smaller or cheaper on its own. Not programmable

<table>
<tr><th colspan="3">Question</th><th>Expected Answer(s)</th><th>Max Mark</th><th>Additional Guidance</th></tr>
<tr><td>3.</td><td></td><td></td><td>
<table>
<tr><th>A</th><th>B</th><th>C</th><th>Z</th></tr>
<tr><td>0</td><td>0</td><td>0</td><td>$\boxed{1}$</td></tr>
<tr><td>0</td><td>0</td><td>1</td><td>1</td></tr>
<tr><td>0</td><td>1</td><td>0</td><td>$\boxed{1}$</td></tr>
<tr><td>0</td><td>1</td><td>1</td><td>0</td></tr>
<tr><td>1</td><td>0</td><td>0</td><td>1</td></tr>
<tr><td>1</td><td>0</td><td>1</td><td>$\boxed{0}$</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>1</td></tr>
<tr><td>1</td><td>1</td><td>1</td><td>0</td></tr>
</table>
</td><td>3</td><td>1 Mark for each correct output.</td></tr>
</table>

Back to Table

Question			Expected Answer(s)	Max Mark	Additional Guidance
4.	(a)			2	1 Mark for correct shuttle valve symbol. 1 Mark for all piping (port to port). If no shuttle drawn then ignore lack of T piece. Do not accept two pipes to 5/2 actuator. Ignore pilot lines.
	(b)		Pilot	1	

Question			Expected Answer(s)	Max Mark	Additional Guidance
5.			Dimension(s) Force(s)	2	Accept: Magnitude and direction/ angle of the forces (2 marks)

Question			Expected Answer(s)	Max Mark	Additional Guidance
6.	(a)	(i)	Idler	1	
		(ii)	It makes gear A and gear C turn in the same direction (without affecting the output speed).	1	Descriptive response Accept change the (output) direction Not keep the direction the same on its own
	(b)		VR = speed of input/speed of output VR = 1200/720 VR = 5:3 (5/3) 1·7:1 (1·67)	2	1 Mark for using the correct substitution. 1 Mark for the correct answer from working (ignore any units) Do not accept $1{\cdot}\dot{6}$

Back to Table

Question			Expected Answer(s)	Max Mark	Additional Guidance
7.			$\sigma = \frac{F}{A}$ $\sigma = \frac{5000}{1962}$ $= 2{\cdot}5\ Nmm^{-2}$ (2 sf) $(2{\cdot}55\ Nmm^{-2})$ $(0{\cdot}0025\ kN\ mm^{-2})$	2	1 mark for substitution 1 mark for correct answer from working with units $2{\cdot}5$ MPa (MNm^{-2}) 2548419PA

Question			Expected Answer(s)	Max Mark	Additional Guidance
8.	(a)		Acts as a switch	1	1 Mark. Accept: amplifying current turn on/switch on heater.
	(b)		Protect/limit the current (to the transistor)	1	1 Mark

Question			Expected Answer(s)	Max Mark	Additional Guidance
9.			Chemical	1	

Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

SECTION 2 — 70 marks

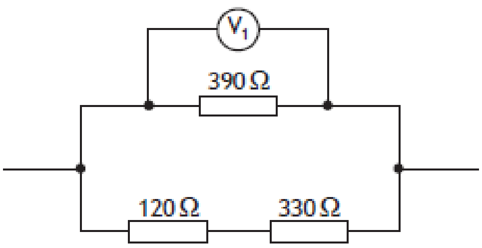
Attempt ALL questions

10. A drone used to film sporting events is shown.

An electronic engineer was involved in the development of the drone.

(a) Describe two roles the electronic engineer may have had in the development of the drone. 2

Part of the electronic circuit used in the drone is shown below.



Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

10. (continued)

(b) Calculate the total resistance for the circuit shown. 3

Show all working and final unit.

(c) Calculate the current through the 390 Ω resistor when the voltage V_1 is 12 V. 3

Show all working and final unit.

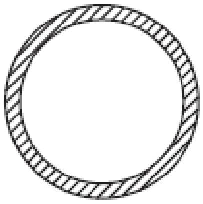
Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

10. (continued)

The cross-section of one of the drone's tubular support arms is shown below.



The stress in the support arm was found to be 0·42 Nmm^{-2} when a force of 310 N was applied.

(d) Calculate the cross-sectional area of the support arm. 3

Show all working and final unit.

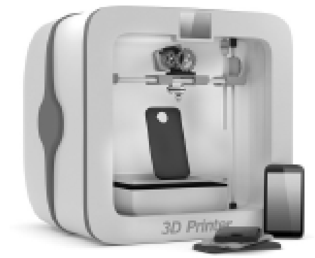
Back to Table

Section 2

Question			Expected Answer(s)	Max Mark	Additional Guidance
10.	(a)		Designing control circuits. Calculating values of components. Selecting the correct components to use. Produce a microcontroller program. Test circuits using computer simulation.	2	1 mark for each correct descriptive response. No mark for generic "developing" "creating" "circuit" or "electronics" on its own. Accept: calculate power supply/ motor values Building or wiring not be accepted without reference to prototyping
	(b)		120 + 330 = 450Ω $R_T = \frac{(R1 \times R2)}{(R1 + R2)}$ $R_T = \frac{(390 \times 450)}{(390 + 450)}$ $R_T = 210\Omega\ (2sf)\ (209\Omega)$	3	1 mark for series branch total (ignore units) Accept 3 resistors in parallel calculation - 2 marks maximum 1 mark for substitution (allow FTE). 1 mark for answer from working with unit.
	(c)		$V = IR$ $12 = I \times 390$ $I = \frac{12}{390}$ $I = 0{\cdot}031A\ (31mA\ 2sf)$	3	1 mark for substitution. 1 mark for transposition. 1 mark for answer from working with unit.
	(d)		$\sigma = \frac{F}{A}$ $0{\cdot}42 = \frac{310}{A}$ $A = \frac{310}{0{\cdot}42}$ $A = 740\,mm^2\ 2sf\ (738\,mm^2)$	3	1 mark for substitution. 1 mark for transposition. 1 mark for answer from working with unit.

MARKS | DO NOT WRITE IN THIS MARGIN

11. 3D printers allow individual users to quickly manufacture complex products from a computer model.



(a) (i) Describe a positive economic impact of a 3D printer. **1**

____

____

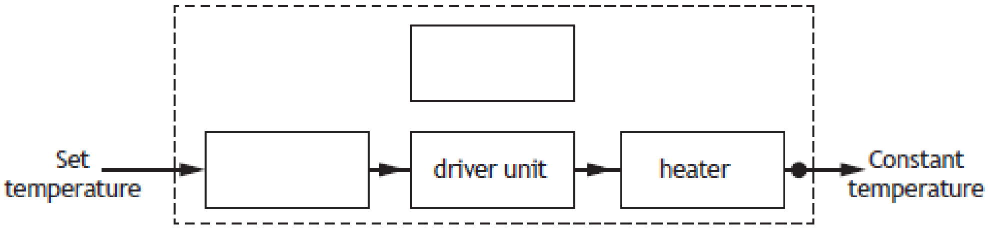
(ii) Describe a negative economic impact of a 3D printer. **1**

____

____

3D products are printed onto a heated platform. The platform is required to maintain a set temperature during the printing process.

(b) Complete the sub-system diagram below for the platform temperature. **3**



(c) Describe how feedback is used to maintain the platform's temperature. **2**

____

____

____

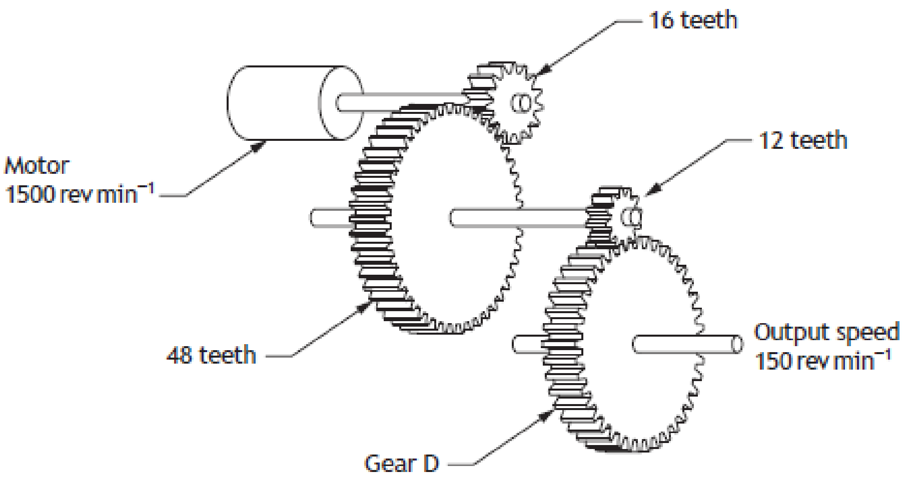
____

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

11. (continued)

Part of the gear mechanism used in the 3D printer is shown below.



(d) Calculate the size of Gear D. **4**

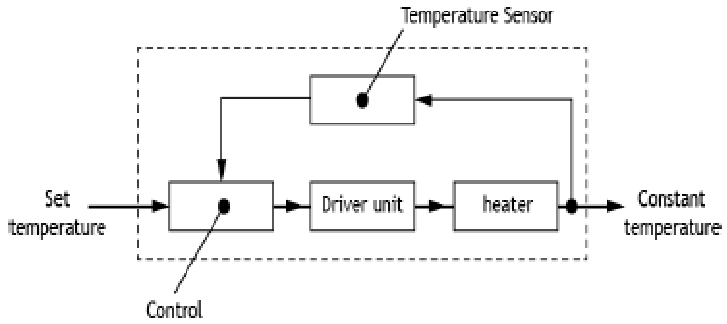
Show all working.

Back to Table

Back to Table

Question			Expected Answer(s)	Max Mark	Additional Guidance
11.	(a)	(i)	Items can be quickly produced thus saving time and money. Jobs will be created in the design and manufacture of the hardware used and that will produce wealth. Lower running costs (than other methods) Parts can be cheaper to print than to manufacture	1	Descriptive response relating to economic advantage. Jobs/employment descriptions need economic advantage. Not cheap on its own. Must be justified or a comparison
		(ii)	Initial setup/training/running/ consumables/maintenance costs. Loss of business/revenue for some companies. Parts can be slow/more expensive to manufacture	1	Descriptive response relating to economic disadvantages. Jobs/employment descriptions need economic disadvantages. Not more expensive on its own Do not accept the same point for (a)(i) and (ii) (max 1 mark)
	(b)		See below	3	"temperature sensor" 1 mark Accept: heat sensor, thermistor, thermocouple or thermostat. thermometer - 0 mark "control" - 1 mark Feedback loop from output arrow with an arrow head (anywhere) through sensor to enter control sub-system (anywhere) 1 mark

Back to Table

Question			Expected Answer(s)	Max Mark	Additional Guidance
					
	(c)		If the feedback signal is greater than/equals the set level the control unit will switch off the heater. 2 marks If the feedback signal falls below the set level the control unit will switch the heater on. 2 marks	2	Feedback compared to set level - 1 mark Switching of heater - 1 mark (switching action has to be specific, correct and related to the comparison) Not accept - if hot/cold switch heater off/on

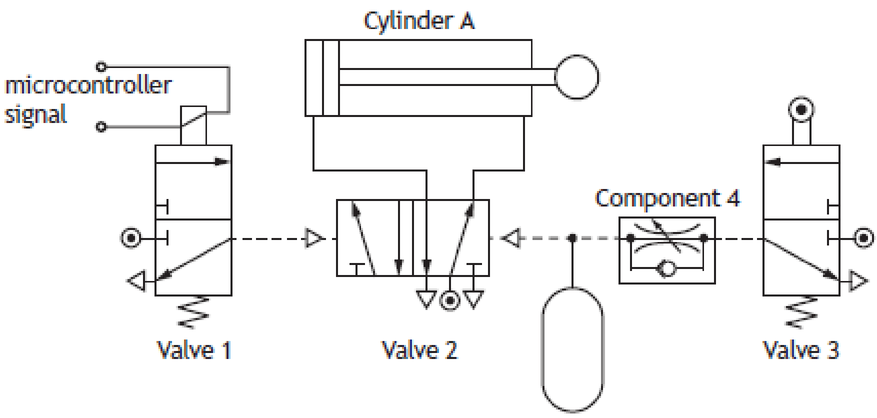
Question			Expected Answer(s)	Max Mark	Additional Guidance
	(d)		Input speed × input size = output speed × output size 1500 × 16 = output speed × 48 Output speed = 500 rev min^{-1} Input speed x input size = output speed × output size 500 × 12 = 150 × D D = 40 teeth OR $VR = \frac{input\ speed}{output\ speed}$ $VR = \frac{1500}{150}$ VR = 10:1 $10 = \frac{48}{16} \times \frac{D}{12}$ $D = \frac{10}{3} \times 12$ $D = 40$	4	1 mark for substitution. 1 mark for answer, unit not required. 1 mark for substitution. 1 mark for answer from working. Ignore any unit. 1 mark for calculating velocity ratio 1 mark for substitution. 1 mark for transposition. 1 mark for answer from working with unit. Ignore any unit.

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

12. A mechanical model of a dinosaur uses pneumatics to control its movement.

Part of the pneumatic circuit used in the model is shown below.



(a) Describe, using appropriate terminology, the operation of the circuit. 3

When a signal is sent from the microcontroller ______

______

______

______

______

______

(b) The circuit is to be altered so that the piston instrokes slowly.

Indicate, with an X, on the pneumatic circuit where a unidirectional restrictor should be connected. 1

* X 7 2 3 7 5 0 1 1 4 *

Back to Table

12. (continued)

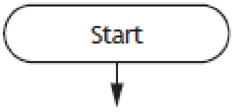
A microcontroller is used to operate the model in the sequence shown below.

1 When a start switch is activated the arms will move.
2 After 1·5 seconds the dinosaur will then roar for 1 second.
3 After another 0·5 seconds the arms should halt.
4 Steps 2 and 3 will repeat three times.
5 The sequence will then repeat.

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

Input Connection	Pin	Output Connection
	2	arms
	1	roar
start switch	0	

(c) Complete the flowchart for the control sequence with reference to the Data Booklet and input/output connections. Include all pin numbers. 8



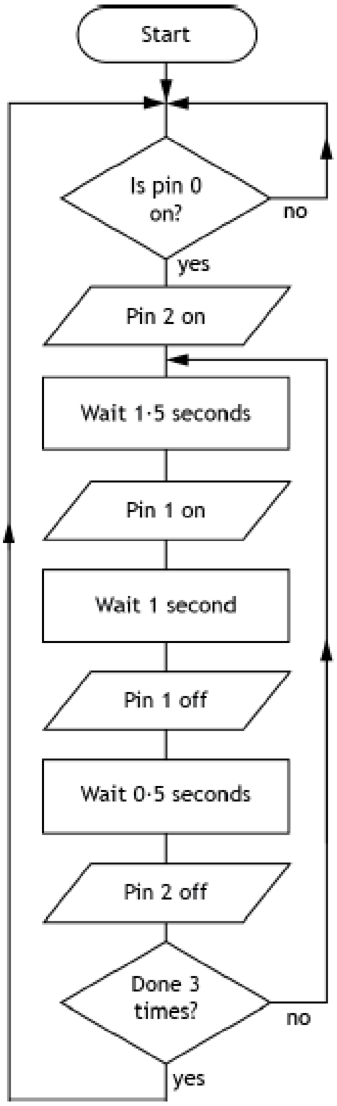
[Turn over

Back to Table

Question			Expected Answer(s)	Max Mark	Additional Guidance
12.	(a)		When a signal from the microcontroller actuates valve 1, pilot air actuating valve 2. This causes the piston to outstroke ...air flow (through the uni-directional restrictor and reservoir) creating a time delay .... ..when valve 3 is actuated the piston will then instroke.	3	1 mark for each descriptive statement. 1 mark - outstroke condition 1 mark - time delay 1 mark - instroke condition
	(b)		Cross shown on left cylinder pipe.	1	Accept on the left hand exhaust port.

Back to Table

Back to Table

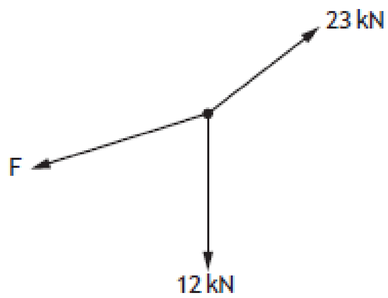
Question			Expected Answer(s)	Max Mark	Additional Guidance
	(c)			8	All pin numbers must be correct where applicable. • (pin) 0 on decision, feedback loop with yes/no and arrow. 1 mark • (pin) 2 on and off. 1 mark • all three delays 1 mark Accept PBASIC/C alternatives (pause 1500 / delay 1500) • (pin) 1 on and off. 1 mark • x3 times decision with yes / no labelled. 1 mark • fixed loop with arrow to return point. 1 mark • Continuous loop with arrow. 1 mark • All symbols correct. 1 mark Credit given for a series of roar/ arm movement without a fixed loop. Ignore any additional steps including symbols used.

Back to Table

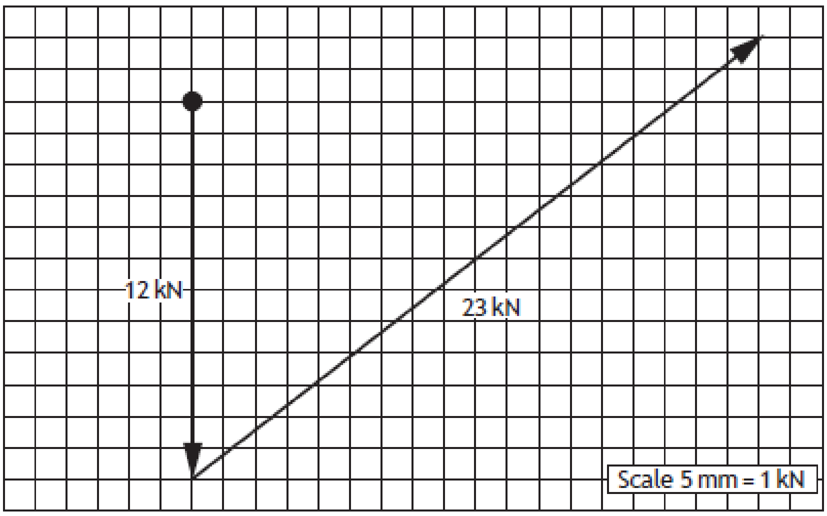
MARKS DO NOT WRITE IN THIS MARGIN

13\. A 12 kN gondola used to transport skiers up to the top of a mountain is shown below.

A diagram showing the forces acting on the supporting cable is shown below.



(a) Determine, by completing the scale drawing of the triangle of forces below, the size of force F in the supporting cable. 1



F = ____________ kN

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

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

13. (continued)

The cable has a strain of 0·00030 and an original length of 127 m.

(b) Calculate the change in length of the cable. 3

Show all working and final unit.

(c) Explain the environmental impact during the construction of the gondola system. 2

(d) An electronic circuit is used as part of the gondola's safety system. The Boolean equation used to describe its operation is shown.

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

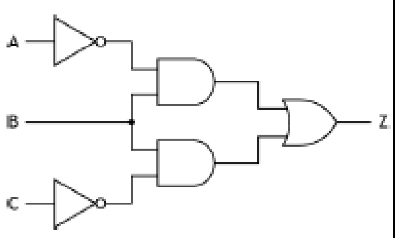
Complete the logic diagram for the Boolean equation. 3

X723750117

[Turn over

Back to Table

Back to Table

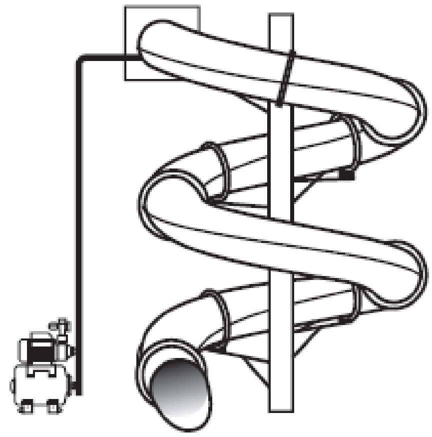
Question			Expected Answer(s)	Max Mark	Additional Guidance
13.	(a)		18 (kN)	1	Accept 17kN to 19kN Units not required
	(b)		$\varepsilon = \frac{\Delta l}{l}$ $0.00030 = \frac{\Delta l}{127}$ $\Delta l = 0{\cdot}00030 \times 127$ $\Delta l = 0{\cdot}038$ m (38 mm)	3	1 mark for substitution. 1 mark for transposition. 1 mark for answer from working with unit.
	(c)		Construction will result in heavy vehicles which may damage roads. Use of construction equipment will cause pollution and increase noise levels. Vehicles access up hillside to erect pylon damage wildlife and affect natural beauty.	2	One environmental explanation based response. One environmental cause (1 mark) and its effect (1 mark) No credit for generic cause based statements such as "during construction" / "construction site" Sound/noise to be taken as an effect and not a cause,
	(d)			3	Both NOT gates. 1 mark Both AND gates with correct connections. 1mark OR gate with correct connections. 1 mark

Back to Table

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

14. Water is pumped to the top of a slide.



The pump used is rated at 13 A, 230 V.

(a) Calculate the electrical energy supplied to the pump in one minute. 2

Show all working and final unit.

Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

14. (continued)

The pump was found to be 64 % efficient.

(b) Calculate the output energy of the pump in one minute. 3

Show all working and final unit.

(c) Explain how the efficiency of the pump could be increased. 2

A mechanical engineer used computer simulation when designing the pump.

(d) Describe an advantage of using computer simulation during the design of the pump. 1

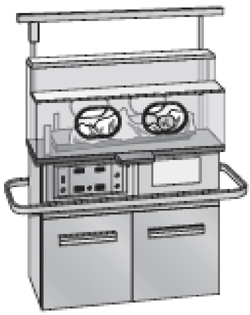
[Turn over

Back to Table

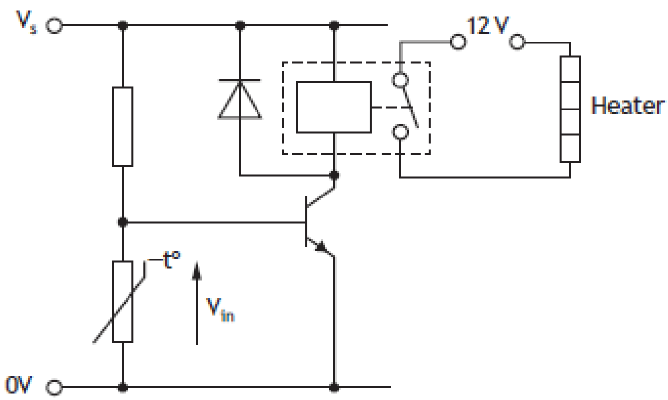
Question			Expected Answer(s)	Max Mark	Additional Guidance
14.	(a)		$E_e = ItV$ $E_e = 13 \times 60 \times 230$ $E_e = 180$ kJ (2sf) (179400 J)	2	1 mark substitution. 1 mark for answer from working with unit.
	(b)		$\eta = \frac{E_{out}}{E_{in}}$ $0 \cdot 64 = \frac{E_{out}}{180000}$ $E_{out} = 0 \cdot 64 \times 180000$ $E_{out} = 120\,kJ\,(2sf)\,(115200\,J)$	3	1 mark substitution. Allow FTE from (a). 1 mark for transposition. 1 mark for answer from working with unit. (accept 114816J or 110kJ 2 sf)
	(c)		Reduce the friction in the pump by lubricating all moving parts.	2	Explanation response. Cause - 1 mark Effect - 1 mark Reduce friction. 1 mark Lubricate moving parts. 1 mark Do not accept lubrication without named part
	(d)		Easier/cheaper/quicker/safer to design/test/modify the gear system without having to physically build it. Highlight errors without damage to components	1	Descriptive answers only. Easier/cheaper/quicker/safer must be qualified Not test/check gears on its own Not computer modelling based aspects such as fitting and assembly etc.

MARKS DO NOT WRITE IN THIS MARGIN

15. The temperature inside an incubator used in a hospital should be kept at a set level.



The electronic circuit used in the incubator is shown below.



(a) Explain the operation of the electronic circuit. 4

As the temperature decreases ______

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

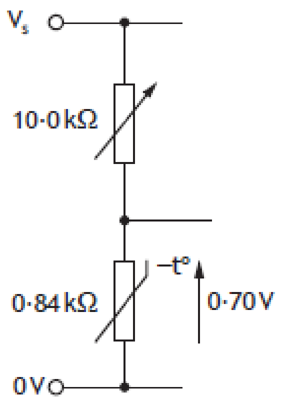
15. (continued)

(b) Explain the purpose of the diode in the circuit. 2

The fixed resistor in the circuit is replaced with a variable resistor.

(c) Describe an advantage of using a variable resistor instead of a fixed resistor in the circuit. 1

The new sensing sub-system is shown below.



(d) Calculate the voltage across the variable resistor. 3

Show all working and final unit.

Back to Table

Back to Table

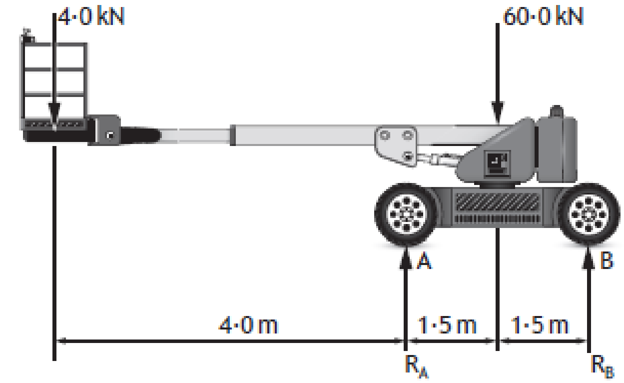
Question			Expected Answer(s)	Max Mark	Additional Guidance
15.	(a)		*As the temparature decreases:* .. the resistance of the thermistor increases ..Vin will increase. The transistor/relay will switch..... ... switching the 12V circuit/ heater.	4	Voltage divider explanation - maximum of 2 marks Transistor/relay switching - maximum 1 mark 12V circuit/heater circuit switching - maximum 1 mark Apply follow through error.
	(b)		Protect the transistor	2	Explanation response. Protection / route for back emf. 1 mark ..the transistor. 1 mark
	(c)		Allows the user to change the temperature required to activate the circuit.	1	Accept change the sensitivity.
	(d)		$\frac{V1}{V2}=\frac{R1}{R2}$ $\frac{0\cdot 70}{V2}=\frac{0\cdot 84}{10\cdot 0}$ $V2=\frac{0\cdot 7}{0\cdot 084}$ $V=8\cdot 3V\,(2sf)$	3	1 mark substitution. 1 mark for transposition. 1 mark for answer from working with unit. Using ohms law also acceptable.

Back to Table

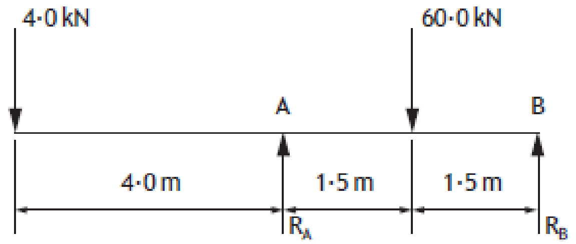
Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

16. A cherry picker is used to access high areas.



A free body diagram of the cherry picker is shown below.



(a) Calculate, by taking moments about B, the reaction force R_A. 3

Show all working and final unit.

Back to Table

Back to Table

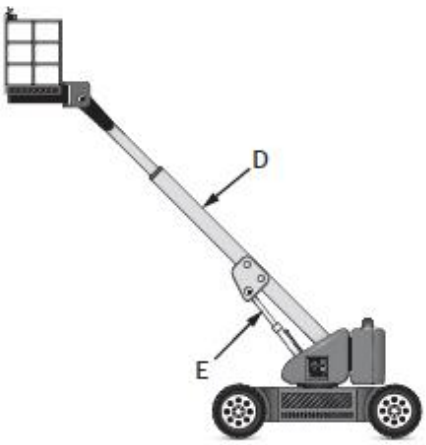
MARKS | DO NOT WRITE IN THIS MARGIN

16. (continued)

(b) Calculate the force R_B. 2

Show all working and final unit.

When in use, the platform is raised to the position shown below. A structural engineer analyses the nature of the forces acting on members D and E.



(c) State the nature of the force in member: 2

D ______________________________

E ______________________________

The cherry picker uses electricity as its power source.

(d) Explain how electric vehicles can contribute towards reducing the environmental effect of climate change. 2

____

____

____

[END OF QUESTION PAPER]

Back to Table

Question			Expected Answer(s)	Max Mark	Additional Guidance
16.	(a)		$\Sigma CWM = \Sigma ACWM$ $(R_A \times 3\cdot0) = (60\cdot0 \times 1\cdot5) + (4\cdot0 \times 7\cdot0)$ $R_A \times 3\cdot0 = 90 + 28$ $R_A = \frac{118}{3\cdot0}$ $R_A = 39\,kN\,(2sf)\,(39\cdot3\,kN)$	3	1 mark substitution. (If R_B is calculated then 2 marks maximum. 1mk transposition 1mk final answer with unit.) 1 mark for transposition. 1 mark for answer from working with unit.
	(b)		$\Sigma F_{vertical} = 0$ $\Sigma F_{up} = \Sigma F_{down}$ $39 + R_B = 60\cdot0 + 4\cdot0$ $R_B = 25kN$ (2 sf) 24.7kN	2	1 mark substitution. Allow FTE 1 mark for answer from working with unit. Accept taking moments about A.
	(c)		D - Tension E - Compression	2	1 mark for each correct answer. (Accept Tie and Strut)
	(d)		Reducing/no fossil fuels being used This will result in the reduction/ no CO_2 emissions/greehouse gasses.	2	Explain based responses relating to environmental impact Cause - 1 mark Effect - 1 mark Cause: Reduction of fossil fuel usage. 1 mark Effect: Reduction of CO_2 emissions 1 mark Do not accept pollution Gasses/emissions must be specific to CO_2 or greenhouse

[END OF MARKING INSTRUCTIONS]

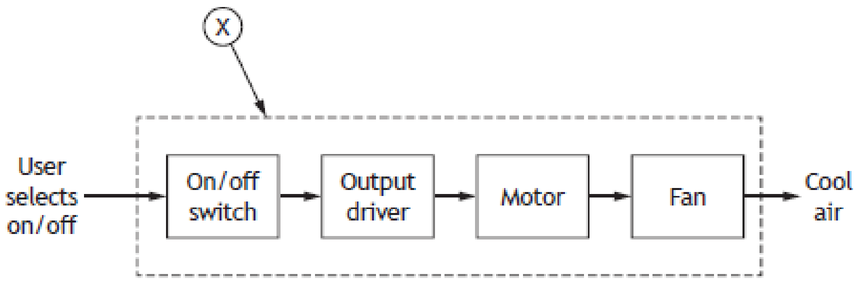
Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

SECTION 1 — 20 marks

Attempt ALL questions

1. A sub-system diagram for a hand held fan is shown below.



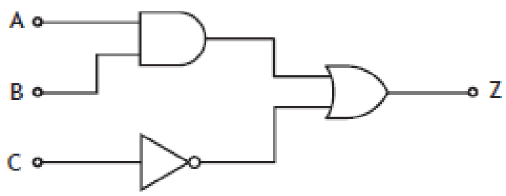
(a) State the type of control used in this system. **1**

____

(b) State the name of X. **1**

____

2. A logic diagram is shown below.



Complete the Boolean equation for this logic diagram. **3**

Z = ______________________________

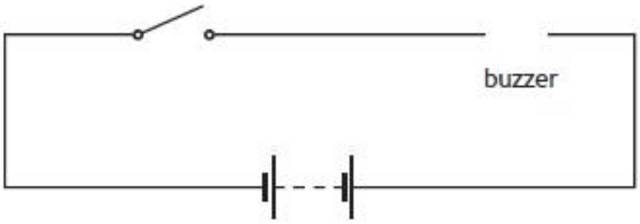
Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

3. A warning circuit is designed to activate a buzzer when a switch is pressed.

(a) Complete the circuit below by adding the symbol for a buzzer in the position shown. 1



(b) State the name of the equipment used to measure the current in a circuit. 1

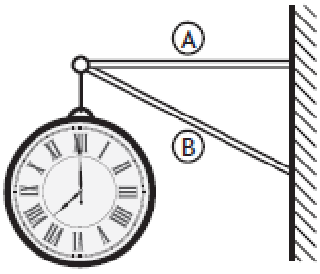
4. A 5·4 kg bowling ball travels down a lane at 8·2 ms^{-1}.

Calculate the kinetic energy of the bowling ball. 2

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

5. A clock is hung from a frame structure and is shown below.



(a) State the nature of the force in: **2**

Member A ______________________________

Member B ______________________________

(b) The clock has a mass of 2·2 kg.

Calculate the downward force of the clock (F = mg). **2**

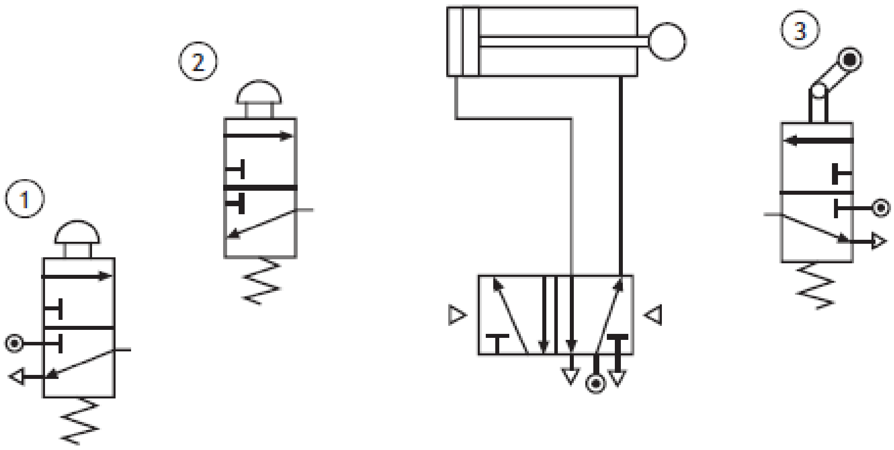
Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

6. A pneumatic circuit used to crush materials in a recycling factory is shown below.

The piston should only outstroke when valve 1 and valve 2 have been actuated. It will then instroke when valve 3 has been actuated.

Complete the piping of the pneumatic circuit shown below. 3



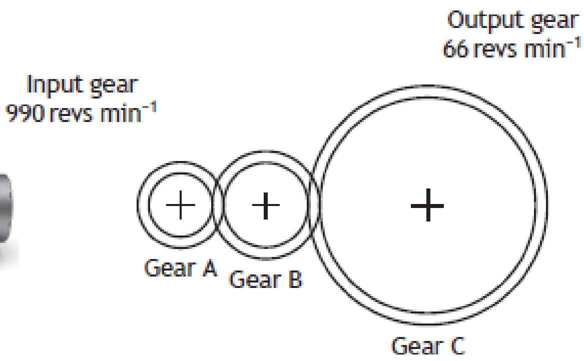
[Turn over

Back to Table

[Back to Table](#)

MARKS | DO NOT WRITE IN THIS MARGIN

7. A simple gear train used in a winch system is shown below.



(a) (i) State the name of gear B. **1**

____

(ii) State the effect of gear B on the output speed. **1**

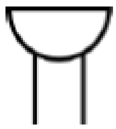
____

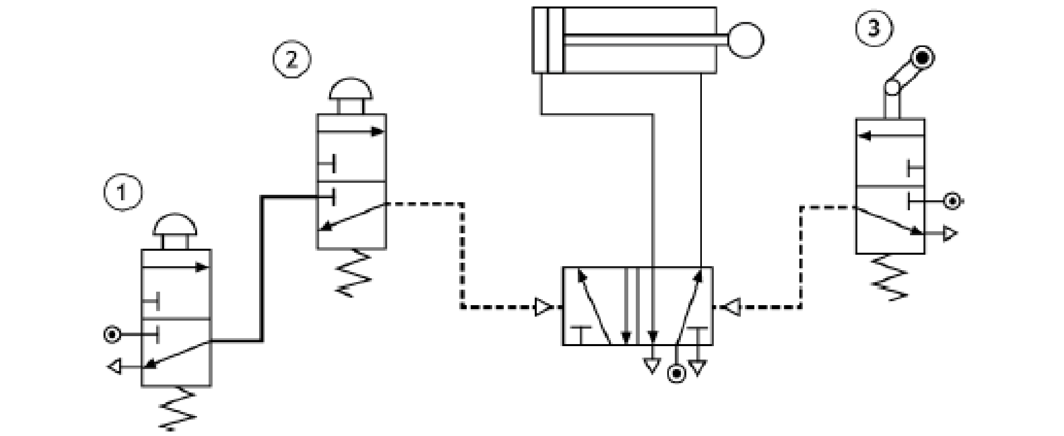
(b) Calculate the velocity ratio of the gear train. **2**

Back to Table

Marking instructions for each question

Section 1

Question			Expected answer(s)	Max mark	Additional guidance
1.	(a)		Open loop	1	Not Open on its own
	(b)		System boundary	1	Not Boundary on its own Accept sub-system boundary
2.			$Z = (A \cdot B) + \overline{C}$	3	1 mark for AND with () 1 mark for OR 1 mark for NOT C If a response only has the Boolean for ANDing then brackets are not required for that mark
3.	(a)			1	1 mark for correct symbol of buzzer in the correct position
	(b)		Ammeter	1	Also accept Multimeter but not Ampmeter
4.			$E_k = \frac{1}{2} mv^2$ $E_k = 0{\cdot}5 \times 5{\cdot}4 \times 8{\cdot}2^2$ E_k = 180 J (2 s.f.) 181·5 J	2	 1 mark substitution 1 mark final answer with unit
5.	(a)		A - Tension/tensile/tie B - Compression/compressive/ strut	2	Stated or inferred
	(b)		F = mg = 2·2 x 9·8 = 22 N (2 s.f.) 21·56 N	2	1 mark for substitution (9·8) 1 mark for correct answer from given working with unit

Question			Expected answer(s)	Max mark	Additional guidance
6.				3	1 mark for both lines creating AND control. 1 mark for line from valve 3 to 5/2 valve. 1 mark for a pilot air line type to 5/2. Piping must be port to port Ignore any additional pipes
					
7.	(a)	(i)	Idler	1	
		(ii)	No effect	1	
	(b)		Velocity Ratio = $\frac{\text{speed of input}}{\text{speed of output}}$ Velocity Ratio = $\frac{990}{66}$ Velocity Ratio = 15 : 1	2	1 mark for substitution 1 mark for correct answer from given working Allow follow through error Ignore any units Accept just 15

page 04

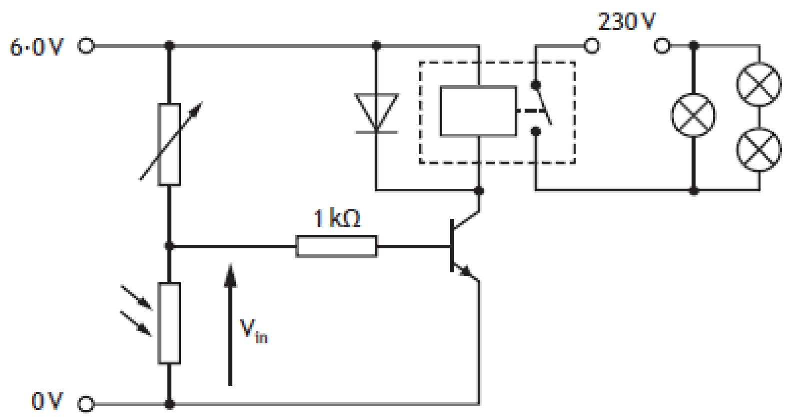
Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

SECTION 2 — 70 marks

Attempt ALL questions

8. The circuit used in a museum lighting system is shown below.



(a) Describe the operation of the voltage divider, as the light level increases. Make reference to the LDR's resistance and the voltage V_{in}. 2

As the light level increases ____________________

(b) Describe the function of the transistor in this circuit. 1

(c) During simulation of the circuit the transistor was found to stop working.

Describe the fault in the above circuit that results in the transistor failing. 1

Back to Table

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

8. (continued)

(d) Three lamps suspended from the museum ceiling are shown below.

The weight of the lamps create a strain in the supporting cable of 0·00056 and an extension of 0·34 mm.

Calculate the original length of the cable. 3

[Turn over

Back to Table

Section 2

Question			Expected answer(s)	Max mark	Additional guidance
8.	(a)		*As the light level increases...* The resistance (of the LDR) decreases Voltage (V_{in}) decreases	2	Descriptive response 1 mark resistance 1 mark voltage must be correct to resistance response Accept V_{in} decreases on own
	(b)		Switch on the relay Acts as a switch	1	Descriptive response Accept amplification Not switch/turn on (the lamps/ other circuit)
	(c)		The diode is the wrong way round	1	Not LED Not diode wired/connected incorrectly
	(d)		$\varepsilon = \frac{\Delta l}{l}$ $0 \cdot 00056 = \frac{0 \cdot 34}{l}$ $l = \frac{0 \cdot 34}{0.00056}$ $l = \mathbf{610\ mm}\ (2s.f.)$ $\quad 607.1\ mm$	3	 1 mark for substitution 1 mark for transposition 1 mark for correct answer from given working with unit

Back to Table

DO NOT WRITE IN THIS MARGIN

9. A question display board in a television game show is operated by a microcontroller. Contestants are shown a question and given 10 seconds to answer.

The system must perform the following sequence:

- When the host presses a question switch, a display turns on showing the question.
- When the host presses a timer start switch, an LED will pulse on and off 16 times over an 8 second period.
- A buzzer will then sound for 2 seconds.
- The buzzer and display board then turn off.
- The system then restarts ready for the next question.

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

Input Connection	Pin	Output Connection
	7	Display board
	6	LED
	5	Buzzer
Timer start switch	1	
Question switch	0	

X723750110

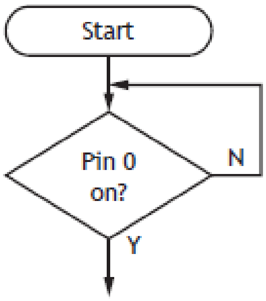
Back to Table

Back to Table

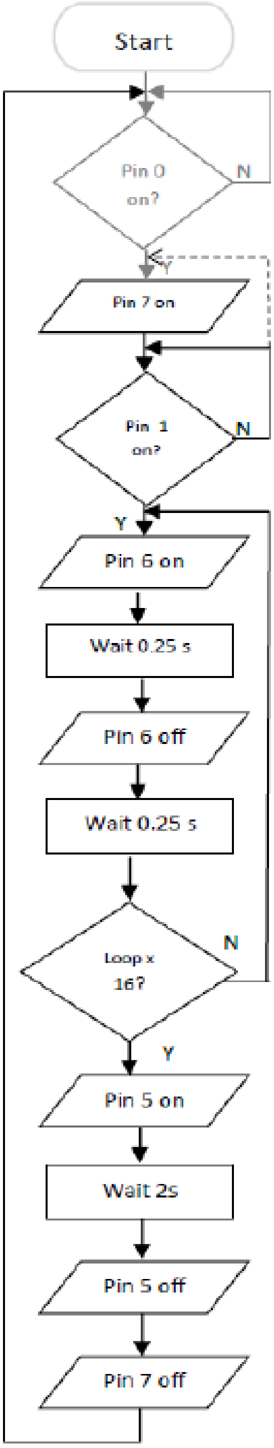
MARKS | DO NOT WRITE IN THIS MARGIN

9. (continued)

Complete, with reference to the Data Booklet and the input and output connections shown, the flowchart for the control sequence. Include all pin numbers in your flowchart. 9



Back to Table

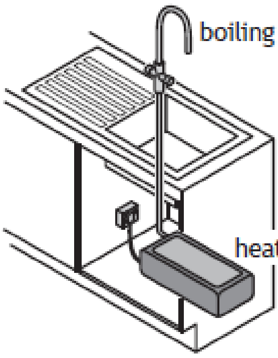
Question			Expected answer(s)	Max mark	Additional guidance
9.				9	Pin numbers must be correct where applicable. Pin 7 on and off - 1 Pin 6 on and off - 1 Pin 5 on and off - 1 Pin 1 on? (inc. Y/N, loop and arrow head) - 1 All 3 delays (with wait 2s) - 1 Assume all delays in seconds unless units are given or a high level command is used: pause 250 (PBASIC) delay 250 (C) LED on/off time total = 0.5 s - 1 Loop x 16? (inc. Y/N, loop and arrow to before pin 6 on) - 1 Continuous loop (with arrow to start) - 1 All marked symbols correct - 1 Ignore any additional steps.

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

10. A boiling water tap and heating tank is shown below. It is installed in a busy office kitchen, where 200 staff can make hot drinks throughout the day.

The boiling water tap produces boiling water instantly.



Water is boiled in the heating tank and then stored until it is ready to be used. 1·4 MJ of electrical energy is used when heating a full tank of water for the first time.

(a) (i) Calculate the output energy of the system if it is 82% efficient. 3

(ii) Calculate, with reference to the Data Booklet, the mass of water in a full tank when the change in temperature is 91 °C. 3

Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

10. (continued)

(b) The temperature of the water is monitored by an electronic circuit.

Describe two tasks an Electronic Engineer would have undertaken when designing this circuit. 2

1 ______________________________

____

____

2 ______________________________

____

____

(c) Boiling water taps are often installed in offices as an alternative to kettles.

Describe a positive and negative economic impact of installing and using a boiling water tap. 2

Positive ______________________________

____

____

Negative ______________________________

____

____

[Turn over

Back to Table

Back to Table

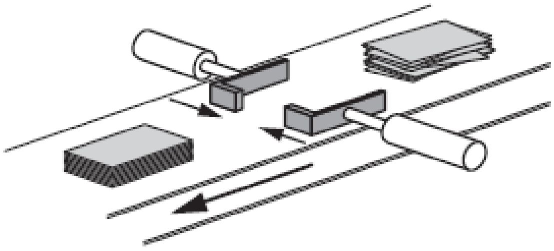
Question			Expected answer(s)	Max mark	Additional guidance
10.	(a)	(i)	Efficiency = $\frac{E\ out}{E\ in}$ $0{\cdot}82 = \frac{E\ out}{1{\cdot}4}$ E out = 0·82 x 1·4 E out = **1·1** MJ (2 s.f.) 1·148 MJ	3	1 mark for substitution 1 mark for transposition 1 mark for final answer from working with unit
		(ii)	$E_h = cm\Delta t$ $1{\cdot}1 \times 10^6 = 4180 \times m \times 91$ $m = \frac{1{\cdot}1 \times 10^6}{4180 \times 91}$ m = 2·9 kg (2 s.f.) 2.892 kg (3.018 kg using 1.148 MJ)	3	1 mark for substitution (allow FTE from (a) (i) 1 mark for transposition 1 mark for final answer from working with unit
	(b)		Designing the sensor Testing the sensor Testing the circuit to see how it works Selecting appropriate components Calculating values/ratings of components Assemble the prototype Simulate the control sequence Writing the control program/ flowchart	2	1 mark for any appropriate descriptive response of an engineer's task. Must be linked to electronic temperature monitoring circuit design. Design/test/build/simulate the circuit is insufficient on own.
	(c)		<u>Positive:</u> Jobs created manufacturing the tap and heating tank creating wealth. Jobs created installing the tap and heating tank creating wealth. Reduced running cost due to efficiency <u>Negative:</u> Reduction in kettles being sold so less profit. Initial costs are more expensive. It is on 24/7 so cost to keep water at correct temperature when office is not in use Higher repair cost because system is more complex	2	1 mark for each economic description. Jobs/employment needs to describe economic impact Not no need to buy a kettle/urn as an economic advantage Not on all the time without reference usage and running costs as an economic disadvantage

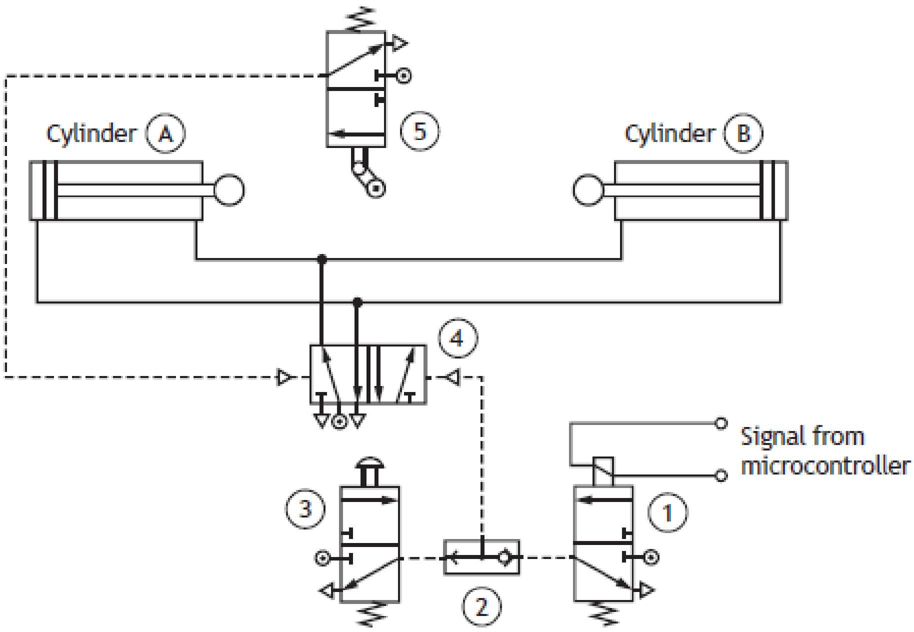
Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

11. A pneumatic circuit used to process components on a production line is shown below.





(a) Describe, using appropriate terminology, the operation of the circuit. 3

Back to Table

Back to Table

11. (continued)

(b) An adjustable time delay is required for the circuit.

Draw a unidirectional restrictor and reservoir to create an adjustable time delay. 3

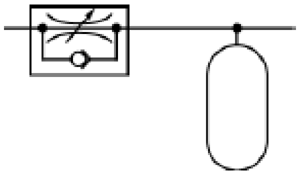
Direction of air flow

(c) A piston rod has a diameter of 16 mm and experiences a stress of $3{\cdot}4\,\text{Nmm}^{-2}$ when fully outstroked.

Calculate the force in the piston rod. 4

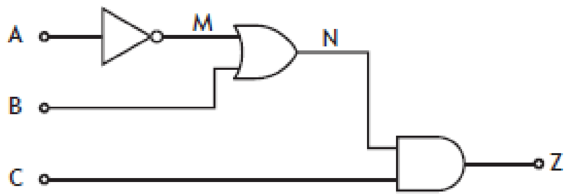
Back to Table

Back to Table

11.	(a)		Valve 1 OR 3 is actuated. Air is sent to valve 4 causing both pistons to outstroke. The piston from cylinder A will actuate valve 5 causing both pistons to instroke.	3	1 mark for OR statement 1 mark for both pistons outstroking 1 mark for valve 5 and both pistons instroking
	(b)			3	1 mark for reservoir symbol 1 mark for uni-directional restrictor symbol 1 mark for correct position and orientation of uni-directional restrictor
	(c)		$A = \frac{\pi d^2}{4}$ $A = \frac{3{\cdot}14 \times 16^2}{4}$ $A = 200{\cdot}96\ mm^2$ ($201.1\ mm^2$ when using π)	4	 1 mark for area (unit not required)
			$\sigma = \frac{F}{A}$ $3{\cdot}4 = \frac{F}{200{\cdot}96}$ $F = 3{\cdot}4 \times 200{\cdot}96$ $F = 680$ N (2 s.f.) 683·3 N (683.9 N when using π)		 1 mark for substitution (accept 16 mm) 1 mark for transposition 1 mark for final answer from working with unit

MARKS | DO NOT WRITE IN THIS MARGIN

12. Part of an electronic circuit used in a self-balancing scooter is shown below.



(a) Complete the truth table for this circuit. 3

A	B	C	M	N	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			

(b) The Boolean equation for a second electronic circuit used in the scooter is shown below.

$Z = (D \bullet \overline{E}) + F$

Draw the logic diagram for this Boolean equation. 3

D ∘

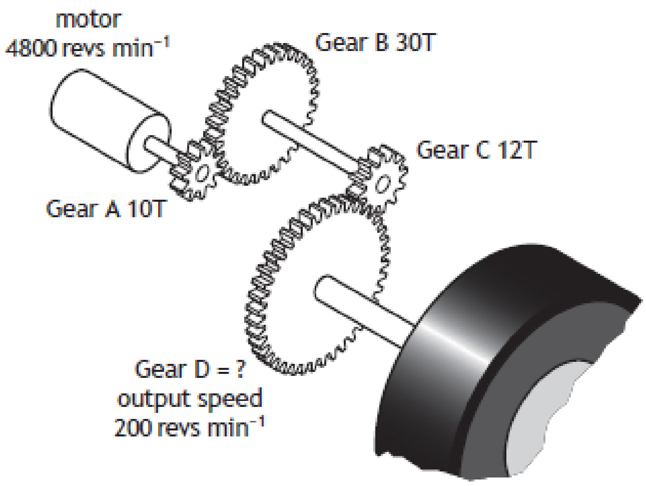
E ∘ ∘ Z

F ∘

MARKS | DO NOT WRITE IN THIS MARGIN

12. (continued)

(c) The mechanical system used in the scooter is shown below.

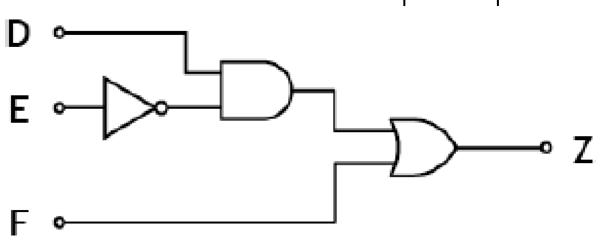


Calculate the number of teeth on gear D. **4**

(d) Explain how this mechanical system could be made more efficient. **2**

Back to Table

<table>
<tr><th colspan="3">Question</th><th>Expected answer(s)</th><th>Max mark</th><th>Additional guidance</th></tr>
<tr><td>12.</td><td>(a)</td><td></td><td><table><tr><th>M</th><th>N</th><th>Z</th></tr><tr><td>1</td><td>1</td><td>0</td></tr><tr><td>1</td><td>1</td><td>1</td></tr><tr><td>1</td><td>1</td><td>0</td></tr><tr><td>1</td><td>1</td><td>1</td></tr><tr><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>0</td></tr><tr><td>0</td><td>1</td><td>1</td></tr></table></td><td>3</td><td>1 mark per correct column

Allow for follow through error</td></tr>
<tr><td></td><td>(b)</td><td></td><td></td><td>3</td><td>1 mark for each gate with connections</td></tr>
<tr><td></td><td>(c)</td><td></td><td>4800 x 10 = output speed x 30

Output speed = $\frac{48000}{30}$

Output speed = 1600 revs min^{-1}

1600 x 12 = 200 x size of D

Size of D = $\frac{19200}{200}$

Size of D = 96 teeth

OR

VR = 4800revs min^{-1} / 200revs min^{-1}

VR = 24 : 1

24 = 30 / 10 x D / 12

D = (24 x 12) / 3

Size of D = 96 teeth</td><td>4</td><td>1 mark for substitution

1 mark for answer from working (unit not required)

1 mark for substitution (allow follow through error)

1 mark for final answer from working (ignore any units)

1 mark for calculating VR

1 mark for substitution

1 mark for transposition

1 mark for answer from given working</td></tr>
<tr><td></td><td>(d)</td><td></td><td>Lubricate/bearings/‘slippier’ material used

to reduce friction/energy loss(to heat/sound); or location for change gears/shafts/moving parts etc</td><td>2</td><td>1 mark lubrication (cause)

1 mark for location / reason (effect)</td></tr>
</table>

Back to Table

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

13. A garden centre is planning to extend its building to include space for a new café. The extension will include solar panels and a system to heat/cool the café.

jessicakirsh / Shutterstock.com

(a) Describe the role of each of the following engineers during the development stage of this project.

(i) Structural Engineer 1

(ii) Electrical Engineer 1

(b) Describe two environmental advantages of installing and/or using solar panels. 2

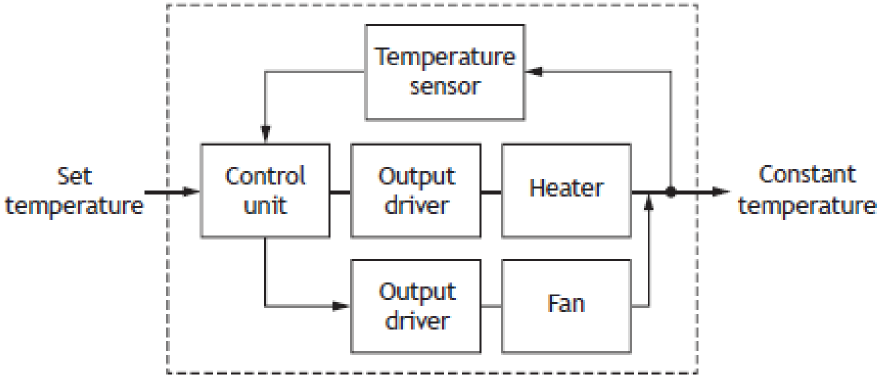
Back to Table

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

13. (continued)

(c) A sub-system diagram for the café's heating/cooling system is shown below.



Describe the control of the system. 4

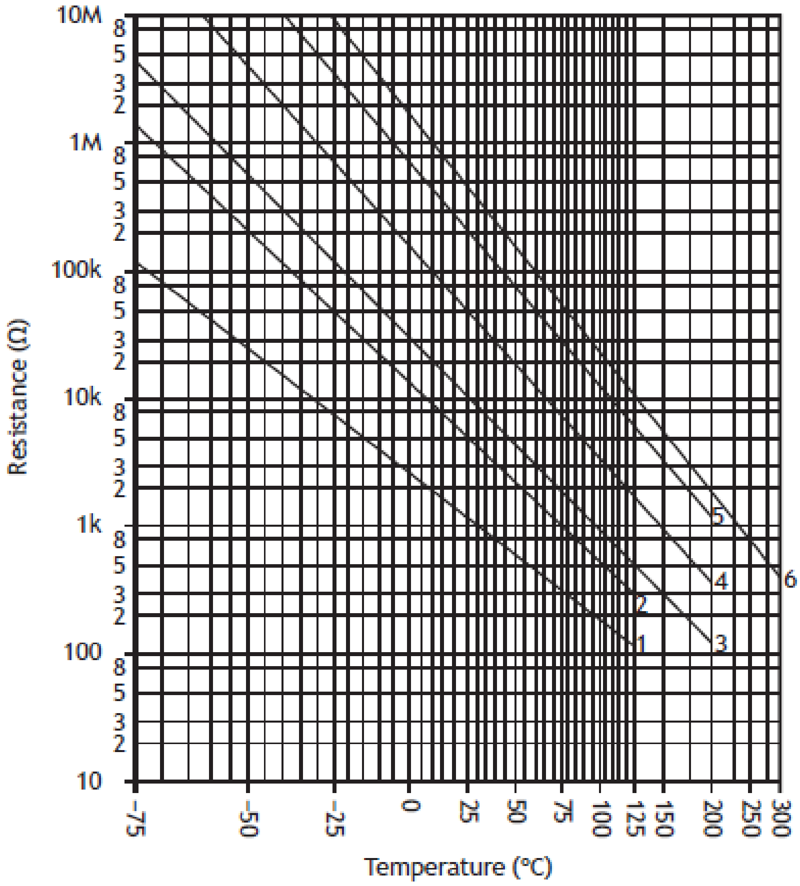
The user sets the required temperature

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

13. (continued)

(d) The graph below shows the behaviour of a range of thermistors considered for use in the heating/cooling system.



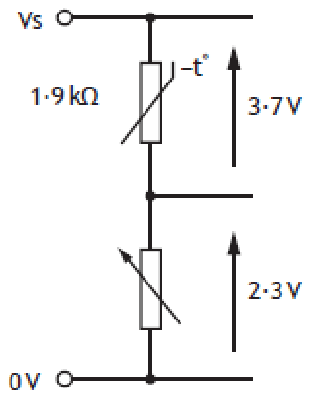
Determine, with reference to this graph, the resistance of the type 1 thermistor at 40 °C. **1**

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

13. (continued)

(e) The sensing circuit, with readings taken at a temperature of 10 °C, is shown below.



Calculate the resistance of the variable resistor for these conditions. 3

Back to Table

Back to Table

Question			Expected answer(s)	Max mark	Additional guidance
13.	(a)	(i)	Design/calculate/select/simulate/model /test [any appropriate structural aspect] Calculate the forces on the structure Select appropriate material for the structure. Design the structure	1	1 mark for any appropriate descriptive response of an engineer's activity and the structural aspect. Must be linked to development.
		(ii)	Design/calculate/select/model/test… [any appropriate electrical aspect] Design the solar panels to connect to the mains supply Calculate the electrical power requirements of the extension	1	1 mark for any appropriate descriptive response of an engineer's activity and the electrical aspect. Must be linked to development. Not design the circuit on its own. Not electronic or electrician related.
	(b)		Less pollution/clean source Lower/no emissions of greenhouse gases Reduction in global warming	2	1 mark for each appropriate descriptive response specific to environmental advantages during use or installation. Not 'renewable' Not 'reduction in fossil fuels'
	(c)		Temperature sensor feeds information (to control unit) Control unit compares set and actual temperatures (Control unit).. switches on heater if it's too cold (Control unit).. switches on fan if it's too hot	4	Descriptive responses covering: 1 mark temperature feedback 1 mark control unit action 1 mark heater switching 1 mark fan switching

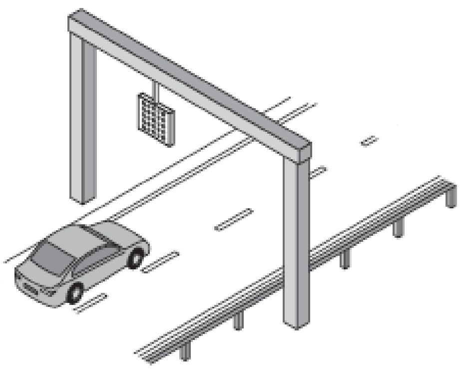
Back to Table

Question			Expected answer(s)	Max mark	Additional guidance
	(d)		800 Ω (0·8 kΩ)	1	Unit required
	(e)		$\frac{R1}{R2}=\frac{V1}{V2}$ $\frac{R1}{1.9}=\frac{2.3}{3.7}$ $R1=\frac{2.3}{3.7}x\ 1.9$ $R2=\mathbf{1.2\ k}\Omega\ (2\ s.f.)$ 1181Ω Alternative Method $I=\frac{V}{R}=\frac{3.7V}{1.9}=1.95mA$ 1 1 $R=\frac{V}{I}=\frac{2.3V}{1.95mA}=1.2k\Omega$ 1	3	1 mark for substitution 1 mark for transposition 1 mark for correct answer from given working with unit Ignore current unit

Back to Table

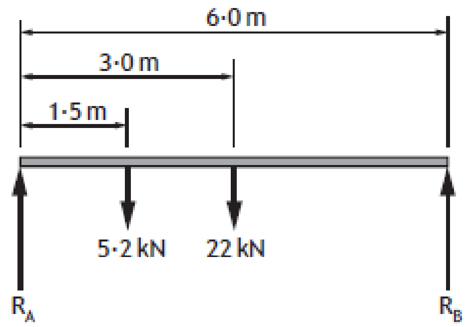
MARKS | DO NOT WRITE IN THIS MARGIN

14. A motorway gantry with a traffic management sign hung over one lane is shown below.



The sign produces a downward force of 5·2 kN and the weight of the gantry itself is 22 kN.

A free body diagram representing the structure is shown below.



(a) Calculate the reaction force R_B by taking moments about R_A. 3

Back to Table

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

14. (continued)

(b) The sign hangs on a metal support. The following materials were considered for the support during the design of the sign.

Material	Maximum Tensile Load	Maximum Compressive Load	Corrosion Resistant
Metal A	4·8 kN	4·8 kN	Yes
Metal B	5·6 kN	5·1 kN	Yes
Metal C	3·6 kN	5·5 kN	No
Metal D	5·2 kN	6·2 kN	No

Select the most suitable metal (A-D) from the table to be used for the support and justify your choice. **2**

Choice of metal ______________________________

Reason for choice ______________________________

____

____

(c) Describe a positive social impact of using the traffic management sign. **1**

____

____

____

[Turn over for next question

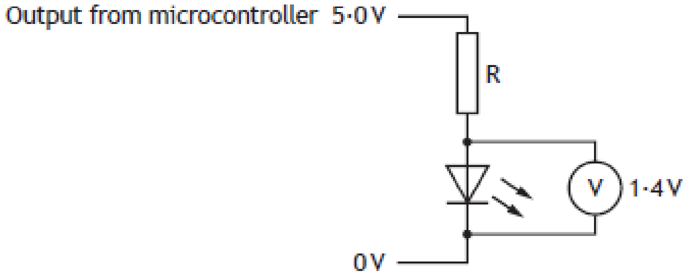
Back to Table

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

14. (continued)

(d) The circuit for one LED on the sign is shown below.



Calculate the value of the resistor R to limit the current to 15 mA. 4

[END OF QUESTION PAPER]

Back to Table

Question			Expected Answer(s)	Max Mark	Additional Guidance
14	(a)		$\Sigma ACWM = \Sigma CWM$ $(RBx6) = (5.2\ x\ 1.5) + (22\ x\ 3)$ $RB = \frac{73.8}{6}$ $RB = \mathbf{12kN}\ (2s.f.)\quad 12300N$	3	 1 mark for substitution 1 mark for transposition 1 mark for correct answer from given working with unit
	(b)		Metal B The maximum tensile load (5·6 kN) exceeds the (5·2 kN) weight of the sign and it is corrosion resistant as the sign will be outdoors.	2	1 mark metal choice 1 mark for reason including reference maximum tensile load and corrosion resistance. Accept highest tensile load but not high tensile load with corrosion resistance.
	(c)		Journey time reduced by early warning of congestion Improved safety because of early warning Feedback may make travel less stressful Job created maintaining the sign	1	Any descriptive response relating to situation Not faster/safer on own
	(d)		V_R = 5V - 1.4V V_R = 3.6 V $V = IR$ $3.6 = 0.015\ x\ R$ $R = \frac{3.6}{0.015}$ $R = 240\Omega$	4	 1 mark for V_R No units necessary 1 mark for substitution (accept 5V but not 1.4V) 1 mark for transposition 1 mark for correct answer from given working with unit

[END OF MARKING INSTRUCTIONS]

Back to Table

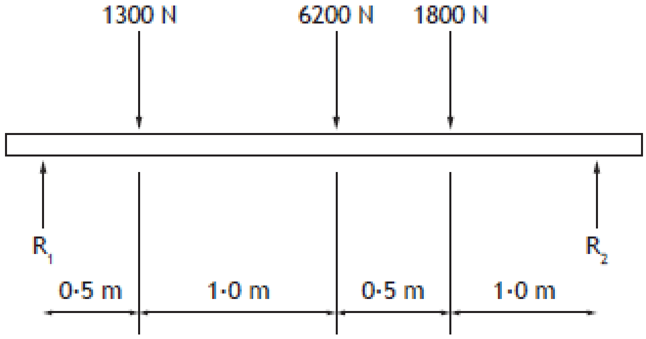
MARKS DO NOT WRITE IN THIS MARGIN

SECTION 1 — 20 marks

Attempt ALL questions

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

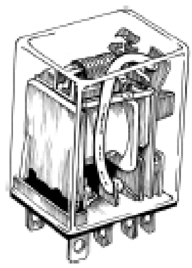
2. The diagram shown below could be used to analyse a structure.



State the name of this type of diagram. 1

3. Relays like the one shown in this diagram are often used in electronic control circuits.

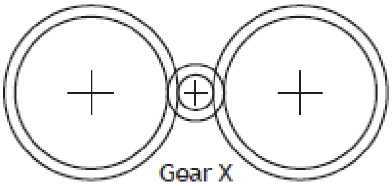
Describe the general purpose of a relay. 2



Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

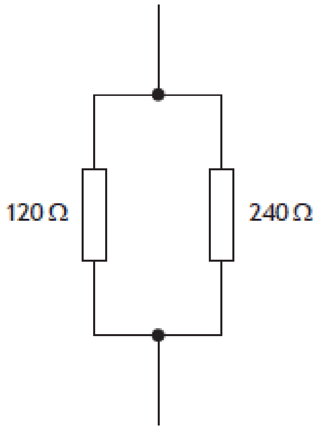
4. The diagram below represents a simple gear train.



(a) State the name of Gear X. 1

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

5. Part of the circuitry in a mobile phone is shown in the diagram below.



Calculate the combined resistance of the two parallel resistors. 2

Back to Table

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

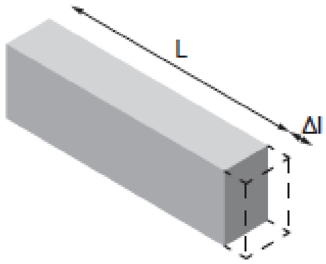
6. Describe three possible environmental impacts of constructing a new bridge over a river. 3

7. A beam in a structure fails when a large force is applied.

Describe two changes to its replacement that would reduce the risk of failure. 2

8. A metal bar (see diagram to the right) is 310 mm long and stretches 2·2 mm when a tensile force is applied.

Calculate the strain in the bar. 2

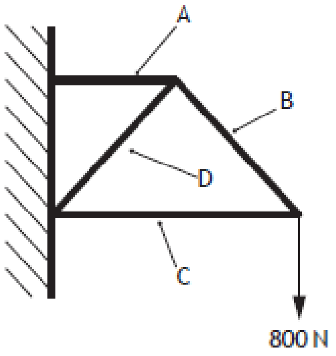


Back to Table

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

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

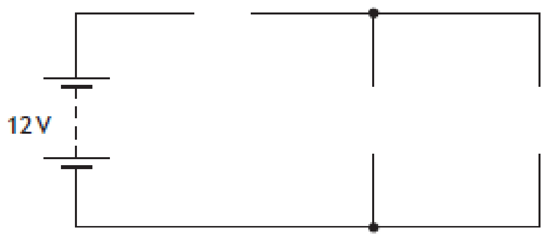


Identify a member of the structure (A–D) that is in:

(a) tension ______ 1

(b) compression ______ 1

10. Complete the circuit diagram below to show a motor operated when one switch or another switch is pressed. 2



[Turn over

Back to Table

General marking principles for National 5 Engineering Science

This information is provided to help you understand the general principles you must apply when marking candidate responses to questions in this paper. These principles must be read in conjunction with the specific marking instructions for each question. The marking schemes are written to assist in determining the 'minimal acceptable answer' rather than listing every possible correct and incorrect answer.

(a) Marks for each candidate response must always be assigned in line with these general marking principles and the specific marking instructions for the relevant question.

(b) Marking should always be positive. This means that, for each candidate response, marks are accumulated for the demonstration of relevant skills, knowledge and understanding: they are not deducted from a maximum on the basis of errors or omissions.

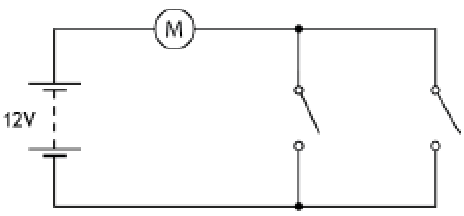
(c) Where a candidate makes an error at an early stage in a multi-stage calculation, credit should normally be given for correct follow-on working in subsequent stages, unless the error significantly reduces the complexity of the remaining stages. The same principle should be applied in questions which require several stages of non-mathematical reasoning.

(d) All units of measurement will be presented in a consistent way, using negative indices where required (eg ms^{-1}). Candidates may respond using this format, or solidus format (m/s) or words (metres per second), or any combination of these (eg metres/second).

Marking instructions for each question

Section 1

Question			Expected response	Max mark	Additional guidance
1			Open loop systems have no feedback (1). Closed loop systems have feedback (1).	2	
2			Free body diagram	1	
3			It acts as a link allowing a low powered electronic control circuit to switch/ control a high powered electrical circuit	2	1 mark for the idea of a link between low and high power circuits (or idea of isolating low from high). 1 mark for the idea that it acts as a switch (or control).
4	a		Idler gear	1	
4	b		It makes the driver and driven turn the same way.	1	Do not accept: that it has no effect on the speed of the gears.

Question			Expected response	Max mark	Additional guidance
5			$R_t = \frac{R1 \times R2}{R1 + R2}$ (1 mark for substitution) $= \frac{120 \times 240}{120 + 240}$ $= 80\,\Omega$ (1 mark for correct answer from candidate's working)	2	
6			Any three valid examples, such as: Landscaping may destroy animal habitat. Construction may impact river ecosystem. Bridge might reduce distance travelled, so reducing fuel consumption. (1 mark for each reasonable description)	3	
7			Choose a stronger material (1). Increase x-section area to reduce stress (1).	2	Or any other valid response.
8			$\varepsilon = \frac{\Delta l}{L}$ $= 2{\cdot}2/310$ (1 mark for substitution) $= 0{\cdot}0071$ (1 mark for correct answer from candidate's working) $= 0{\cdot}007$	2	
9	a		A or B	1	
9	b		C or D	1	
10				2	1 mark for motor and switch symbol. 1 mark for correct positions of three components. Ignore any additional symbols.

page 03

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

SECTION 2 — 90 marks

Attempt ALL questions

11. A prototype solar panel is being tested.

(a) Describe the role of the following engineers in the development of the panel.

(i) Type of engineer — Electronic Engineer 1

Role — ______________________________

(ii) Type of engineer — Structural Engineer 1

Role — ______________________________

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

(b) Calculate the output electrical energy produced. 3

* S 8 2 3 7 5 0 1 0 6 *

Back to Table

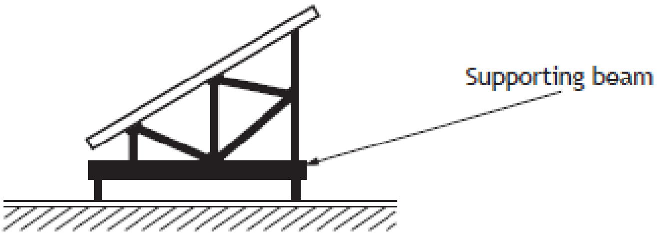
Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

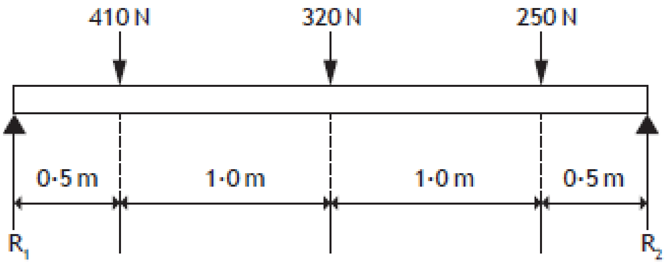
11. (continued)

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

The solar panels are fitted to a frame supported by a beam, as shown in the diagram below.



The forces acting on the beam are shown in the diagram below.



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

Back to Table

Back to Table

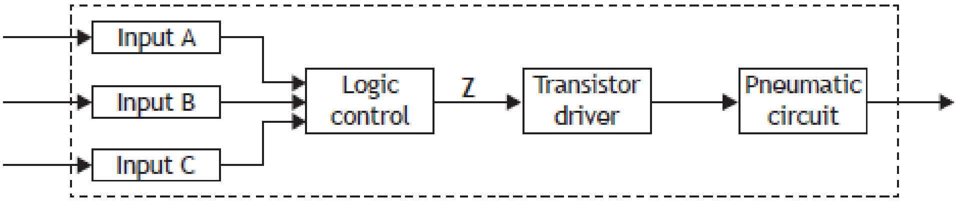
Section 2

Question			Expected response	Max mark	Additional guidance
11	a	i	Electronic Engineer: Designing the electronic control systems and circuitry	1	(1 mark for each valid example, which could relate to any aspects of design or production, but must clearly be electronic and engineering roles).
11	a	ii	Structural Engineer: Designing the supporting structure	1	(1 mark for each valid example, which could relate to any aspects of design or production, but must clearly be structural and engineering roles).
11	b		$E_{out} = E_{in}$ x efficiency (1 for manipulating given formula) E_{out} = 0·73 x 15 MJ (1 for substituting values) = 10·95 MJ (1 for correct answer from candidate's working) = 11 MJ (2 sf)	3	
11	c		They reduce the need for power produced using fossil fuels (1) which means reduced carbon dioxide output (1).	2	Reduced pollution not acceptable; answer must relate to climate change, so must refer to carbon dioxide output.
11	d		∑Anticlockwise moments = ∑Clockwise moments (410 x 0·5) + (320 x 1·5) + (250 x 2·5) = R2 x 3 (1 for substitution) R2 = $\frac{1310}{3}$ (1 for manipulation) = 436·7 N (1 for correct answer from candidate's working) = 437 N = 440 N	3	

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

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

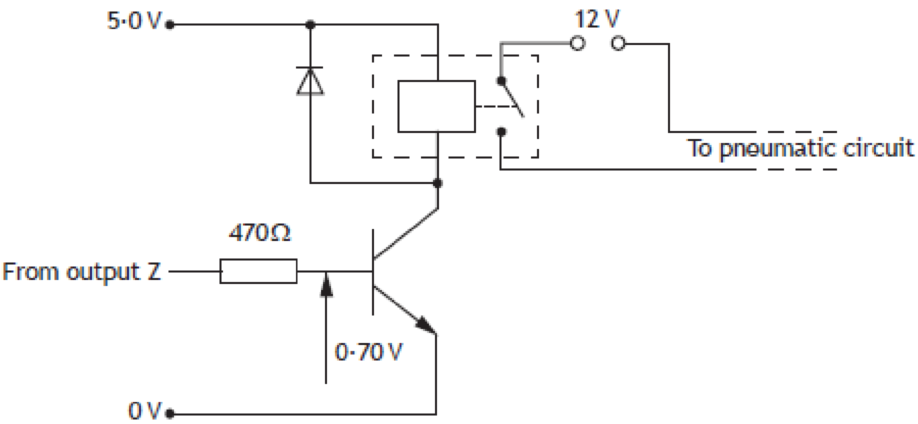


The logic control activates the transistor driver when the following conditions are met:

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

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

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



Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

12. (continued)

(b) Calculate the base current when output Z is high (5·0 V). 4

(c) An engineer simulates the electronic system on a computer before building a prototype on breadboard. Explain why the system is simulated before a prototype is built. 2

[Turn over

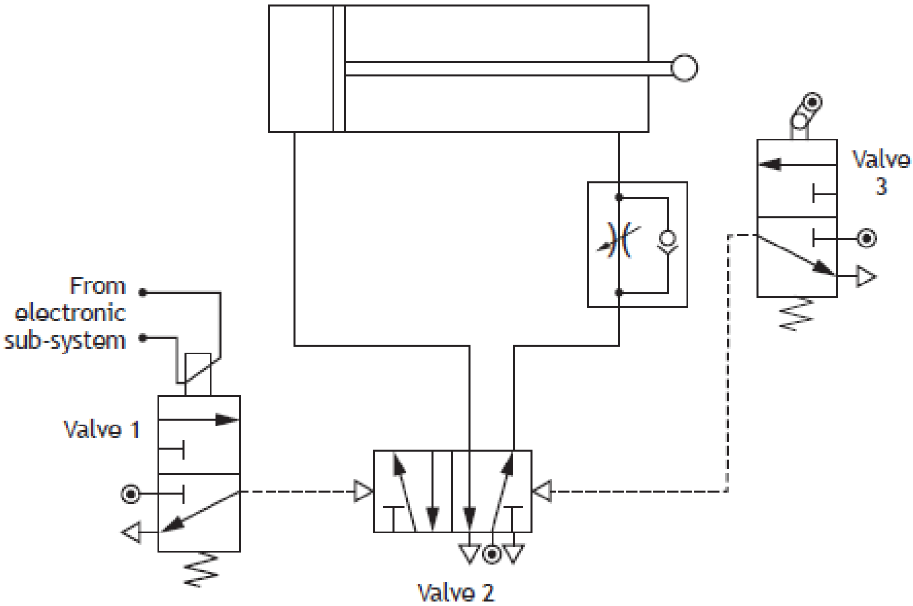
Back to Table

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

12. (continued)

The electronic sub-system controls the pneumatic circuit shown in the diagram below.

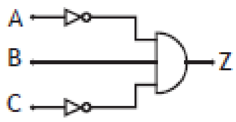


(d) Describe, using appropriate terminology, the operation of the pneumatic circuit. 3

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

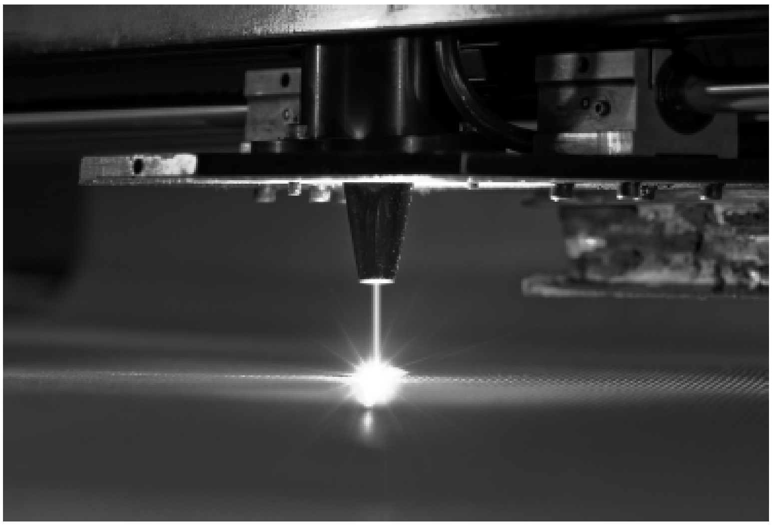
Back to Table

Back to Table

Question			Expected response	Max mark	Additional guidance
12	a		1 mark for correct logic symbols 1 mark for correct AND connection 1 mark for correct NOT connection 	3	
12	b		V = IR, I = V/R (1 mark for manipulating equation) $I = \frac{(5\cdot0 - 0\cdot7)}{470}$ (1 mark for calculating voltage) (1 mark for substitution) = 9·1 mA (1 mark for correct answer from candidate's working)	4	
12	c		eg real, expensive components will not be damaged if there is a problem or mistake.	2	1 mark for cause 1 mark for effect
12	d		1 mark for correct outstroking condition 1 mark for correct instroking condition 1 mark for speed outstroking controlled	3	

Back to Table

13. A laser cutting machine is used to cut sheet steel, as shown in the photograph below.



The laser is positioned by motors A and B which are operated by a microcontroller.

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

Input connection	Pin	Output connection
	7	Motor A forward (move right)
	6	Motor A reverse (move left)
	5	Motor B forward (move forward)
	4	Motor B reverse (move back)
	3	Laser (on when high, off when low)
	2	
	1	
	0	

The cutter is required to perform the following sequence of operations:

1: Switch on the laser

2: Move right for 0·5 seconds

3: Move forward for 0·5 seconds

4: Repeat steps 2 and 3 four times

5: Switch off laser and motors

DO NOT WRITE IN THIS MARGIN

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

13. (continued)

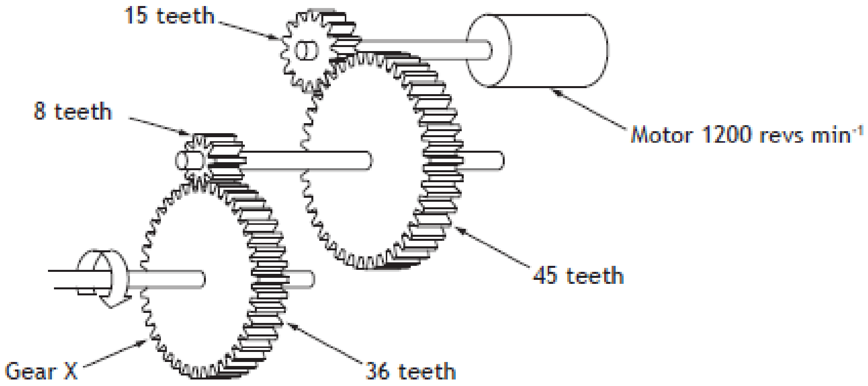
(a) Complete, with reference to the data booklet and input/output connections, the flowchart for the control sequence. Include all pin numbers. 7

[Back to Table](#)

MARKS DO NOT WRITE IN THIS MARGIN

13. (continued)

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



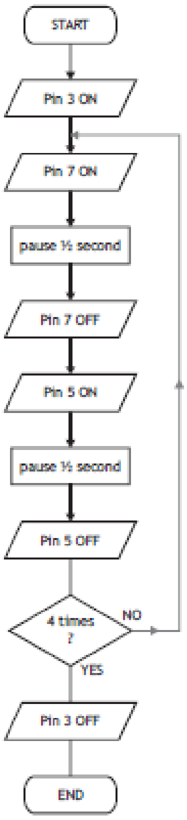
(b) (i) State the name of this type of drive system. **1**

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

[Turn over

[Back to Table](#)

Back to Table

Question			Expected response	Max mark	Additional guidance
13	a			7	1 mark for all symbols used correctly 1 mark for feedback loop with arrows 1 mark for decision including yes/no 1 mark for both pause commands 1 mark for PIN 3 ON and OFF 1 mark for PIN 7 ON and OFF 1 mark for PIN 5 ON and OFF
13	b	i	Compound gear	1	
13	b	ii	*First pair of gears* 15 x 1200 = 45 x Output speed (1 mark for substitution) Output speed = 400 revs min^{-1} (1 mark for answer from candidate's working) *Second pair of gears* 400 x 8 = 40 x Output speed (1 mark for substitution) Output speed = 89 revs min^{-1} (1 mark for answer from candidate's working)	4	Do not accept rpm

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

14. An electric guitar is shown in the photograph below.

Tuning a guitar string produces an 80 N tensile load in the string.

The table below gives the properties of three alloys that could be used to make a guitar string.

Alloy	Maximum load	Brittle/ductile
A	120 N	Brittle
B	90 N	Ductile
C	65 N	Ductile

(a) (i) State which alloy (A–C) would be most appropriate for the guitar string. ________ 1

(ii) Explain, with reference to the table, your choice of alloy. 1

____

____

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

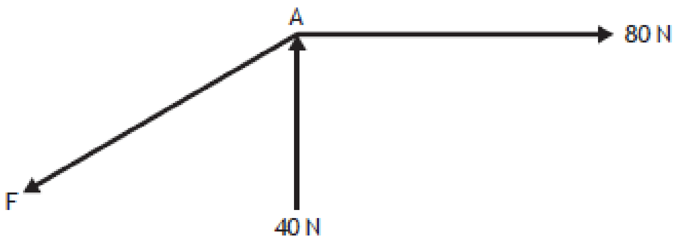
(b) Calculate the stress in the guitar string. 2

Back to Table

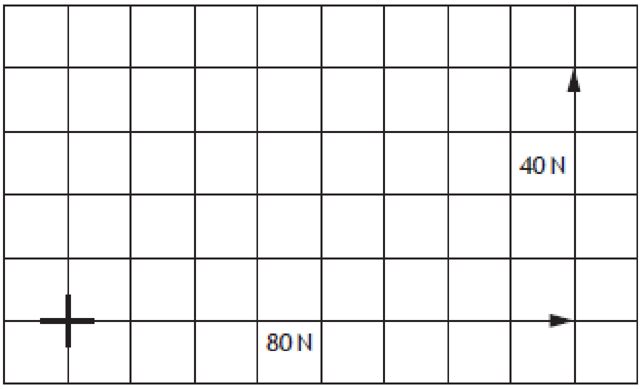
MARKS | DO NOT WRITE IN THIS MARGIN

14. (continued)

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



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



F =_____N

[Turn over

MARKS | DO NOT WRITE IN THIS MARGIN

14. (continued)

An "effects pedal", as shown in the photograph below, can be attached to the guitar to change the sound produced. The effects pedal uses complex electronic circuitry.

(d) Explain why a microcontroller might be used in place of a hard wired circuit in the effects pedal. **2**

Back to Table

Question			Expected response	Max mark	Additional guidance
14	a	i	B	1	
14	a	ii	It is strong enough to support the load and will bend as appropriate.	1	Explanation must refer to both relevant points (load support and bending).
14	b		Stress = Force/Area = 80 N/0·2 (1 mark for substitution) = 400 N mm^{-2} (1 mark for correct answer from candidate's working)	2	
14	c		~89 N (1 mark for answer)	1	Accept answers between 85 and 95. (A drawn arrow is not required for the mark to be awarded.) Answer must be taken from drawing and not calculated.
14	d		Any valid point with explanation, such as: • reduced size • quicker assembly • reduced cost, etc ... due to fewer components	2	

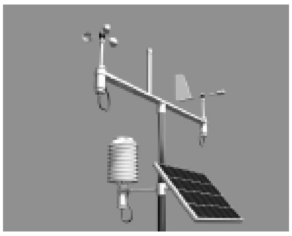
Back to Table

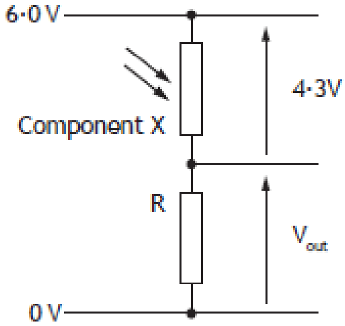
Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

15. A weather monitoring station, as shown in the photograph to the right, is used to collect data.

Light levels are measured using the sensing sub-system shown in the diagram below.





(a) State the full name of Component X. **1**

Component X and the fixed resistor R are connected in series.

(b) State the name given to this arrangement. **1**

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

Component X is found to have a resistance of 1·5 kΩ.

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

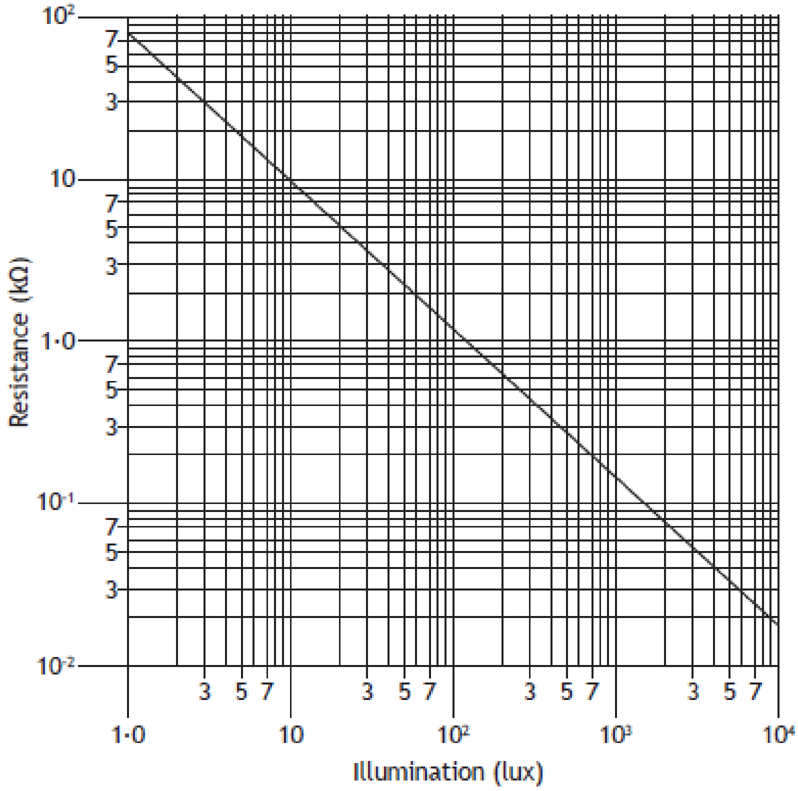
Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

15. (d) (continued)

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



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

____

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

____

____

____

____

____

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

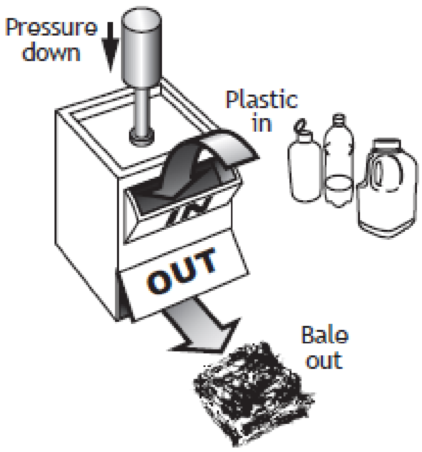
Back to Table

15	a		Light dependent resistor	1	LDR not acceptable
15	b		Voltage divider	1	
15	c		V_{out} = 6·0 — 4·3 = 1·7 V (1 mark for correct answer from candidate's working)	1	
15	d	i	V1/V2 = R1/R2 4·3/1·7 = 1500 / R (1 mark for substitution) R = (1·7/4·3) x 1500 (1 mark for rearranging formula) = 593 Ω (1 mark for correct answer from candidate's working) = 590 (2 sf)	3	Allow FTE from 15(c)
15	d	ii	10 Lux	1	
15	e		1 mark for each valid statement (as below) up to 3 marks: • as light level increases the LDR's resistance decreases • as the LDR's resistance decreases V_{out} increases • as light level decreases the LDR's resistance increases • as the LDR's resistance increases V_{out} decreases.	3	

MARKS | DO NOT WRITE IN THIS MARGIN

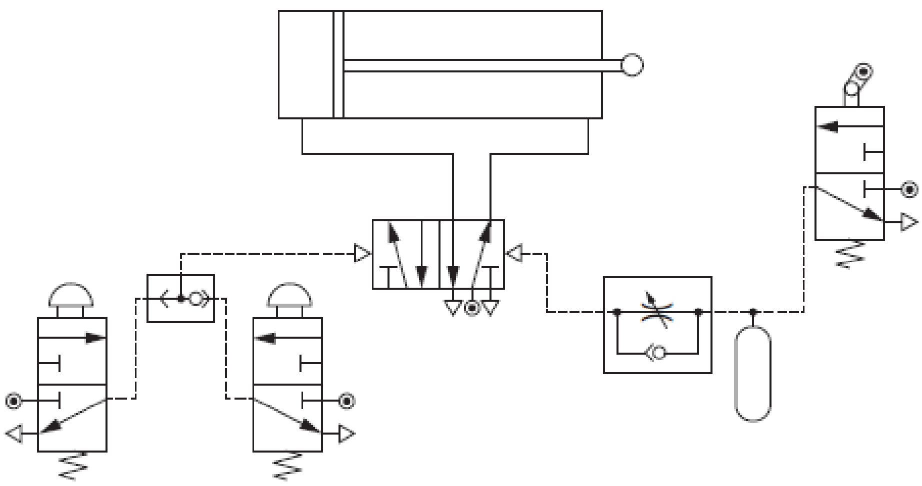
16. A prototype system to compress plastic bottles is operated by pneumatics.

For safety reasons, two buttons must be pressed before the plastic is compressed by a pneumatic cylinder. After a set period of time, the piston must instroke automatically (see diagram below).



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

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

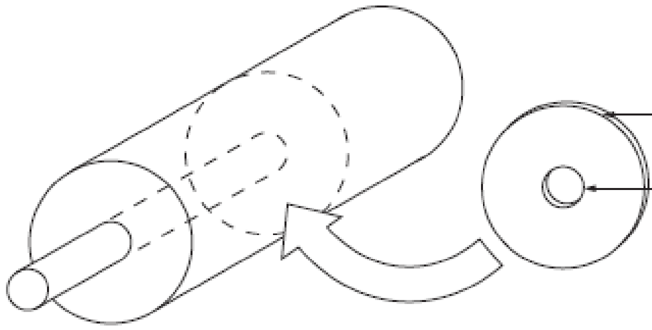


Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

16. (continued)

The diagram below shows the pneumatic cylinder used. Air is supplied to the cylinder at $2{\cdot}0\ \text{Nmm}^{-2}$.



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

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

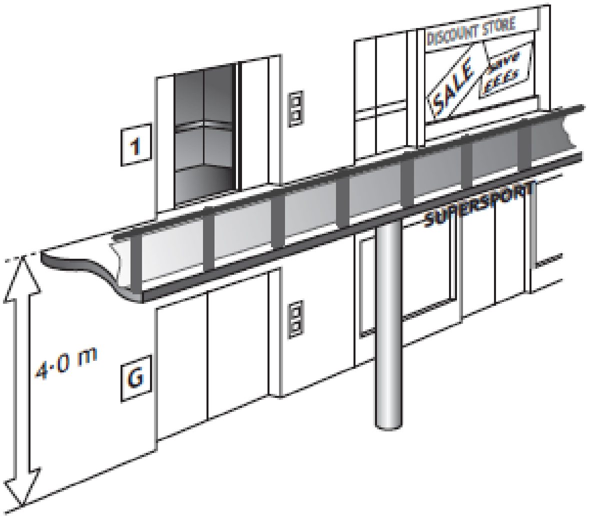
(c) Describe how the length of the delay could be increased. **1**

Back to Table

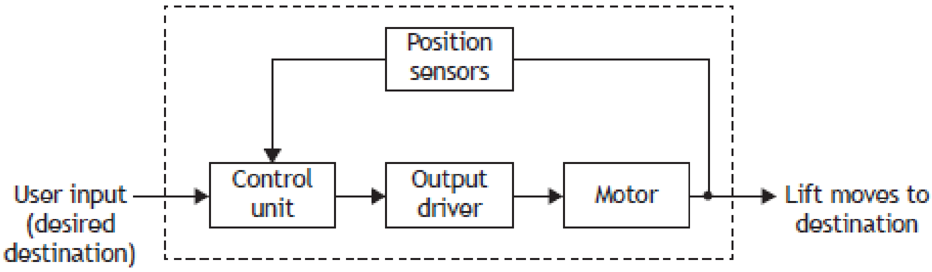
16	a		The shuttle valve produces an OR function rather than the desired AND (1). The reservoir is positioned in front of the uni-directional restrictor rather than after it (1).	2	
16	b		Outstroking area = 3·14 x 21^2 = 1384·74 mm^2 (1 mark for calculating area) Instroking area = 1384·74 — (3·14 x $4{\cdot}0^2$) = 1334·5 mm^2 (1 mark for instroking area) Force = Pressure x Area = 2·0 x 1334·5 (1 mark for substitution) = 2669 N (1 mark for correct answer from candidate's working) = 2700 N	4	
16	c		1 mark for a valid method, eg: • increase restriction on uni-direction restrictor • increase volume of reservoir	1	

MARKS | DO NOT WRITE IN THIS MARGIN

17. A shopping centre decides to introduce a lift to give all its customers access to shops on the first floor (see diagram below).



A simplified diagram for part of the system is shown below.



(a) Describe the control of the lift with reference to the diagram and using appropriate terminology. **4**

Back to Table

17. (continued) MARKS | DO NOT WRITE IN THIS MARGIN

When the lift is full of people it has a total mass of 1250 kg.

(b) (i) Calculate the potential energy gained when the lift has moved up 4·0 m to the first floor. 2

The lift is powered by an electric motor that is supplied with 240 V and 22 A.

(ii) Calculate how long it would take the lift to reach the first floor when full. Assume no energy loss. 3

(iii) In reality, the lift took longer to reach the first floor. Explain why the lift was less than 100% efficient. 2

(c) (i) Describe one positive economic effect of introducing the lift to the shopping centre. 1

(ii) Describe one negative economic effect of introducing the lift to the shopping centre. 1

Back to Table

17	a		Up to 4 marks for four valid statements, such as: • The user's desired destination is fed into the control unit. • The control unit compares the current position with the desired destination. • The control unit sends the appropriate signal to activate the output driver. • The position sensors provide feedback.	4	
17	b	i	$E_p = mgh$ $= 1250 \times 9{\cdot}8 \times 4{\cdot}0$ (1 mark for substitution) $= 49\,000$ J (1 mark for correct answer from candidate's working)	2	
17	b	ii	$E_e = ItV$ $49\,000 = 22 \times t \times 240$ (1 mark for substitution) $t = 49\,000 / (22 \times 240)$ (1 mark for rearranging formula) $= 9{\cdot}3$ seconds (1 mark for correct answer from candidate's working)	3	Allow FTE from 17(b)(i)
17	b	iii	Some energy would be transferred (1) in the form of heat/sound due to friction (1).	2	1 mark for cause (friction) 1 mark for effect (energy 'lost' to heat/sound)
17	c	i	It would allow increased access to shops on the first floor, so more spending in these shops.	1	
17	c	ii	It would be expensive to design/install.	1	

Back to Table

18. A rollercoaster is shown below. MARKS DO NOT WRITE IN THIS MARGIN

(a) Describe two tasks a mechanical engineer would undertake during the design of the rollercoaster.

1 ____________________ 1

____

2 ____________________ 1

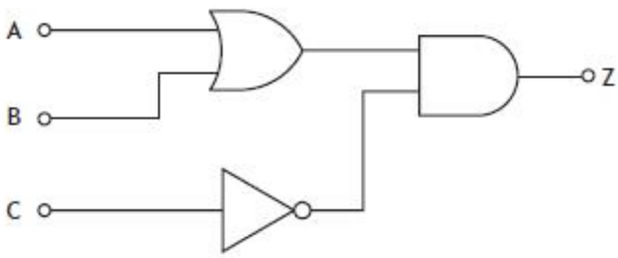
____

An electronic engineer used computer simulation during the design of the rollercoaster.

(b) State one feature of the rollercoaster design that the electronic engineer would simulate. 1

____

The logic diagram for part of the electronic control system used in the rollercoaster is shown below.



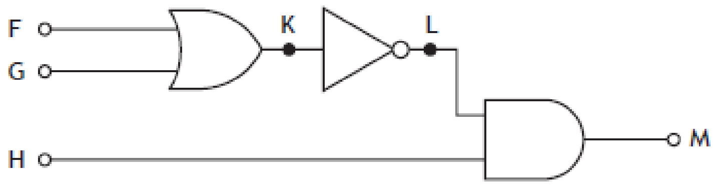
(c) Complete the Boolean equation for the logic diagram. 3

Z = ____________________

Back to Table

18. (continued) MARKS | DO NOT WRITE IN THIS MARGIN

The logic diagram for a second part of the electronic control system is shown below.



(d) Complete the truth table below for the logic diagram. 3

F	G	H	K	L	M
0	0	0			
0	0	1			
0	1	0			
0	1	1			
1	0	0			
1	0	1			
1	1	0			
1	1	1			

(e) An emerging technology can be defined as something new that has great potential but is not yet fully tried commercially in a product or system.

One of the most exciting emerging technologies today is nanosensors. These tiny sensors have many uses; for example, they could be embedded in construction materials.

Explain the possible impacts of an emerging technology with which you are familiar. 2

(f) Explain one positive social impact of having a theme park built in a small community. 2

* S 8 2 3 7 5 0 1 2 4 *

Back to Table

<table>
<tr><th colspan="3">Question</th><th>Expected response</th><th>Max mark</th><th>Additional guidance</th></tr>
<tr><td>18</td><td>(a)</td><td></td><td>Calculating drive systems VR/torque

Selecting suitable gear sizes

Creating brake system</td><td>2</td><td>1 mark per correct descriptive response

Statements must be mechanical engineer based and relate to the design stage.</td></tr>
<tr><td></td><td>(b)</td><td></td><td>To simulate control circuits, safety systems, lighting, braking systems, program/flowchart and test their operation. (1 mark for any relevant answer)</td><td>1</td><td>Statement based response</td></tr>
<tr><td></td><td>(c)</td><td></td><td>$(A + B) \cdot \overline{C} = Z$</td><td>3</td><td>(1 mark OR with bracket,
1 mark AND,
1 mark NOT)

Other correct Boolean equations are acceptable</td></tr>
<tr><td></td><td>(d)</td><td></td><td><table><tr><th>K</th><th>L</th><th>M</th></tr><tr><td>0</td><td>1</td><td>0</td></tr><tr><td>0</td><td>1</td><td>1</td></tr><tr><td>1</td><td>0</td><td>0</td></tr><tr><td>1</td><td>0</td><td>0</td></tr><tr><td>1</td><td>0</td><td>0</td></tr><tr><td>1</td><td>0</td><td>0</td></tr><tr><td>1</td><td>0</td><td>0</td></tr><tr><td>1</td><td>0</td><td>0</td></tr></table></td><td>3</td><td>1 mark for each correct column

Allow follow through error for column L and M;

L = NOT K

M = H AND L</td></tr>
<tr><td></td><td>(e)</td><td></td><td>Self-driving cars will reduce congestion and speed up journey times because they can safely travel much closer together.

Less power required to run devices

Quicker diagnostics</td><td>2</td><td>Explanation response only
1 mark cause
1 mark effect

No mark without specific emerging technology named.

Maximum of 1 mark if given example, nanosensors, is used.</td></tr>
<tr><td></td><td>(f)</td><td></td><td>The new theme park will need workers which means more jobs for local people.

The new theme park will need construction workers so local trades could be used.

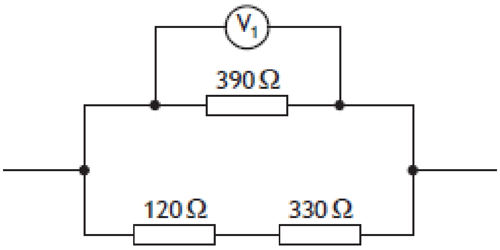
Happiness/wellbeing in community increased due to greater employment opportunities/affluence.</td><td>2</td><td>Cause and effect response. Any other response that refers to a positive social impact.</td></tr>
</table>

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

19. A drone used to film sporting events is shown below.

Part of the electronic circuit used in the drone is shown below.



(a) Calculate the total resistance for the circuit shown. 3

Show all working and final unit.

Back to Table

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

19. (continued)

(b) Calculate the current through the 390 Ω resistor when the voltage V_1 is 12 V. 3

Show all working and final unit.

[END OF SPECIMEN QUESTION PAPER]

S823750126

Back to Table

Back to Table

Question			Expected response	Max mark	Additional guidance
19	(a)		120 + 330 = 450Ω $R_T = \frac{(R1 \times R2)}{(R1 + R2)}$ $R_T = \frac{(390 \times 450)}{(390 + 450)}$ $R_T = 210\Omega\ (2sf)\ (209\Omega)$	3	1 mark for series branch total (ignore units) Accept 3 resistors in parallel calculation – 2 marks maximum 1 mark for substitution (allow FTE). 1 mark for answer from working with unit.
	(b)		$V = IR$ $12 = I \times 390$ $I = \frac{12}{390}$ $I = 0 \cdot 031A\ (31mA\ 2sf)$	3	1 mark for substitution. 1 mark for transposition. 1 mark for answer from working with unit.

[END OF SPECIMEN MARKING INSTRUCTIONS]

Back to Table

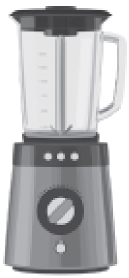
Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

SECTION 1 — 20 marks

Attempt ALL questions

1. A team of engineers is designing a kitchen blender.



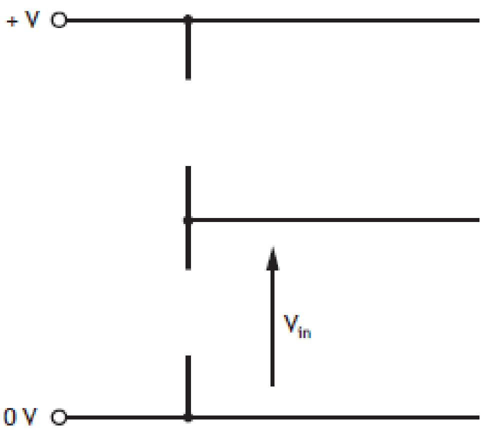
(a) State the type of engineer that would calculate the size of the gears to be used in the kitchen blender. 1

(b) State the type of engineer that would simulate the speed control circuit in the kitchen blender. 1

2. An electronic circuit is being designed to meet the following specification:

- V_{in} should increase as the light level detected increases.

Complete the circuit diagram below to include an LDR and a fixed resistor so that the circuit meets the required specification. 3



X823750102

page 02

Back to Table

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

3. A bike and carrier are shown below. Each bike wheel applies a force of 15 N onto the carrier.

Draw a free body diagram for the bike and carrier shown above. 2

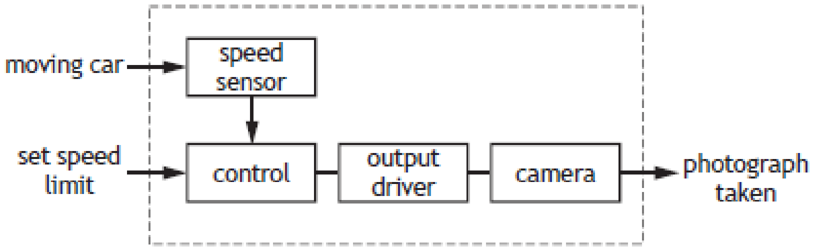
Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

4. A motorway speed camera is designed to photograph any car that is being driven above a set speed limit.

The sub-system diagram used to represent the control of the motorway speed camera is shown.



(a) State the type of control shown in this sub-system diagram. 1

(b) Describe the operation of the motorway speed camera. 3

The speed limit is set.

5. A buzzer is a commonly used electronic component.

Draw the symbol for a buzzer. 1

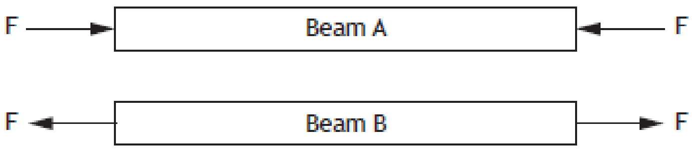
* X 8 2 3 7 5 0 1 0 4 *

Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

6. Two beams with applied forces (F) are shown below.

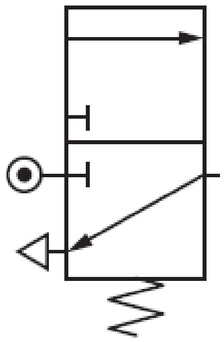


State the nature of the force acting on: 2

Beam A ______________________________

Beam B ______________________________

7. Complete the pneumatic symbol shown below for a 3/2 solenoid spring return valve. 1



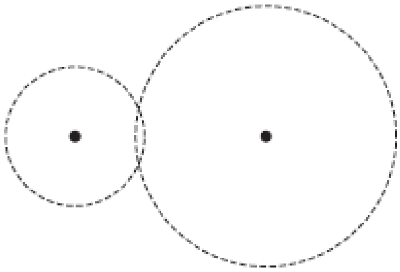
[Turn over

Back to Table

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

8. The simple gear train, shown below, has been drawn using incorrect conventions.



Describe two errors that were made when drawing this simple gear train. 2

Error 1 ______________________________

____

Error 2 ______________________________

____

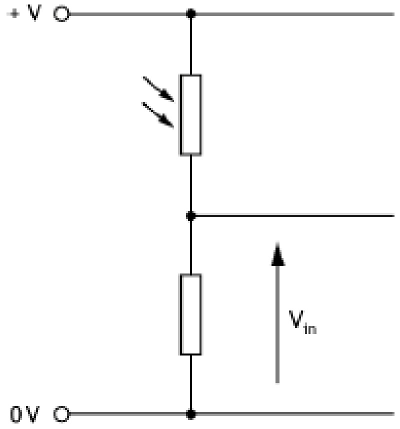
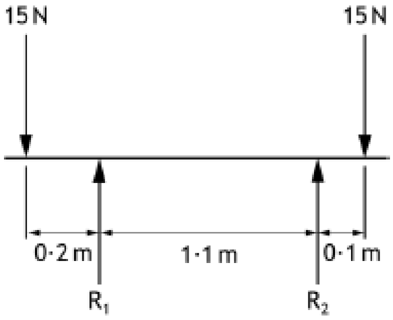
9. Draw the logic diagram for the Boolean equation shown below. 3

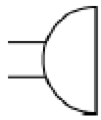
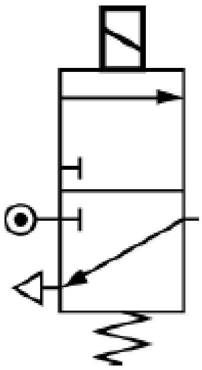
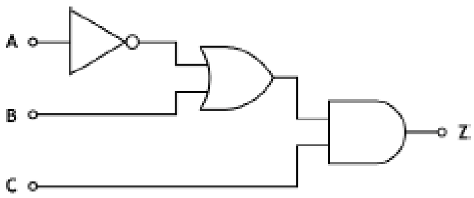
$$Z = (\overline{A} + B) \bullet C$$

Back to Table

Marking instructions for each question

Section 1

Question			Expected response	Max mark	Additional guidance
1.	(a)		Mechanical (engineer)	1	
	(b)		Electronic (engineer)	1	Not electrical engineer
2.				3	1 mark for LDR symbol 1 mark for fixed resistor symbol 1 mark for correct wiring of components with given sensor at top of voltage divider
3.				2	1 mark for all forces with arrows and units in the correct position 1 mark for all dimensions with units (dimension and leader lines are not required)
4.	(a)		Open loop	1	Do not accept open on its own
	(b)		*The speed limit is set.* The sensor measures the speed of the car The control unit compares the set speed limit with the speed of the car If the speed is too fast then camera is activated taking the photograph	3	Descriptive response covering: 1 mark sensor measuring car speed (inferred) Do not accept speed sensor detects a car without reference to speed 1 mark control unit decision 1 mark camera being activated when speed is too fast / no photo taken when within speed limit

Question	Expected response	Max mark	Additional guidance
5.		1	1 mark for correct symbol
6.	A - Compressive/compression B - Tensile/tension	2	Accept strut/tie/squashed/ stretched No FTE
7.		1	Correct actuator symbol drawn on the top surface of the valve symbol Should include both the rectangle and an inclined line (any direction)
8.	Incorrect line type used / not solid lines Should be crosses in the centres / not dots Double outlines missing	2	Must be descriptive response Do not accept overlapping Do not accept lines incorrect
9.		3	1 mark for NOT gate on A 1 mark for OR gate with correct connections 1 mark for AND gate with correct connections

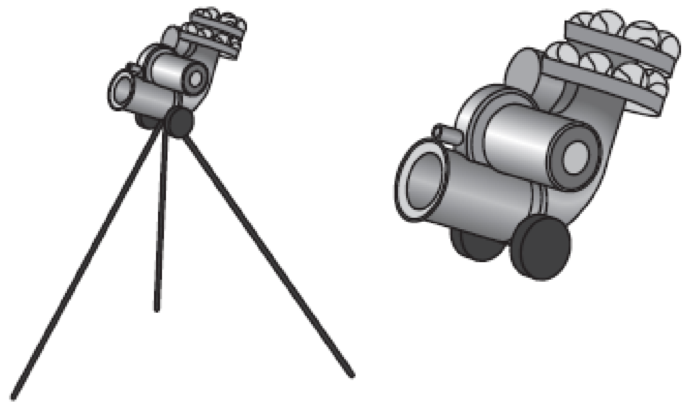
Back to Table

SECTION 2 — 90 marks

Attempt ALL questions

DO NOT WRITE IN THIS MARGIN

10. A ball firing machine used by tennis players to practise is shown below.



The machine is operated by a microcontroller. Input and output connections to the microcontroller are shown in the table below.

Input connections	Pin	Output connections
	7	ball firing motor
	6	red light
	5	green light
	4	ball release
start button	0	

The machine operates using the following sequence.

1. When the start button is pressed the ball firing motor starts and the red light switches on.
2. There is a 5 second delay after which the red light switches off and the green light switches on.
3. The ball release is then switched on for 0·5 seconds.
4. The ball release is then switched off for 2 seconds.
5. Steps 3 and 4 are then repeated ten times.
6. The ball firing motor and green LED then switch off and the system resets ready to be used again.

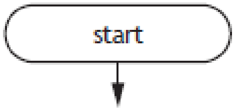
X823750108

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

10. (continued)

(a) Complete the flowchart for the sequence, with reference to the Data Booklet and input/output connections. Include all pin numbers and delay units in your flowchart. **10**



Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

10. (continued)

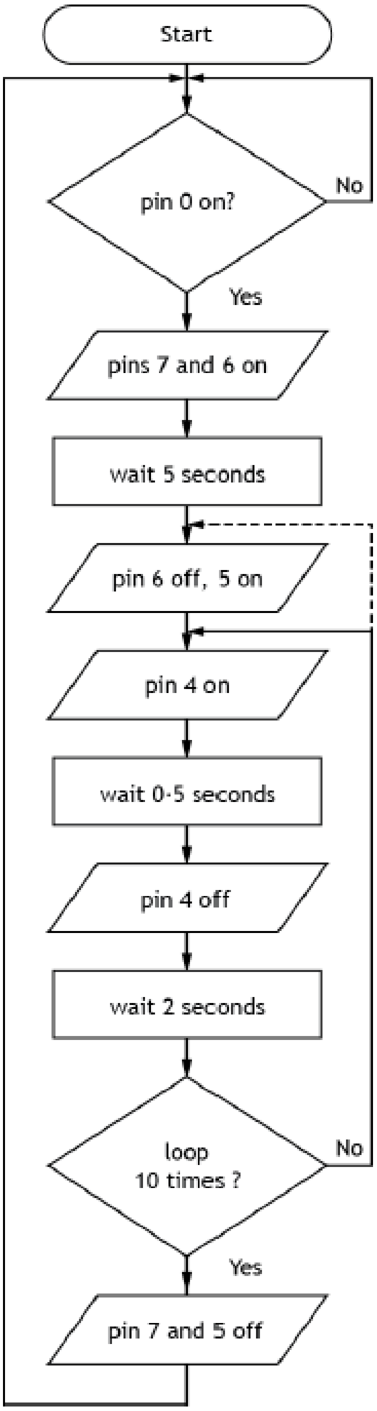
During the design stage, the strain acting on the machine was analysed. It was found that when the machine was fully loaded with tennis balls, one leg had a strain of 0·0016.

(b) Calculate the change in length of this leg when its original length was 1200 mm. 3

Back to Table

Back to Table

Section 2

Question			Expected response	Max mark	Additional guidance
10.	(a)			10	Pin numbers must be correct where applicable Pin 0 on ? (inc Y or N, loop and arrow head) - 1 mark Pin 7 on and off positions - 1 mark Pin 6 on and off positions - 1 mark Pin 5 on and off positions - 1 mark Pin 4 on and off positions - 1 mark All three delays with unit - 1 mark Loop x10 ? decision (inc Y or N) - 1 mark Feedback loop and arrow to before pin 4 on - 1 mark Continuous loop (with arrow to start) - 1 mark All marked symbols correct - 1 mark Ignore any additional steps.

Back to Table

Back to Table

Question			Expected response	Max mark	Additional guidance
10.	(b)		$0.0016 = \frac{\Delta l}{1200}$ $\Delta l = 0{\cdot}0016 \times 1200$ $\Delta l = 1.92$ mm **1·9 mm (2 sf)**	3	1 mark for substitution 1 mark for transposition 1 mark for correct answer from given working with unit

Back to Table

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

11. A circus acrobat on a trapeze swing is suspended high above the ground. The motion of the trapeze swing is shown below.

(a) State the type of motion shown. 1

(b) The acrobat and trapeze swing have a combined mass of 69 kg.

For the acrobat and trapeze swing:

(i) calculate their potential energy when they are 6·8 m above the ground; 2

[Turn over

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

Back to Table

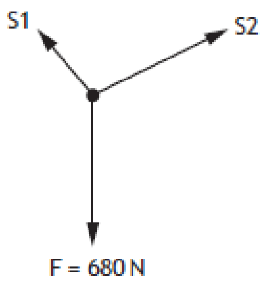
Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

11. (b) (continued)

(ii) calculate their velocity when their kinetic energy is 970 J. 3

(c) Part of the supporting structure for the trapeze swing is shown below.



(i) State, with reference to the Data Booklet, the condition of equilibrium which does not need to be considered when studying forces acting at a single point. 1

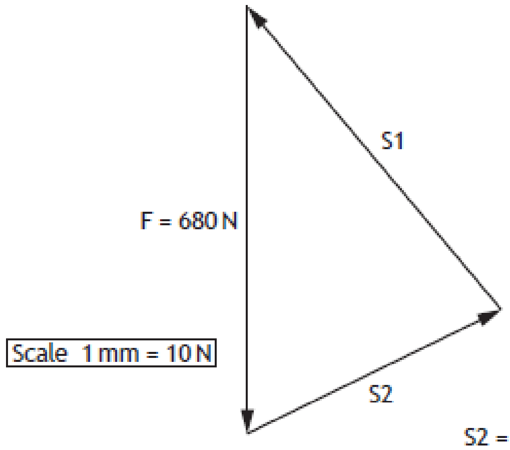
Back to Table

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

11. (c) (continued)

(ii) Determine the size of force S2 using the scale drawing of the triangle of forces shown below. 1



S2 = ________ N

[Turn over

Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

11. (continued)

(d) A maximum of two acrobats can hang from the trapeze swing at any one time. When this happens the forces in support wires S1 and S2 are as follows:

S1 = 1300N   S2 = 930N

The table below shows materials that were considered for the support wires.

	Material A	Material B	Material C	Material D
Maximum tensile load	1000 N	1300 N	3250 N	4500 N
Durability	High	Low	High	Low

Select the most suitable material (A-D) from the table above to be used for the support wires and justify your choice. 2

Choice of material ________________________________

Reason for choice ________________________________

* X 8 2 3 7 5 0 1 1 4 *

Back to Table

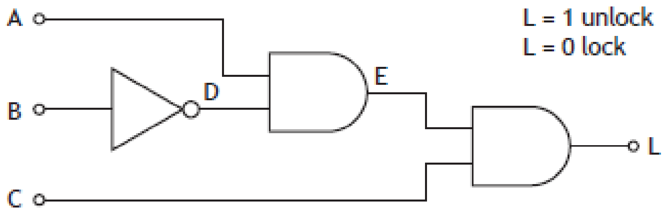
Question			Expected response	Max mark	Additional guidance
11.	(a)		Oscillating	1	
	(b)	(i)	$E_p = mgh$ $E_p = 69 \times 9{\cdot}8 \times 6{\cdot}8$ $E_p = 4598$ J $E_p = 4600$ J (2 sf)	2	1 mark for substitution 1 mark for answer from given working with unit
		(ii)	$Ek = \frac{1}{2}mv^2$ $970J = \frac{1}{2}69kg\ v^2$ $v = \sqrt{\frac{2 \times 970}{69}}$ $5{\cdot}302\ ms^{-1}$ $v = 5{\cdot}3\ ms^{-1}$ (2 sf)	3	1 mark for substitution 1 mark for transposition 1 mark for answer from given working with unit
	(c)	(i)	$\sum M = 0$	1	Accept $\Sigma CWM = \Sigma ACM$ or written response
		(ii)	450 (N)	1	Accept 445N-455N
	(d)		Material C It is durable and will support the (1300N) load It is strong (enough) to support the acrobats and it is durable	2	1 mark for correct material 1 mark for justification in terms of durability and tensile load/ strength

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

12. A design for a child's secret diary is being developed. The design includes a keypad to enter a code to unlock the diary.

The logic circuit for the control of the lock is shown below.



(a) (i) Complete the Boolean equation, in terms of inputs A, B and C, for this logic circuit. 2

L = ______________________________

(ii) Complete the truth table for the logic circuit shown above. 3

A	B	C	D	E	L
0	0	0			
0	0	1			
0	1	0			
0	1	1			
1	0	0			
1	0	1			
1	1	0			
1	1	1			

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

12. (continued)

(b) An electronic engineer decides to use a microcontroller based system to operate the lock rather than a logic circuit.

(i) Describe a functional advantage of using a microcontroller based system rather than a logic circuit to operate the lock. 1

(ii) Explain why using a microcontroller based system, rather than a logic circuit, is better for the environment. 2

<table>
<tr><th colspan="3">Question</th><th>Expected response</th><th>Max mark</th><th>Additional guidance</th></tr>
<tr><td>12.</td><td>(a)</td><td>(i)</td><td>$L = (A \cdot \overline{B}) \cdot C$</td><td>2</td><td>1 mark for NOT B

1 mark for ANDing A and B and C (ignore brackets if given)</td></tr>
<tr><td></td><td></td><td>(ii)</td><td><table><tr><th>D</th><th>E</th><th>L</th></tr><tr><td>1</td><td>0</td><td>0</td></tr><tr><td>1</td><td>0</td><td>0</td></tr><tr><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>0</td><td>0</td></tr><tr><td>1</td><td>1</td><td>0</td></tr><tr><td>1</td><td>1</td><td>1</td></tr><tr><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>0</td><td>0</td></tr></table></td><td>3</td><td>1 mark for each correct column

Allow FTE:

column E - A AND D

column L - E AND C</td></tr>
<tr><td></td><td>(b)</td><td>(i)</td><td>A variety of unlock codes can be programmed

User can set own unlock code

Time delays can be incorporated

Automatic lockout after a set number of incorrect attempts</td><td>1</td><td>1 mark for any description of an advantage relating to function

Response must relate to the context (lock control/coding)</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>Less components needed to be manufactured so less fumes produced.

Less materials needed so fewer natural resources used up

Can be reprogrammed/reusable therefore less waste (to landfill).</td><td>2</td><td>Response must relate to environment

1 mark for cause (advantage)

1 mark for effect (reason for advantage)

Do not accept less materials used as an effect on its own.

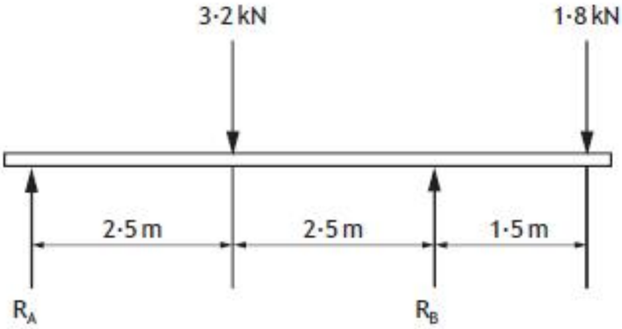
Do not accept less waste material</td></tr>
</table>

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

13. A sailing catamaran is shown.

A simplified diagram showing the forces from the catamaran and crew is shown below.



(a) (i) Calculate the size of reaction force R_A, by taking moments about R_B. 3

Back to Table

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

13. (a) (continued)

(ii) Calculate the size of reaction force R_B. 2

(b) Describe two specific roles a structural engineer may have had in the development of the catamaran. 2

1 __________

____

2 __________

____

[Turn over

Back to Table

Back to Table

Question			Expected response	Max mark	Additional guidance
13.	(a)	(i)	$(1{\cdot}8 \times 1{\cdot}5) + (R_A \times 5{\cdot}0) = (3{\cdot}2 \times 2{\cdot}5)$ $R_A = \frac{5{\cdot}3}{5{\cdot}0}$ 1·06 kN R_A = **1·1 kN** (2 sf)	3	1 mark for substitution 1 mark for transposition 1 mark for correct answer from given working with unit If R_B is calculated correctly (3·9 kN) 2 marks
		(ii)	$3{\cdot}2 + 1{\cdot}8 = 1{\cdot}1 + R_B$ $R_B = 5{\cdot}0 - 1{\cdot}1$ R_B = **3·9 kN** (2 sf)	2	1 mark for substitution (allow FTE from 13(a)(i) 1 mark for correct answer from given working with unit
	(b)		Calculate the forces on the hull Select material for the mast Test the mast cables / ensure the cables are strong enough Design the deck (to ensure the loads are supported)	2	1 mark for each appropriate descriptive response of an engineer's activity and specific structural aspect Must be linked to development - design/calculate/select/simulate/ model/test (ensure) and management related activities Two different activities must be used Do not accept design the sail on its own Do not accept developing as an activity on its own

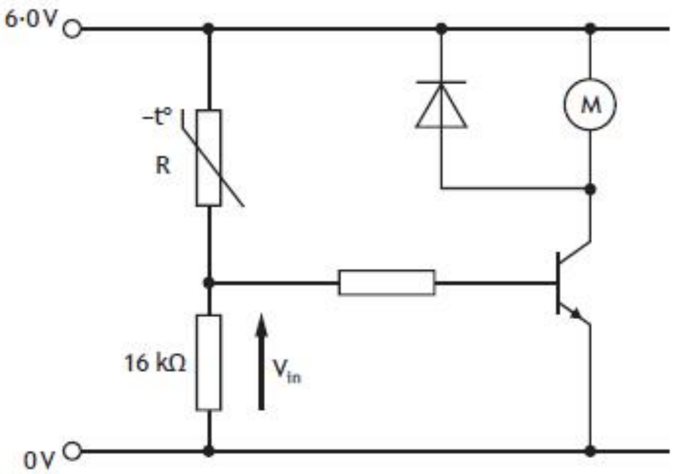
Back to Table

Back to Table

14. A desktop fan is shown.

MARKS | DO NOT WRITE IN THIS MARGIN

A possible circuit used to control the operation of the fan's motor is shown below.



Back to Table

Back to Table

14. (continued)

DO NOT WRITE IN THIS MARGIN

(a) Describe the operation of the circuit shown opposite, as the temperature in the room increases. **4**

Include reference to the resistance of the thermistor and the voltage V_{in}.

As the temperature increases...

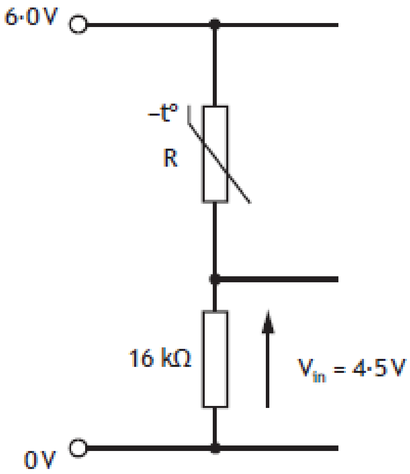
[Turn over

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

14. (continued)

The input sensing circuit of the fan is shown below.



(b) Calculate the resistance R, when $V_{in} = 4{\cdot}5\,V$. 4

(c) Describe how the input sensing circuit could be modified so that the user can alter the temperature at which the fan motor switches on. 1

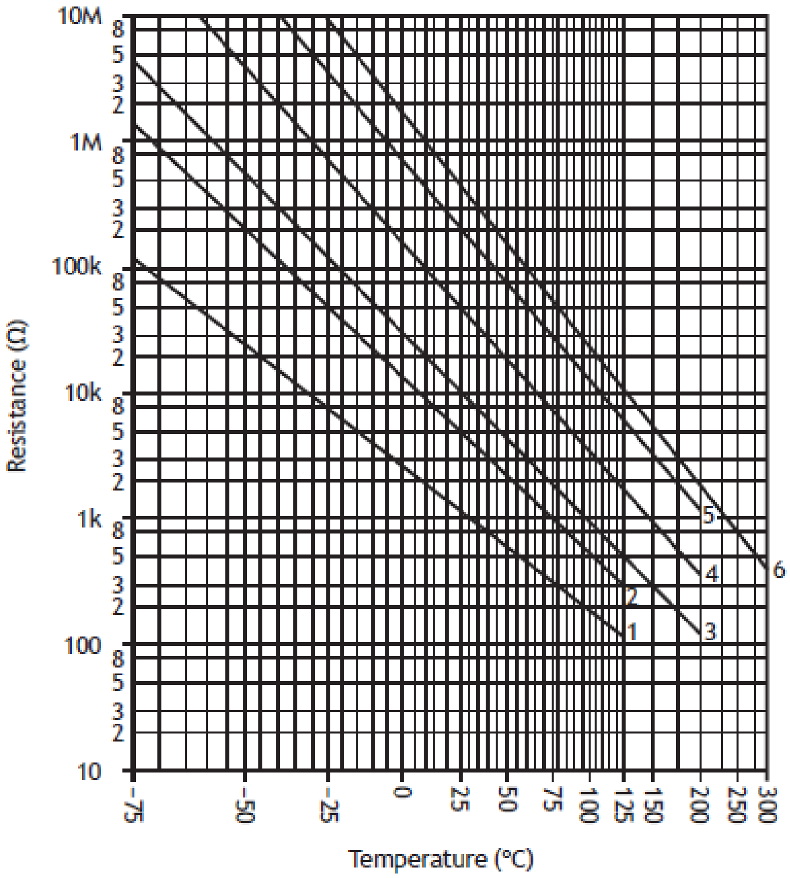
* X 8 2 3 7 5 0 1 2 2 *

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

14. (continued)

(d) Determine, with reference to the graph shown below, the resistance of a type 4 thermistor when the temperature is 25 °C. **1**



[Turn over

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

14. (continued)

(e) The base of the fan has a force of 25 N applied to it and a stress of $0{\cdot}029\ \text{N mm}^{-2}$.

Calculate the cross sectional area of the base of the fan. 3

Back to Table

Question			Expected response	Max mark	Additional guidance
14.	(a)		The resistance of the thermistor decreases… …this results in V_{in} increasing… …the transistor switches on… …and the motor will switch on	4	Descriptive responses covering: 1 mark thermistor resistance decreasing 1 mark V_{in} increasing 1 mark transistor switching on/saturating / $V_{BE} = 0{\cdot}7$ V (do not accept $V_{in} = 0{\cdot}7$ V) (do not accept transistor acts as a switch on its own) 1 mark motor switching on Apply FTE from each statement
	(b)		$V_1 = 6{\cdot}0 - 4{\cdot}5 = 1{\cdot}5$ V $\frac{R}{16k} = \frac{1{\cdot}5V}{4{\cdot}5V}$ $R = 0{\cdot}333 \times 16k$ $R = 5328\ \Omega$ $R = 5{\cdot}3\ k\Omega$ (2 sf) OR $V_2 = IR_2$ $I = V_2/R_2$ $I = 4{\cdot}5/16000$ $I = 0{\cdot}000281A$ $V_1 = 6{\cdot}0 - 4{\cdot}5 = 1{\cdot}5$ V $V_1 = IR_1$ $R_1 = V_1/I$ $R = 1{\cdot}5/0{\cdot}000281$ $R = 5{\cdot}33\ k\Omega$ $R = 5{\cdot}3\ k\Omega$ (2 sf)	4	1 mark for calculating voltage V_1. (ignore unit) 1 mark for substitution (apply FTE and accept 6·0 V if V_1 not calculated) 1 mark for transposition 1 mark for correct answer from given working with unit 1 mark for calculating current (ignore unit) 1 mark for calculating voltage V_1 (ignore unit). 1 mark for substitution (allow FTE) 1 mark for correct answer from given working with unit

Back to Table

Question			Expected response	Max mark	Additional guidance
Question			Expected response	Max mark	Additional guidance
14.	(c)		Replace the fixed resistor with a variable resistor Add a variable resistor	1	Descriptive response Do not accept just use a variable resistor
	(d)		50 kΩ	1	Unit required
	(e)		$0.029 = \frac{25}{A}$ $A = \frac{25}{0.029}$ A = 862.1 mm^2 A = 860 mm^2 (2 sf)	3	1 mark for substitution 1 mark for transposition 1 mark for correct answer from given working with unit

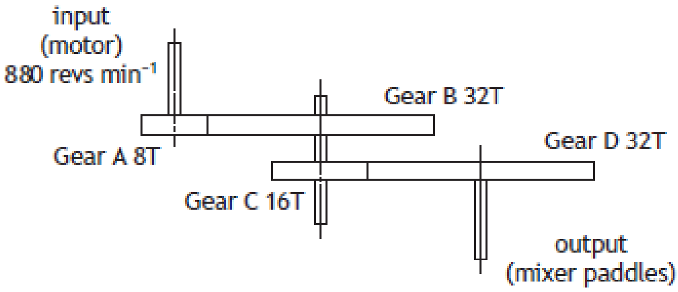
page 11

Back to Table

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

15\. A food processing company uses an industrial mixing machine to combine pastry ingredients. A compound gear train which forms part of the mixing machine is shown below.



(a) (i) Calculate the output speed of the mixer paddles. 4

(ii) Calculate the velocity ratio of the compound gear train. 2

Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

15. (continued)

(b) During testing it was found that the mixing paddles were rotating too slowly.

Describe one change that could be made to Gear B in order to increase the speed of the mixing paddles. 1

[Turn over

Back to Table

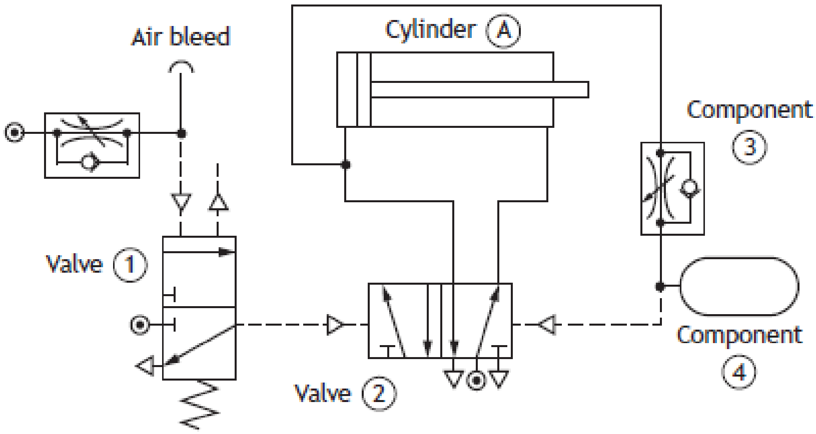
Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

15. (continued)

Portions of the pastry travel along a conveyor belt where a pneumatic piston presses them into pie casings.

The pneumatic circuit shown below operates the piston when the pastry is sensed in position.



(c) Describe, using appropriate terminology, the operation of the pneumatic circuit, shown above. 3

When the air bleed is covered valve 1 is actuated.

Back to Table

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

15. (continued)

(d) Explain why an air bleed was selected as an appropriate way of sensing the pastry. 2

(e) The piston has a cross sectional area of $810\,mm^2$ and produces a force of 73 N.

Calculate the pressure supplied to outstroke the piston. 2

[Turn over

X823750129

Back to Table

Question			Expected response	Max mark	Additional guidance
15.	(a)	(i)	Teeth A x Speed A = Teeth B x Speed B $8 \times 880 = 32 \text{x } B$ $\frac{8 \text{x} 880}{32} = Speed\ B$ B = 220 revs min^{-1} Teeth C x Speed C = Teeth D x Speed D $16 \times 220 = 32 \times D$ $\frac{16 \text{x} 220}{32} = Speed\ D$ D = 110 revs min^{-1} OR $\frac{\text{input speed}}{\text{output speed}} = \frac{A}{B} x \frac{C}{D}$ $output\ speed = \frac{8}{32} x \frac{16}{32} x\ 880$ output speed = 110 revs min^{-1}	4	1 mark for substitution 1 mark for answer from working (units not required) 1 mark for substitution (allow FTE) 1 mark for answer from working with unit Do not accept RPM 1 mark for first ratio 1 mark for second ratio 1 mark for substitution. (880/8 if ratios inverted) 1 mark for answer from working with unit
		(ii)	$VR = \frac{\text{input speed}}{\text{output speed}}$ $VR = \frac{880}{110}$ VR = 8:1 or 8	2	1 mark for substitution (allow FTE from 15(a)(i)) 1 mark for answer from working (ignore units)
	(b)		Reduce/remove a number of teeth Make the gear smaller	1	1 mark for descriptive response

Question			Expected response	Max mark	Additional guidance
15.	(c)		*When the air bleed is covered valve 1 is actuated…* …pilot air is sent to Valve 2 causing the piston in Cylinder A to outstroke… …air is also sent to (Components 3 and 4) creating a time delay… …pilot air is sent to Valve 2 again causing the piston in Cylinder A to instroke.	3	Must be descriptive responses using appropriate terminology 1 mark for Valve 2 causing piston to outstroke 1 mark for time delay before instroking (second piston movement) 1 mark for Valve 2 causing piston to instroke
	(d)		It is clean therefore will not contaminate pastry/hygienic Does not apply pressure therefore will not damage pastry	2	Response must be in the context/ referencing pastry 1 mark for cause 1 mark for effect
	(e)		$P = \frac{F}{A}$ $P = \frac{73}{810}$ P = 0·09012 Nmm^{-2} P = 0·090 Nmm^{-2} (2 sf)	2	1 mark for substitution 1 mark for answer from working with unit Accept 0.090 x 10^{6} Nm^{-2} (Pa)

MARKS DO NOT WRITE IN THIS MARGIN

16. Electric cars have been developed as an alternative to fossil fuel powered vehicles.

(a) (i) Describe one positive environmental impact of using an electric car. **1**

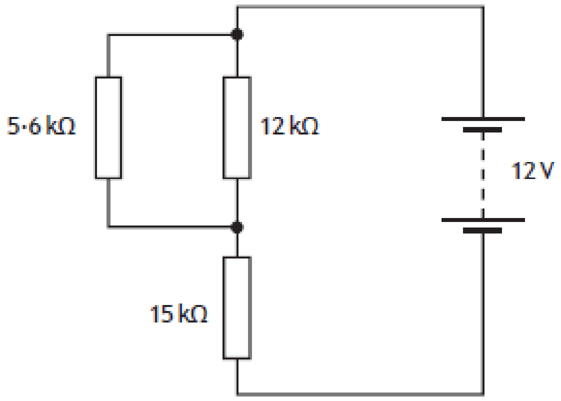
(ii) Describe one negative economic impact of the increasing use of electric cars. **1**

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

16. (continued)

Part of a circuit used in an electric car is shown.



(b) Calculate the total resistance of this circuit. 3

Back to Table

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

16. (continued)

(c) (i) Calculate the voltage across the 15 kΩ resistor when the current flowing through it is 0·6 mA. 2

(ii) Calculate the current flowing through the 5·6 kΩ resistor. 4

Electric vehicles are now considered to be an established technology. An emerging technology is one that has still to be tried commercially within a product or system.

(d) Explain the possible impact of an emerging technology that you are familiar with. 2

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

[Turn over

Back to Table

Question			Expected response	Max mark	Additional guidance
16.	(a)	(i)	Less pollution/clean source of energy Lower/no emissions of greenhouse gases Reduction in global warming.	1	1 mark for any appropriate descriptive response of a positive environmental impact Do not accept does not use fossil fuel on its own
		(ii)	Cost of having to build additional power stations to cope with demand. Reduction in fossil fuel cars being sold so less profit. Installation costs (charging points) Specialist vehicle technicians may be more expensive	1	1 mark for any appropriate descriptive response of a negative economic impact of the increasing use Do not accept it costs money to charge the batteries Do not accept loss of jobs / unemployment on its own without link to economy Do not accept expensive to manufacture
	(b)		$R_p = \frac{5 \cdot 6 \times 12}{5 \cdot 6 + 12}$ $R_p = \frac{67 \cdot 2}{17 \cdot 6}$ $R_p = 3{\cdot}82$ $R_t = 3{\cdot}82 + 15$ $R_t = 18{\cdot}82\ \text{k}\Omega$ $R_t = 19\ \text{k}\Omega$ (2 sf)	3	1 mark for R_p substitution 1 mark for R_p answer (ignore units) 1 mark for correct answer with unit (apply FTE for R_p)

Question			Expected response	Max mark	Additional guidance
16.	(c)	(i)	$V = 0{\cdot}6 \times 15$ $V = 9{\cdot}0$ V (2 sf)	2	1 mark for substitution 1 mark for correct answer from given working with unit
		(ii)	$12 - 9{\cdot}0 = 3{\cdot}0$V $3{\cdot}0\text{V} = I \times 5{\cdot}6\text{k}$ $I = \frac{3{\cdot}0}{5{\cdot}6\text{k}}$ $I = 0{\cdot}5357$ mA $I = 0{\cdot}54$ mA (2 sf)	4	1 mark for calculating voltage across 5·6 kΩ resistor (FTE from (c)(i)) 1 mark for substitution (allow FTE for calculated voltage) 1 mark for transposition 1 mark for correct answer from given working with unit
	(d)		Graphene Conducts and stores electricity more efficiently than other materials. This will result in batteries being charged quicker/holding their charge for longer Self driving car Impact of emerging system is it may not be fully tested and so may have faults and be unreliable/unsafe	2	Accept impact for any emerging technology 1 mark for cause 1 mark for effect If no technology named or the given example is clearly an established / developing type, 1 mark maximum for cause and effect

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

17. A grilling machine is shown below.

The grilling machine has an input electrical energy of 1200 J. Only 790 J is transformed as useful output energy in the form of heat.

(a) Complete the energy audit diagram below for the grilling machine. Include details of the energy forms and their values. 3

energy in

energy out

____

______________ J → Grilling machine → ______________ J

energy losses

____

______________ J

Space for rough working

Back to Table

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

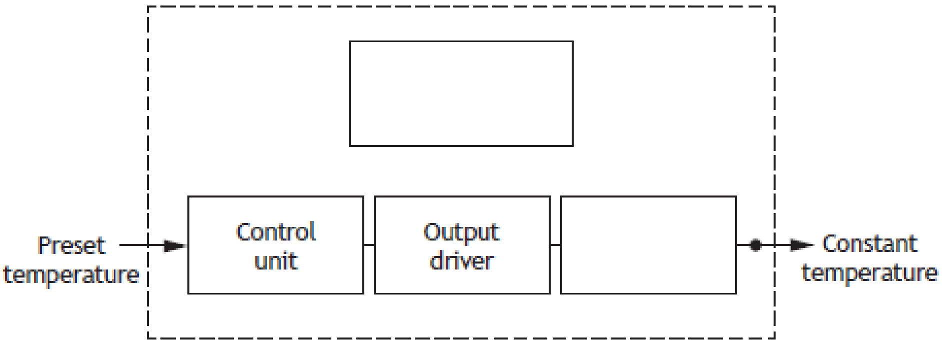
17. (continued)

(b) Calculate the efficiency of the grilling machine. 2

(c) The grilling machine uses feedback to maintain a constant temperature.

(i) State the type of control that uses feedback. 1

(ii) Complete the sub-system diagram below for the grilling machine. 3



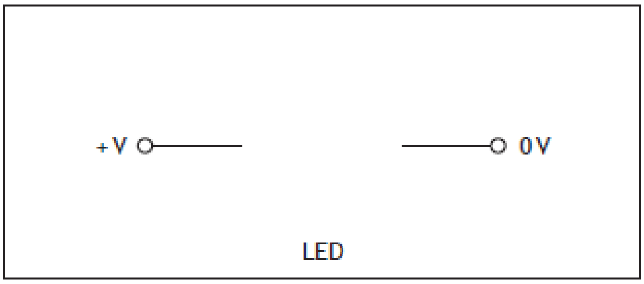
[Turn over for next question

MARKS | DO NOT WRITE IN THIS MARGIN

17. (continued)

(d) An upgrade to the grilling machine includes an LED to show when the required temperature has been reached.

(i) Draw the symbol for an LED in the position shown below. 2



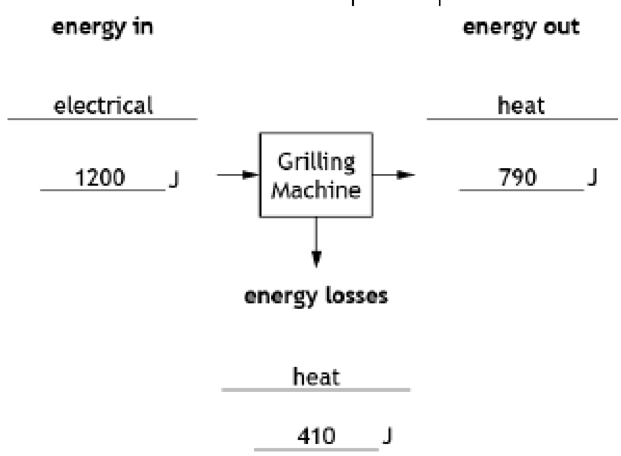
(ii) During testing of the circuit it was found that the LED was destroyed.

Describe one alteration that could be made to the circuit to prevent the LED from being destroyed. 1

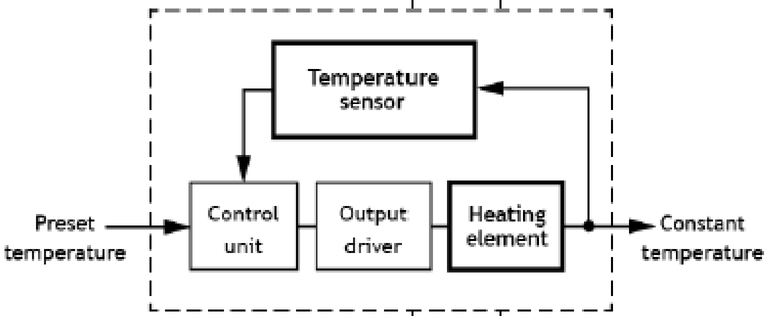
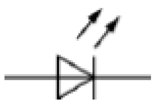
____

____

[END OF QUESTION PAPER]

Question			Expected response	Max mark	Additional guidance
17.	(a)			3	1 mark for electrical and 1200 (J) input Do not accept electricity 1 mark for heat and 790 (J) output 1 mark for heat/sound/light and 410 (J) lost
	(b)		$\eta = \frac{Energy\ out}{Energy\ in}$ $\eta = \frac{790}{1200}$ $\eta = 0{\cdot}6583$ $\eta = 0{\cdot}66$ (2 sf) or 66%	2	1 mark for substitution 1 mark for answer from working (ignore any units)
	(c)	(i)	Closed loop (control)	1	

Back to Table

Question			Expected response	Max mark	Additional guidance
		(ii)		3	1 mark for heating element/ heater 1 mark for temperature sensor accept thermistor/thermostat/heat sensor 1 mark for feedback lines from node into control unit, with an arrow head showing direction. Do not accept feedback joining preset temperature input
17.	(d)	(i)		2	1 mark for correct symbol 1 mark for correct orientation (apply FTE mark if diode is drawn)
	(ii)		Add a resistor (in series). Lower the voltage	1	1 mark for descriptive answer

[END OF MARKING INSTRUCTIONS]

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

SECTION 1 — 20 marks

Attempt ALL questions

1. An iron is shown.

(a) Complete the system diagram below by stating the main input energy and the main output energy for the iron. 2

The iron uses feedback to monitor the output.

(b) State the type of control that uses feedback. 1

A thermistor could be used as part of a temperature sensing circuit.

(c) Draw the symbol for a thermistor. 1

Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

2. A soldering iron and circuit board are shown below.

When the soldering iron was switched on for 270 seconds it used 6750 J of energy.

Calculate the power used. 2

3. Pneumatic circuits can use both main air and pilot air.

Describe the function of

(a) main air 1

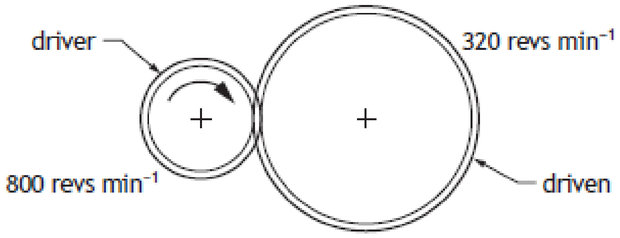
(b) pilot air. 1

Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

4. A simple gear train is shown below.



(a) Calculate the velocity ratio of this simple gear train. 2

The driver gear in the diagram above rotates clockwise.

(b) State the direction of rotation of the driven gear. 1

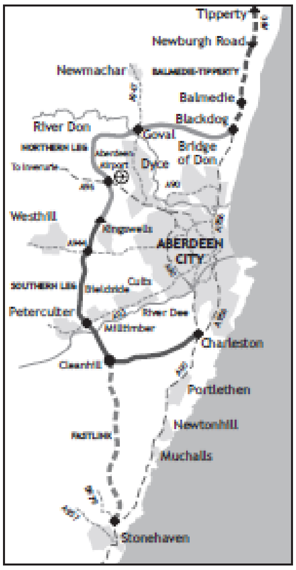
* X 8 2 3 7 5 0 1 0 4 *

Back to Table

[Back to Table](#)

MARKS | DO NOT WRITE IN THIS MARGIN

5. Engineers are involved in large scale projects such as the Aberdeen city bypass road shown below.



Key
- populated areas
- Balmedie - Tipperty
- Fastlink
- southern leg
- northern leg
- bypass
- road
- river

(a) State the branch of engineering that would be responsible for

(i) designing the connecting roads **1**

____

(ii) monitoring the impact to local wildlife during construction. **1**

____

(b) Describe two positive social impacts of a city bypass. **2**

1 ____________________

____

2 ____________________

____

[Turn over

[Back to Table](#)

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

6. The Boolean equation for a logic circuit is shown below.

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

Draw the logic diagram for this Boolean equation. 3

* X 8 2 3 7 5 0 1 0 6 *

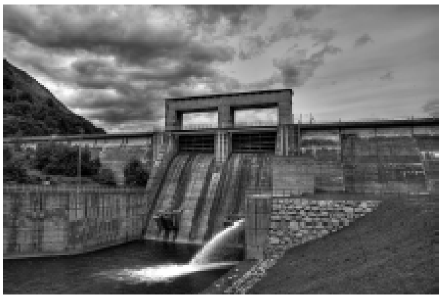
page 06

Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

7. Hydropower is a source of energy which is used to generate electricity.



Describe one positive and one negative environmental impact of using hydropower as a source of energy. 2

Positive ____

____

____

Negative ____

____

____

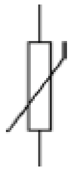
[Turn over

Back to Table

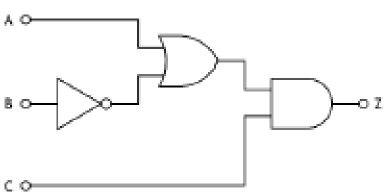
Back to Table

Marking instructions for each question

Section 1

Question			Expected response	Max mark	Additional guidance
1.	(a)			2	1 mark for electrical as input. 1 mark for heat as output. Do not accept electricity/electric.
	(b)		Closed loop (control)	1	Do not accept closed on its own.
	(c)			1	1 mark for correct symbol. -t' not required. Small line must be parallel to long side of resistor. Do not accept an arrow on any end.
2.			$P = \frac{E}{t}$ $P = \frac{6750}{270}$ P = 25 **P = 25** W **(2 sf)**	2	1 mark for substitution. 1 mark for correct answer from given working with unit.
3.	(a)		Air that operates a piston/cylinder.	1	Descriptive response of function. Accept instroke/outstroke/actuate a cylinder. Must specifically refer to operating (stated or inferred) a cylinder/ piston.
	(b)		Air used to actuate a valve.	1	Descriptive response of function. Must specifically refer to operating (stated or inferred) a valve.

Back to Table

Question			Expected response	Max mark	Additional guidance
4.	(a)		$\text{Velocity Ratio} = \frac{\text{Speed of Input}}{\text{Speed of Output}}$ $\text{Velocity Ratio} = \frac{800}{320}$ Velocity Ratio = 5 : 2	2	1 mark for substitution. 1 mark for correct answer from given working. Accept 2·5 : 1 or 2·5 Ignore any units.
	(b)		Anti-clockwise.	1	Do not accept other way or opposite way. Accept indication of direction on diagram.
5.	(a)	(i)	Civil.	1	
		(ii)	Environmental.	1	
	(b)		Less stressful journeys . Journey time quicker. City roads less congested. Areas bypassed will be quieter/safer. City will be less polluted to live in. Jobs created in the construction of the bypass/of housing in outlying areas.	2	1 mark for each descriptive response of positive social impact of a city bypass. Assume impact refers to bypass unless indicated in response. Do not accept quick on its own. Do not accept less congestion on bypass.
6.				3	1 mark for NOT gate wired to input B. 1 mark for OR gate wired to A and (NOT) B. 1 mark for AND gate wired to input C and A (OR) B. No FTE from gate.

page 04

Back to Table

Back to Table

Question			Expected response	Max mark	Additional guidance
7.			Positive: It does not produce CO_2 when in use. Reduces the need to burn fossil fuels. Does not contribute towards global warming. No pollution/clean when in use. Negative: Wildlife disrupted/habitats destroyed. Flow of water/flooding may erode the land/river bank. Unattractive pylons/dam site spoiling natural landscape. Vehicles noise when accessing the dam site.	2	1 mark for a description of an appropriate positive environmental impact when in use. 1 mark for a description of an appropriate negative environmental impact when in use. Do not accept renewable/does not use fossil fuel on its own. Do not accept the same environmental impact of use as both positive and negative impact.

Back to Table

Back to Table

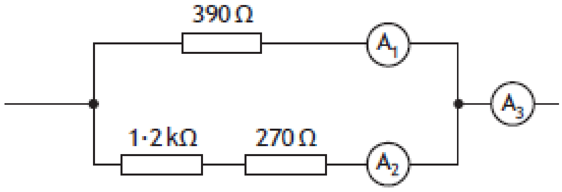
MARKS DO NOT WRITE IN THIS MARGIN

SECTION 2 — 90 marks

Attempt ALL questions

8. An interactive speaker used in a 'smart home' is shown.

Part of the circuit used in the speaker is shown below.



(a) Calculate the total resistance of this circuit. 3

Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

8. (continued)

The reading on ammeter A_1 is 0·031 A.

(b) (i) Calculate the voltage across the 390 Ω resistor. 2

(ii) Calculate the current A_2. 3

(iii) Calculate the current A_3. 1

Back to Table

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

8. (continued)

The interactive speaker used in a 'smart home' can be considered to be an established technology.

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

(c) Explain a possible impact of an emerging technology which you are familiar with. 2

Emerging technology ______________________________

Impact ______________________________

____

____

____

Back to Table

Back to Table

Section 2

Question			Expected response	Max mark	Additional guidance
8.	(a)		1200 + 270 = 1470 (Ω) $RT = \frac{R1 \times R2}{R1 + R2}$ $RT = \frac{1470 \times 390}{1470 + 390}$ RT = 308·2 RT = 310 Ω (2 sf)	3	1 mark for series resistance (unit not required). 1 mark for substitution Allow for FTE. 1 mark for answer with unit from given working.
	(b)	(i)	V = IR V = 0·031 x 390 V = 12·09 V = 12 V (2 sf)	2	1 mark for substitution. 1 mark for answer with unit from given working with unit.
		(ii)	V = IR 12 = I x 1470 $I = \frac{12}{1470}$ I = 0·00816 I = 8·2 mA (2 sf)	3	1 mark for substitution. Allow for FTE from (b)(i). 1 mark for transposition. 1 mark for correct answer from given working with unit.
		(iii)	A_3 = 0·0082 + 0·031 A_3 = 0·0392 A_3 = 39 mA (2 sf) OR V = IR 12 = I x 310 $I = \frac{12}{310}$ A_3 = 0.0387 A_3 = 39 mA (2 sf)	1	1 mark for answer with unit. Allow for FTE from (b)(ii). Allow for FTE from (a) and (b)(i).

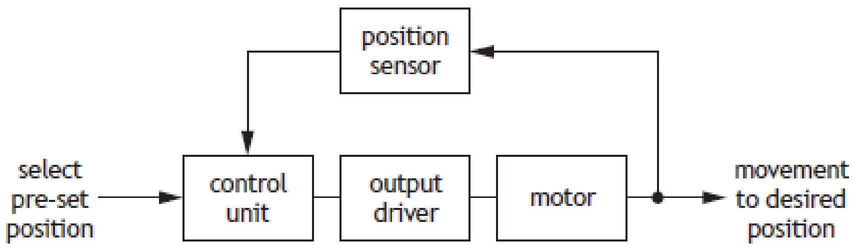
Question			Expected response	Max mark	Additional guidance
	(c)		Graphene. Conducts electricity quickly. This would result in batteries charging quicker/circuits working quicker. Self driving car. Impact of emerging system is it may not be fully tested and so may have faults and this could cause an accident.	2	Accept impact for any emerging technology. 1 mark for cause. 1 mark for effect. If no technology named or the given example is clearly an established/ developing; 1 mark maximum for cause and effect.

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

9. The angle of a hospital bed can be changed to a pre-set position as shown.

An incomplete sub-system diagram for the control of the bed movement is shown.



(a) Complete the sub-system diagram above by adding the system boundary. 1

(b) Describe, with reference to the sub-system diagram, the control of the bed movement. 3

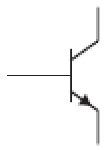
The pre-set position is selected . . .

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

9. (continued)

An electronic engineer has selected the transistor shown below to be used as part of the output driver unit.



(c) Explain the switching function of the transistor shown above. 2

Make reference to the base, collector and emitter connections.

A logic circuit is used in the operation of the bed. The truth table for the logic circuit is shown below.

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

(d) Complete the Boolean equation for output Z in terms of inputs A and B. 3

Z = ______________________

[Turn over

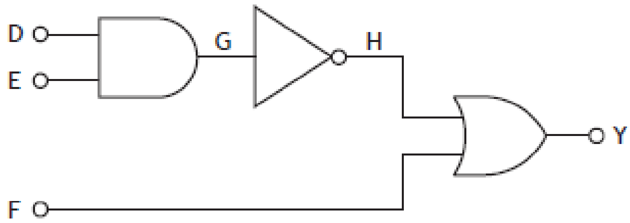
Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

9. (continued)

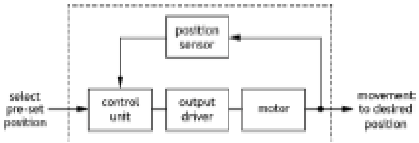
The diagram for part of another logic circuit used in the operation of the bed is shown below.



(e) Complete the truth table for this logic circuit. 3

D	E	F	G	H	Y
0	0	0			
0	0	1			
0	1	0			
0	1	1			
1	0	0			
1	0	1			
1	1	0			
1	1	1			

Back to Table

<table>
<tr><th colspan="3">Question</th><th>Expected response</th><th>Max mark</th><th>Additional guidance</th></tr>
<tr><td>9.</td><td>(a)</td><td></td><td>
</td><td>1</td><td>Dashed box around process.</td></tr>
<tr><td></td><td>(b)</td><td></td><td>The pre-set position is selected…

The control unit compares the pre-set position with the actual position.

The bed/motor will start to move (if it is not in the desired position).

When the desired position is detected the motor will stop.</td><td>3</td><td>1 mark for comparison by control unit of positional sensor signal to pre-set value.

1 mark for motor starting.

1 mark for motor stopping in relation to desired position.</td></tr>
<tr><td></td><td>(c)</td><td></td><td>When an appropriate input signal is applied to the base an output current will flow at the collector/emitter.</td><td>2</td><td>1 mark for input signal at base (cause). Accept voltage as signal.

1 mark for output current at collector/emitter based on given cause (effect).</td></tr>
<tr><td></td><td>(d)</td><td></td><td>$Z = (\overline{A}\bullet\overline{B}) + (A\bullet B)$</td><td>3</td><td>1 mark $(\overline{A}\bullet\overline{B})$ with brackets.

1 mark $(A\bullet B)$ with brackets.

1 mark for OR-ing all statements.

If just a single statement is given then bracket not required.

accept alternatives such as

$Z = \overline{A \oplus B}$

$Z = \overline{(A+B)} + (A\bullet B)$</td></tr>
<tr><td></td><td>(e)</td><td></td><td><table><tr><th>G</th><th>H</th><th>Y</th></tr><tr><td>0</td><td>1</td><td>1</td></tr><tr><td>0</td><td>1</td><td>1</td></tr><tr><td>0</td><td>1</td><td>1</td></tr><tr><td>0</td><td>1</td><td>1</td></tr><tr><td>0</td><td>1</td><td>1</td></tr><tr><td>0</td><td>1</td><td>1</td></tr><tr><td>1</td><td>0</td><td>0</td></tr><tr><td>1</td><td>0</td><td>1</td></tr></table></td><td>3</td><td>1 mark per correct complete column.

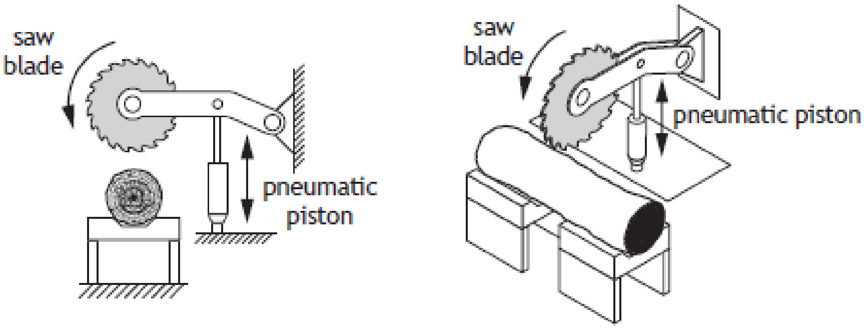
Allow for follow through error.

Column H = NOT G..

Column Y = F OR.</td></tr>
</table>

MARKS DO NOT WRITE IN THIS MARGIN

10. A pneumatic circuit is used in the operation of an industrial saw.

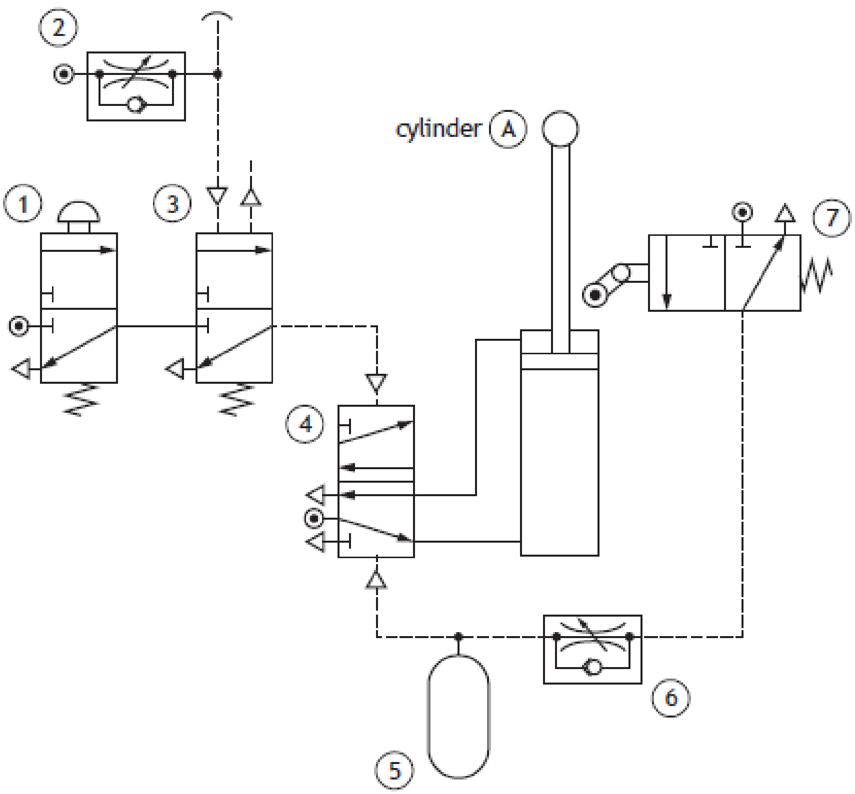


(a) State, with reference to the diagram above, the type of motion shown at the 2

saw blade ______________________________

pneumatic piston. ______________________________

The pneumatic circuit used to control the movement of the saw is shown below.



Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

10. (continued)

(b) Describe the operation of the circuit shown opposite. 3

When an increase in pressure is detected by valve (3) . . .

The piston is to be instroked slowly and smoothly.

(c) Indicate on the circuit shown opposite, with an X, where a uni-directional restrictor should be connected. 1

The roller trip on valve (7) is to be replaced with a solenoid and components (5) and (6) are to be removed. The solenoid will receive a signal from a microcontroller based circuit when the piston instrokes.

(d) Describe an advantage of using a microcontroller to control the movement of the piston. 1

[Turn over

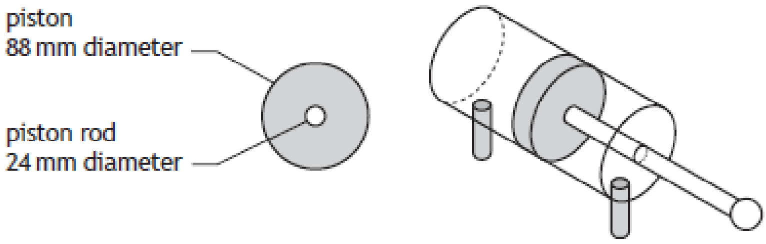
Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

10. (continued)

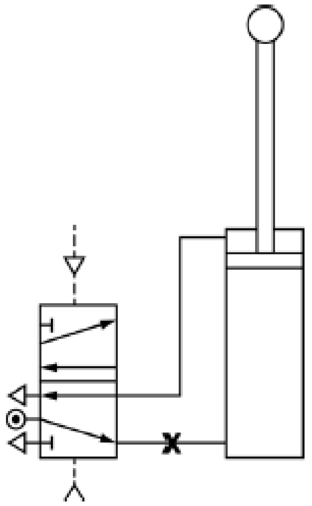
The pneumatic cylinder used in the system is shown below.



(e) (i) Calculate the effective area of the piston when it instrokes. 3

(ii) Calculate the force applied by the piston when it instrokes if air is supplied at a pressure of $0{\cdot}20\,\mathrm{N\,mm^{-2}}$. 3

Back to Table

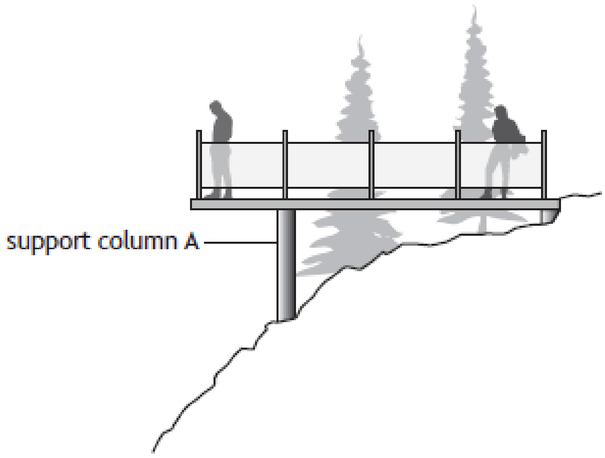
Question			Expected response	Max mark	Additional guidance
10.	(a)		Saw blade: rotary. Pneumatic piston: reciprocating.	2	1 mark for saw blade motion. 1 mark for piston motion. Accept rotational/reciprocal. Do not accept rotating.
	(b)		*When an increase in pressure is detected by valve 3…* …and when valve 1 is actuated (air is sent actuating valve 4), causing the piston to instroke… valve 7 is actuated then there is a time delay… …then valve 4 actuates causing the piston to outstroke.	3	1 mark for AND control with valve 1 and 3 causing the piston to instroke. 1 mark for time delay after valve 7 being actuated. 1 mark piston outstroke after valve 4 actuated and valve 7/time delay.
	(c)			1	X on lower pipe to double acting cylinder. Accept X on the bottom exhaust port of the 5/2 valve.
	(d)		The control of the piston movement could be easily changed/updated. The piston time delay could be easily changed/shortened. The piston time delay could be more consistent/accurate.	1	Descriptive response relating to advantage of microcontroller control of piston movement. Do not accept fewer components or cost savings.

Question			Expected response	Max mark	Additional guidance
10.	(e)	(i)	$\text{Apiston} = \frac{\pi d^2}{4}$ $\text{Apiston} = \frac{3 \cdot 14 \times 88^2}{4} = 6079 \ (\text{mm}^2)$ $\text{Arod} = \frac{\pi d^2}{4}$ $\text{Arod} = \frac{3 \cdot 14 \times 24^2}{4} = 452 \cdot 2 \ (\text{mm}^2)$ $A_{effective} = A_{piston} - A_{rod}$ $A_{effective} = 6079 - 452{\cdot}2$ $A_{effective} = 5627$ $A_{effective} = 5600 \text{ mm}^2$ (2 sf)	3	1 mark for area of rod (unit not required). 1 mark for area of piston (unit not required). 1 mark for correct subtraction answer with unit. Using the π function will give different intermediary values (6082 and 452·4) but same final answer to 2 sf.
		(ii)	$P = \frac{F}{A}$ $0 \cdot 20 = \frac{F}{5600}$ F = 0·20 x 5600 F = 1120 F = 1·1 kN (2 sf)	3	1 mark for substitution Allow FTE from part (e)(i). 1 mark for transposition. 1 mark for correct answer from given working with unit.

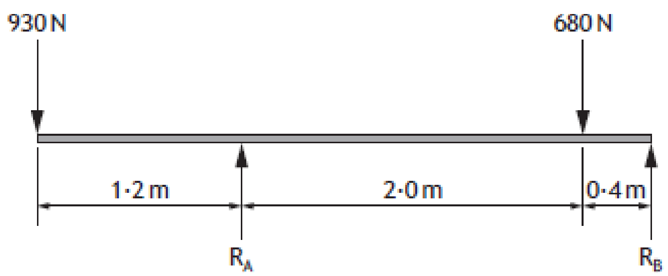
Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

11. A viewing platform at a tourist destination is shown.



A free body diagram indicating the main forces acting on the platform is shown below.



(a) (i) Calculate the reaction force R_A by taking moments about R_B. **3**

Back to Table

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

11. (a) (continued)

(ii) Calculate the reaction force R_B. 2

(b) State the term used to describe when forces acting on a structure are balanced. 1

Support column A was tested by applying a force of 2500 N.

(c) Calculate the cross-sectional area of support column A when a stress of $0{\cdot}060\ \text{N mm}^{-2}$ was measured for this force. 3

[Turn over

Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

11. (continued)

A visitor centre is to be built next to the platform. An electrical engineer works as part of a team designing the visitor centre.

(d) Describe two tasks an electrical engineer would carry out during the design. 2

1 ______________________________

____

____

2 ______________________________

____

____

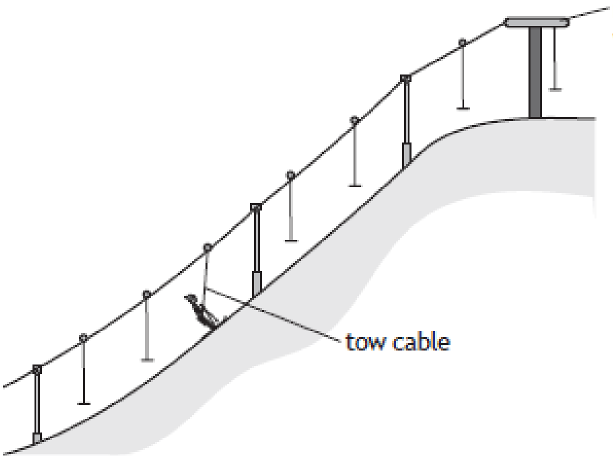
Back to Table

Question			Expected response	Max mark	Additional guidance
11.	(a)	(i)	$\Sigma CWM = \Sigma ACWM$ $(R_A \times 2 \cdot 4) = (680 \times 0 \cdot 4) + (930 \times 3 \cdot 6)$ $R_A = \frac{3620}{2 \cdot 4}$ $R_A = 1508$ $R_A = 1 \cdot 5$ kN (2 sf)	3	1 mark for substitution. 1 mark for transposition. 1 mark for correct answer from given working with unit.
		(ii)	$\Sigma F_{vertical} = 0$ $930 + 680 = 1500 + R_B$ $R_B = 1610 - 1500$ $R_B = 110$ $R_B = 110$ N (2 sf)	2	1 mark for substitution Allow FTE from part a(i). 1 mark for correct answer from given working with unit. If moments used to determine R_B then accepted $101 \cdot 7$ N .
	(b)		Equilibrium.	1	Ignore additional description
	(c)		$\sigma = \frac{F}{A}$ $0 \cdot 06 = \frac{2500}{A}$ $A = \frac{2500}{0 \cdot 06}$ A = 41670 A = 42000 mm^2 (2 sf)	3	1 mark for substitution.. 1 mark for transposition. 1 mark for correct answer from given working with unit.
	(d)		Design how to connect the visitor centre to the national grid. Calculate the electrical power requirements of the visitor centre. Select appropriately rated cables. Calculate the lighting requirements/ plan the lighting layout.	2	1 mark for any appropriate descriptive response of an engineer's task (design/calculate/select/model...) and the electrical aspect (must be linked to design of visitor centre). Not design a circuit/wiring on its own. Not electronic or electrician related.

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

12. A ski tow used to move skiers to the top of a slope is shown below.



A motorised winch which is rated at 230 V, 12 A, is used in the operation of the tow.

(a) (i) Calculate the electrical energy used when the winch is operated for 1 minute and 20 seconds. 3

(ii) Calculate the output energy if the system is 64% efficient. 3

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

12. (continued)

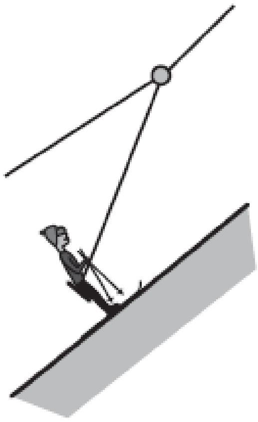
(b) Explain how the efficiency of the motorised winch could be increased. 2

Back to Table

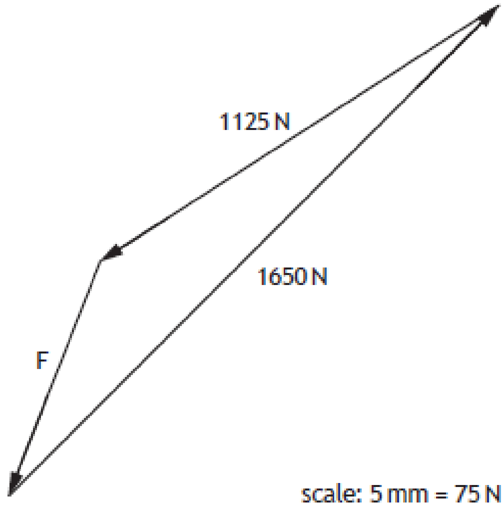
MARKS | DO NOT WRITE IN THIS MARGIN

12. (continued)

A structural engineer analyses the forces exerted by a skier on the tow.



The triangle of forces scale drawing used in the analysis is shown below.



scale: 5 mm = 75 N

(c) Determine, with reference to the triangle of forces shown, the unknown force F. 1

F = ____________ N

Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

12. (continued)

The tow cable has an original length of 2·7 m.

(d) Calculate the change in length of the cable when a strain of 0·0030 is experienced. 3

Back to Table

Back to Table

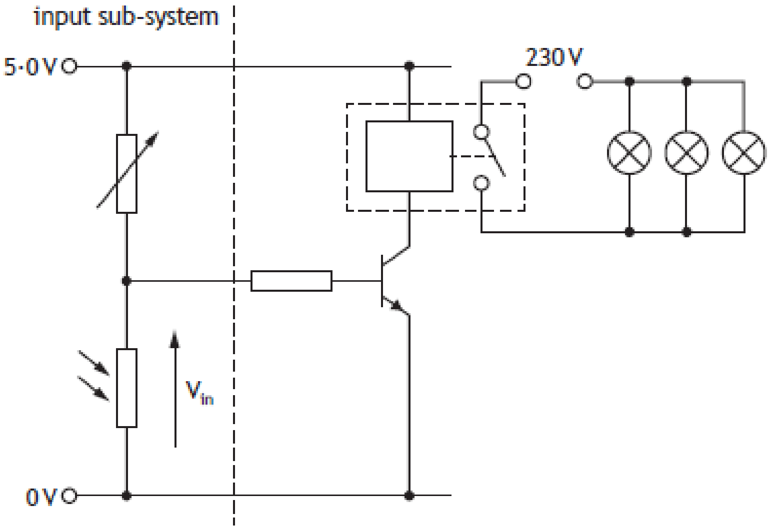
Question			Expected response	Max mark	Additional guidance
12.	(a)	(i)	time = 60 + 20 = 80 (s) $E_e = V\ I\ t$ $E_e = 230 \times 12 \times 80$ $E_e = 220800$ E_e = 220 kJ (2 sf)	3	1 mark for determining time in seconds. Unit not required. 1 mark for substitution. Allow FTE for time. 1 mark for correct answer from given working with unit. Accept calculating energy from power x time.
		(ii)	$\eta = \frac{Eout}{Ein}$ $0 \cdot 64 = \frac{Eout}{220000}$ Eout = 0·64 x 220000 Eout = 140800 Eout = 140 kJ (2 sf)	3	1 mark for substitution Allow for FTE from part a(i). 1 mark for transposition.. 1 mark for correct answer from given working with unit
	(b)		Lubricate winch axles to reduce friction. Use a V belt so that there is less slippage/energy lost.	2	Explanation must relate to motorised winch modifications. 1 mark for cause that increases the efficiency of the winch. Accept use of lubrication/bearings/ toothed belt/V belt chain. 1 mark for effect on friction/energy losses from given cause.
	(c)		600 (N)	1	Unit not required
	(d)		$\varepsilon = \frac{\Delta l}{l}$ $0 \cdot 0030 = \frac{\Delta l}{2700}$ $\Delta l = 0 \cdot 003 \times 2700$ $\Delta l = 8 \cdot 1$ Δl = 8·1 mm (2 sf)	3	1 mark for substitution. 1 mark for transposition. 1 mark for correct answer from given working with unit.

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

13. An automatic lighting system along the side of a path is shown.

A circuit designed to operate the lighting system is shown below.



(a) Describe two advantages of connecting the lamps in parallel instead of in series. 2

1 ______________________________

____

2 ______________________________

____

Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

13. (continued)

When the circuit was tested it was found that the transistor was destroyed. A diode is to be connected into the circuit to protect the transistor.

(b) Draw the symbol for a diode on the circuit shown opposite to protect the transistor. 2

(c) Describe the operation of the input sub-system as the light level decreases. Make reference to the resistance of the LDR and the voltage, V_{in}. 2

As the light level decreases . . .

(d) State the effect on V_{in} when the resistance of the variable resistor is decreased. 1

[Turn over

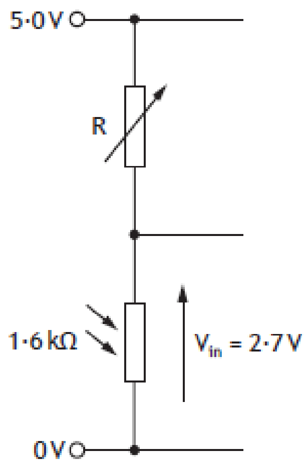
* X 8 2 3 7 5 0 1 2 9 *

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

13. (continued)

The input sub-system used to detect a change in light level is shown below.



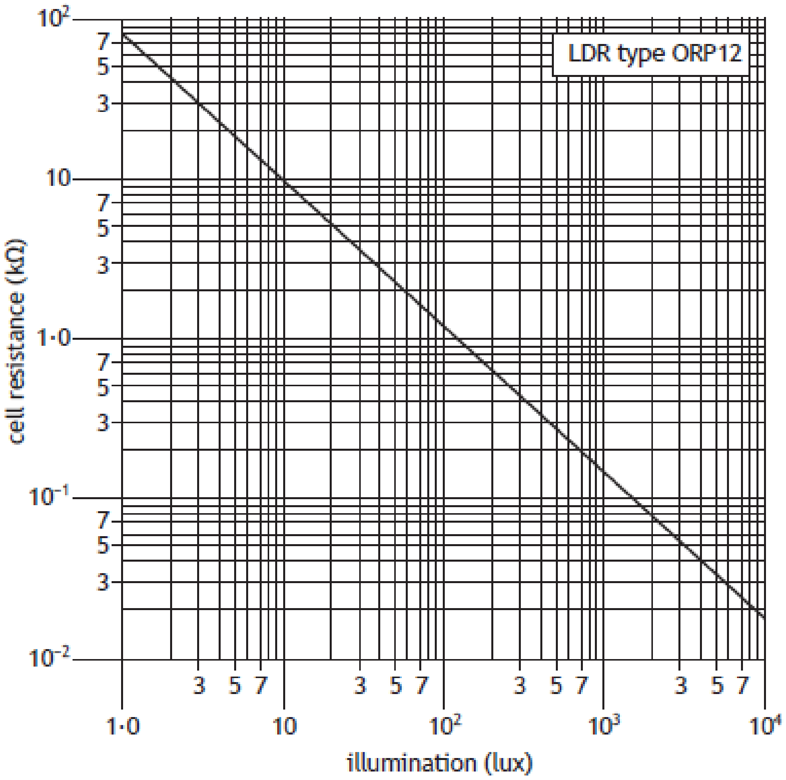
(e) Calculate the resistance of the variable resistor (R) for the condition shown above. 4

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

13. (continued)

The operating characteristics of the LDR used are shown on the graph below.



(f) Determine, with reference to the graph, the illumination level when the LDR has a resistance of 200 Ω. **1**

__________ lux

[Turn over

Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

13. (continued)

An electronic engineer used computer simulation when designing the circuit for the lighting system.

(g) Describe two advantages of using computer simulation, compared to building a circuit, when initially designing a solution. 2

1 ______________________________

____

____

2 ______________________________

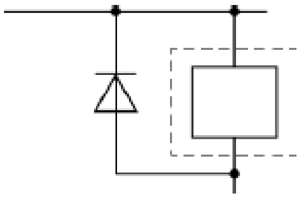
____

____

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

Back to Table

Back to Table

Question			Expected response	Max mark	Additional guidance
13.	(a)		All lamps will have maximum brightness/230 volts. If one lamp fails the rest will remain on.	2	Descriptive response. 1 mark for each advantage. Do not accept all lamps will be the same brightness/voltage on its own.
	(b)			2	1 mark for correct symbol (accept if line in centre of triangle is omitted. 1 mark for correct orientation and connection. Allow FTE.
	(c)		*As the light level decreases…* …the resistance (of the LDR) increases.. …voltage (V_{in}) will increase.	2	Descriptive response. 1 mark for resistance of LDR increase. 1 mark for input voltage increase. Apply FTE based on resistance response.
	(d)		V_{in} will increase.	1	No FTE from 13(c).

Question			Expected response	Max mark	Additional guidance
13.	(e)		$5 - 2{\cdot}7 = 2{\cdot}3$ (V) $\frac{R_1}{1{\cdot}6} = \frac{2{\cdot}3}{2{\cdot}7}$ $R_1 = \frac{2{\cdot}3}{2{\cdot}7} \times 1{\cdot}6$ $R = 1{\cdot}363$ $R = 1{\cdot}4\ k\Omega$ (2 sf) OR $V_R = IR$ $2{\cdot}7 = I \times 1{\cdot}6$ $I = 1{\cdot}688$ (mA) $V_R = 5{\cdot}0 - 2{\cdot}7 = 2{\cdot}3$ (V) $V = IR$ $2{\cdot}3 = 1{\cdot}688 \times R_R$ $R = \frac{2{\cdot}3}{1{\cdot}688}$ $R = 1{\cdot}363$ $R = 1{\cdot}4\ k\Omega$ (2 sf)	4	1 mark for voltage across variable resistor. Ignore unit. 1 mark for substitution (apply FTE and accept 5·0 V if V_1 is not calculated). 1 mark for transposition. 1 mark for correct answer from given working with unit. 1 mark for calculating current (ignore unit). 1 mark for calculating voltage V_R (ignore unit). 1 mark for transposition (allow FTE). 1 mark for correct answer from given working with unit.
13.	(f)		700 (lux)	1	Unit not required.
13.	(g)		Quicker to develop solution. Easier to change circuit during testing. Reduces cost of designing as components will not be destroyed. Safer as 230 V circuit can be tested without fear of electrocution. No risk of damage to any actual components.	2	Descriptive advantage. 1 mark for each relevant statement. Not faster, cheaper, easier or safer on its own. Do not accept testing can be carried out without an advantage. Cost responses must relate to speed or no damaged components.

Back to Table

14. A mechanical harvester used to pick fruit on a farm is shown.

(a) Describe two economic impacts of the mechanical harvester. 2

1 ________________________________

2 ________________________________

[Turn over

Back to Table

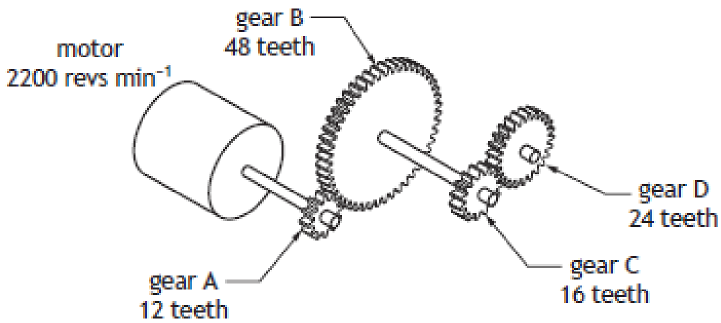
Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

14. (continued)

A conveyor belt used to transport fruit along the machine is shown below.

Part of the conveyor belt mechanism is shown below.



(b) Calculate the output speed of gear D. **4**

Back to Table

[Back to Table]

14.	(a)		The harvester would be expensive to buy/maintain/run. Workers would lose their jobs therefore lose income. Harvester would be able to pick the fruit quicker/more fruit picked in a day meaning more profit. Increase profit for the farmer as wages would be reduced. Only ripe fruit would be picked therefore reducing waste increasing overall tonnage and profit. No need to house so many workers therefore increased profits. Workers would move away causing local shops to lose income.	2	1 mark for each appropriate economic description. Job and speed based responses must include reference to income/profit.

14.	(b)		2200×12 = Output speed x 48	4	1 mark for substitution.
			Output speed $= \frac{26400}{48}$		
			Output speed = 550 (revs min^{-1})		1 mark for correct answer from given working (unit not required).
			550×16 = Output speed x 24		1 mark for substitution Allow FTE.
			Output speed $= \frac{8800}{24}$		
			Output speed = 366·7		
			Output speed = 370 revs min^{-1} (2 sf)		1 mark for correct answer from given working with unit. Do not accept RPM.
			OR		
			$\frac{output\ speed}{input\ speed} = \frac{A}{B} x \frac{C}{D}$		
			$\frac{\text{output speed}}{2200} = \frac{12}{48} \times \frac{16}{24}$		1 mark for first ratio. 1 mark for second ratio.
			output speed $= \frac{12}{48} \times \frac{16}{24}$ x 2200		
			Output speed $= \frac{1}{6} \times 2200$		1 mark for transposition (2200/6 if ratios inverted).
			Output speed = 366·7		
			Output speed = 370 revs min^{-1} (2 sf)		1 mark for answer from working with unit.

[Back to Table]

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

15. A set of hair straighteners is shown.

A microcontroller is used to operate the hair straighteners using the following simplified sequence.

- When a push switch is operated the heating plates turn on.
- A buzzer will then sound for 0·8 seconds and then turn off.
- An LED will then repeatedly turn on for 0·3 seconds and turn off for 0·3 seconds until the correct temperature is reached.
- When the push switch is pressed again the heating plates turn off.
- The sequence will then repeat.

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

Input connection	Pin	Output connection
	7	Heating plates
	6	Buzzer
	5	LED
Temperature sensor (1 = correct temperature)	1	
Push switch	0	

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

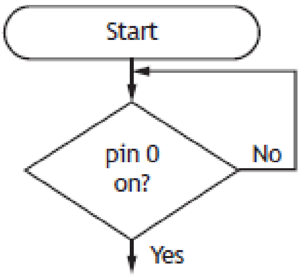
Include all pin numbers and delay units in your flowchart. 9

Back to Table

Back to Table

DO NOT WRITE IN THIS MARGIN

15. (a) (continued)



[Turn over for next question

Back to Table

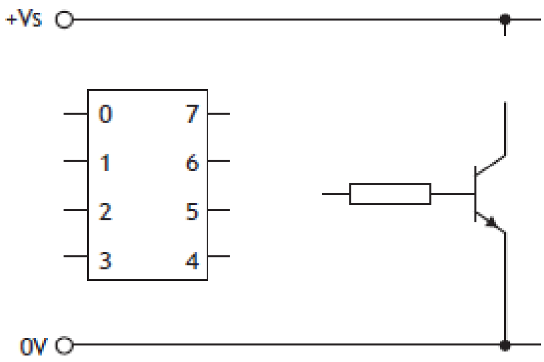
Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

15. (continued)

The buzzer is switched on by a transistor connected to pin 6 of the microcontroller.

(b) Complete the diagram below by adding the symbol for a buzzer and the connection to the microcontroller. 2

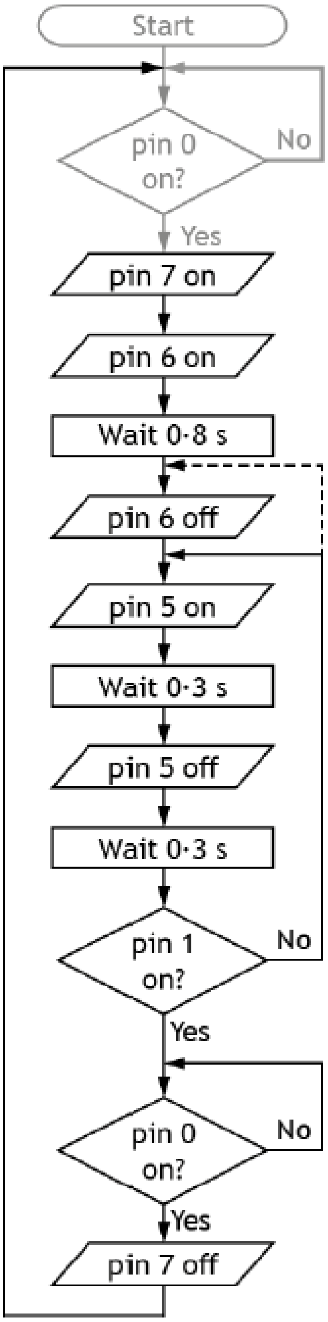
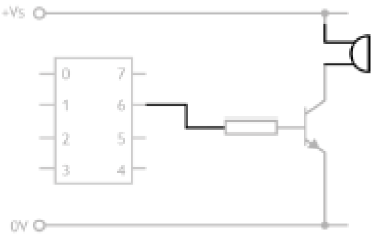


[END OF QUESTION PAPER]

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

Back to Table

Back to Table

Question			Expected response	Max mark	Additional guidance
15.	(a)			9	Pin numbers must be correct where applicable. Pin 7 on and off positions - 1 mark. Pin 6 on and off positions - 1 mark. All three delays positions (0·8 s and 2 x 0·3 s) with unit - 1 mark. Pin 5 on and off in positions - 1 mark. Pin 1 on ? with Y/N - 1 mark. Loop and arrow (Pin 1 on ?) back to before Pin 5 on - 1 mark. Pin 0 on ? with Y/N loop and arrow - 1 mark. Continuous loop to start with arrow - 1 mark. All marked symbols correct - 1 mark. Ignore any additional steps.
	(b)			2	1 mark pin 6 connection. 1 mark for buzzer symbol and connection.

[END OF MARKING INSRUCTIONS]

page 17

Back to Table

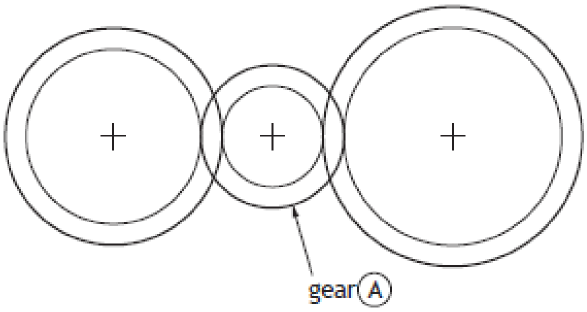
Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

SECTION 1 — 20 marks

Attempt ALL questions

1. A gear train is shown below.



(a) State the type of gear train shown. 1

(b) State the name of gear A. 1

2. An incomplete system diagram for a hair dryer is shown.

(a) Complete the system diagram above by adding the missing output. 1

(b) State the type of control that has no feedback. 1

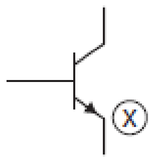
Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

3. A force of 2200 N is required to push a workbench across a workshop floor.

Calculate the work done when the workbench is pushed a distance of 12 m. 2

4. Transistors are used in many electronic products.



(a) Describe the function of a transistor. 1

(b) State the name of connection X on the transistor symbol above. 1

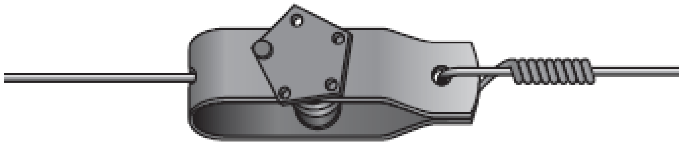
[Turn over

Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

5. A tensioner is used to tighten the wire on a farm fence.



A 25 m length of wire was stretched by 0.012 m when fully tensioned.

(a) Calculate the strain in the wire. 2

The table below shows details of materials that were considered for the wire.

Material	Corrosion resistant	Property
A	no	ductile
B	yes	brittle
C	yes	ductile
D	no	brittle

(b) Select the most suitable material (A–D) from the table for the wire and justify your choice. 2

Choice of material ____________________

Justification ____________________

____

____

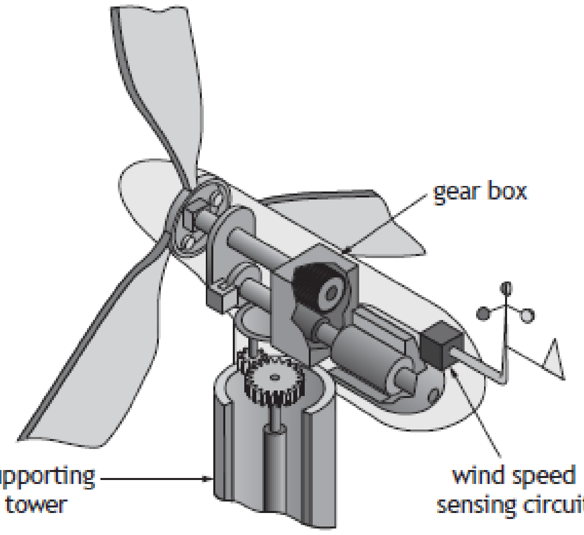
Back to Table

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

6. An offshore wind farm has wind turbines which are located out at sea.

A diagram of the inside of one of the wind turbines is shown.



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

(i) wind speed sensing circuit **1**

(ii) supporting tower **1**

(iii) gear box. **1**

(b) Describe one role an environmental engineer would have during the construction of the offshore wind farm. **1**

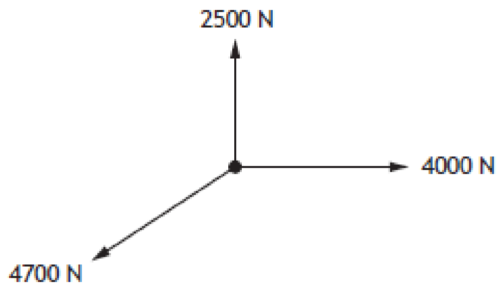
[Turn over

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

Back to Table

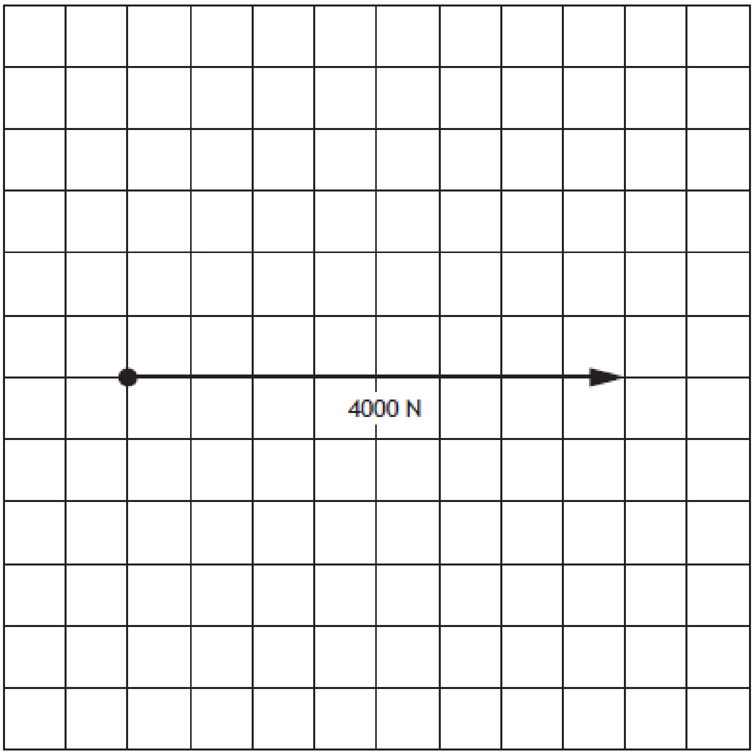
MARKS | DO NOT WRITE IN THIS MARGIN

7. Three forces, in equilibrium, acting on part of a structure are shown below.



Complete the triangle of forces scale drawing below for the given forces.
Forces must include an arrow head to show the direction. 2

scale 10 mm = 500 N



Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

8. A solar farm is shown.

Describe two environmental impacts of solar as a source of energy. 2

1 ____

____

2 ____

____

[Turn over

Back to Table

Back to Table

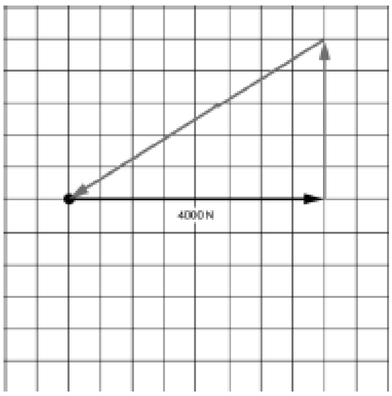
Marking instructions for each question

Section 1

Question			Expected response	Max mark	Additional guidance
1.	(a)		Simple	1	
	(b)		Idler	1	
2.	(a)		Sound/movement (air)	1	Accept noise/kinetic. Ignore any additional words. Do not accept wind.
	(b)		Open loop (control)	1	Do not accept open on its own
3.			Work done = Force × Distance Work done = 2200 × 12 Work done = 26400 Work done = 26000 J (2 sf)	2	1 mark for substitution. 1 mark for correct answer from given working with unit. Accept Nm as unit.
4.	(a)		Acts as a (electronic) switch	1	Descriptive response of function. Accept amplifies current/signal.
	(b)		Emitter	1	
5.	(a)		$\varepsilon = \frac{\Delta l}{l}$ $\varepsilon = \frac{0.012}{25}$ $\varepsilon = 0.00048$ (2 sf)	2	1 mark for substitution. 1 mark for correct answer from given working. Ignore any unit.
	(b)		(material) C it is corrosion resistant and it is ductile/not brittle it is resistant to corrosion because it will be used outside it is ductile and so it will not snap	2	1 mark for material C. 1 mark for identification of both properties or justification of one. Do not accept strong. Allow FTE from chosen material.

Back to Table

Back to Table

Question			Expected response	Max mark	Additional guidance
6.	(a)	(i)	Electronic	1	Do not accept electrical.
		(ii)	Structural	1	
		(iii)	Mechanical	1	
	(b)		Monitoring the sea life Monitoring the impact on the sea bed Check that the contractors are meeting legislation	1	Descriptive response during construction phase. 1 mark for any appropriate response of an engineer's activity and an environmental aspect. Accept land-based descriptions.
7.				2	1 mark for vertical line (2500N - 5 squares) upward joined nose to tail to 4000N. 1 mark for the inclined (4700N) force drawn to scale with arrow (slopping down to left) onto the end of the 4000N line. Allow FTE from incorrect vertical force. 1 mark for completing the triangle with an arrow (any direction).
8.			It does not produce greenhouse gases It does not pollute (when in use) Solar reduces the need to burn fossil fuels/extracting resources/fewer greenhouse gases Reduced effect on climate change/ carbon footprint (when in use) Spoils/disrupts the natural landscape Wildlife distrupted/habitats destroyed	2	Descriptive response. 1 mark for each environmental impact. Can be an advantage or disadvantage. Accept solar used in other contexts. Do not accept renewable/does not use fossil fuel/uses lots of land, on its own. Accept disruption/resources used during construction.

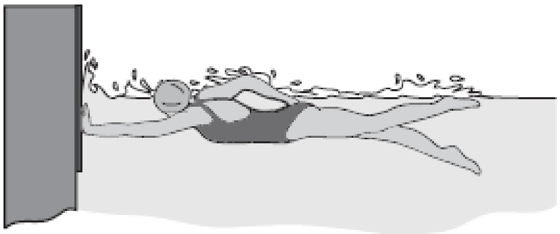
Back to Table

DO NOT WRITE IN THIS MARGIN

SECTION 2 — 90 marks

Attempt ALL questions

9. In a swimming competition, a system is used to automatically measure a competitor's time.



The system is operated by a microcontroller.

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

Input connections	Pin	Output connections
	7	buzzer
	6	timer
lane switch	1	
master switch	0	

The system operates using the following sequence.

- A master switch is pressed
- A buzzer then sounds on and then off three times over 1.5 seconds
- The timer then starts
- When a lane switch is pressed the timer stops
- The system will then reset ready to be used again

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

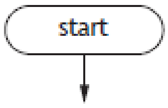
Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

9. (continued)

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

Include all pin numbers and delay units in your flowchart. **10**



MARKS | DO NOT WRITE IN THIS MARGIN

9. (continued)

A program used in a different control system is listed below.

```
line  program
1     main:     let count = 0
2     label_1:     switch on 4
3                  switch on 5
4                  pause 600
5                  switch off 4
6                  switch off 5
7                  pause 600
8                  let count = count + 1
9               if count = 20 then label_2
10              goto main
11    label_2:  if Input0 is on then label_3
12              goto label_2
13    label_3:  switch on 7
14              pause 3000
15              switch off 7
16              goto main
```

(b) Describe the function of line 16 in the program. **1**

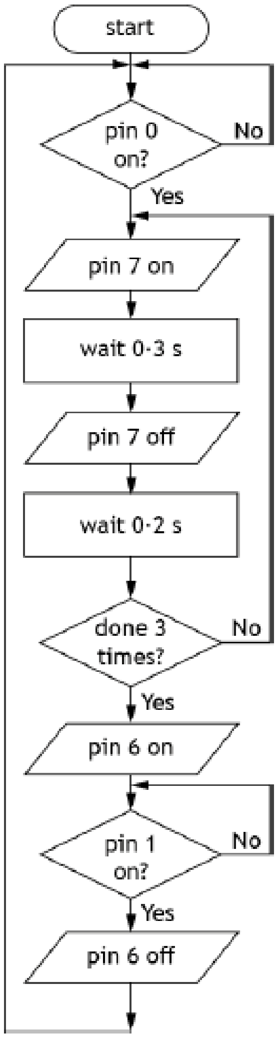
Lines 2 to 9 should repeat twenty times before moving on to line 11.

During testing an electronic engineer found that this did not happen.

(c) Explain why lines 2 to 9 did not repeat twenty times before moving on to line 11. **2**

X823750110

Back to Table

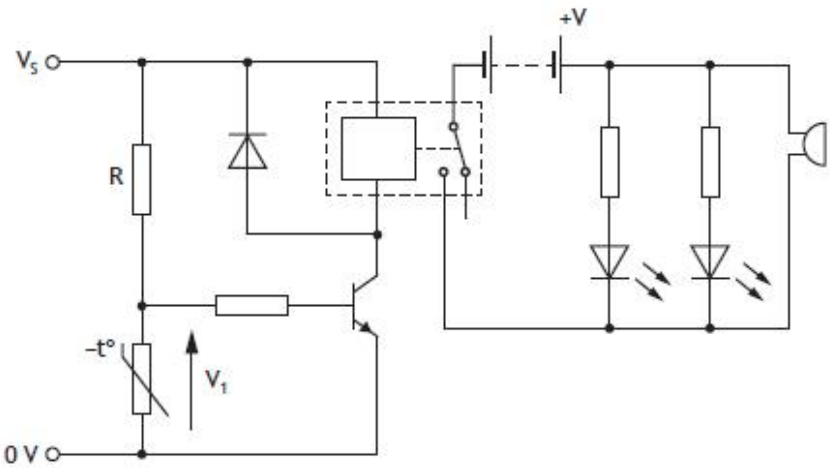
Question			Expected response	Max mark	Additional guidance
9.	(a)			10	Pin 0 on ? with Y/N, loop and arrow in correct position - 1 mark. Pin 7 on and off in correct position - 1 mark. Both delays in correct position (ignore incorrect values and unit) - 1 mark. Total delay time(s) with unit = 0.5 s per cycle - 1 mark. X3 decision with Y/N in correct position - 1 mark. Loop and arrow (x3 decision) back to before pin 7 on - 1 mark. Pin 6 on and off in correct position - 1 mark. Pin 1 on? with Y/N, loop and arrow in correct position - 1 mark. Accept decision feedback loop to before pin 6 on. Continuous loop to start with arrow - 1 mark. All marked symbols correct - 1 mark. Ignore any additional steps. accept on/off repeated 3 times max 2 marks.

9.	(b)		To go back to line 1/main/restart the program To create a continuous loop.	1	Descriptive response. 1 mark for looping program back to start. Accept reset the program. Do not accept go to main on its own.
	(c)		The program loops back to line 1/main/"let count = 0"/wrong line …therefore it will reset the count/ the count will not pass 1/count will not reach 20.	2	1 mark for program looping back to the line 1 (cause). 1 mark for resetting the count (effect).

Back to Table

10. The road gritter shown below is used to spread salt on icy roads.

The warning circuit shown below is used to alert the driver of a low temperature.



Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

10. (continued)

(a) Describe the operation of the warning circuit shown opposite. Make reference to the resistance of the thermistor and the voltage V_1. 4

When the temperature decreases to a low temperature . . .

The fixed resistor (R) is replaced with a variable resistor.

(b) Explain the effect on the operation of the warning circuit by replacing the fixed resistor (R) with the variable resistor. 2

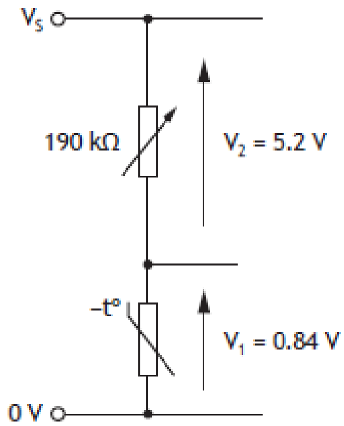
[Turn over

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

10. (continued)

The input sensing circuit (which is part of the warning circuit) is shown below.



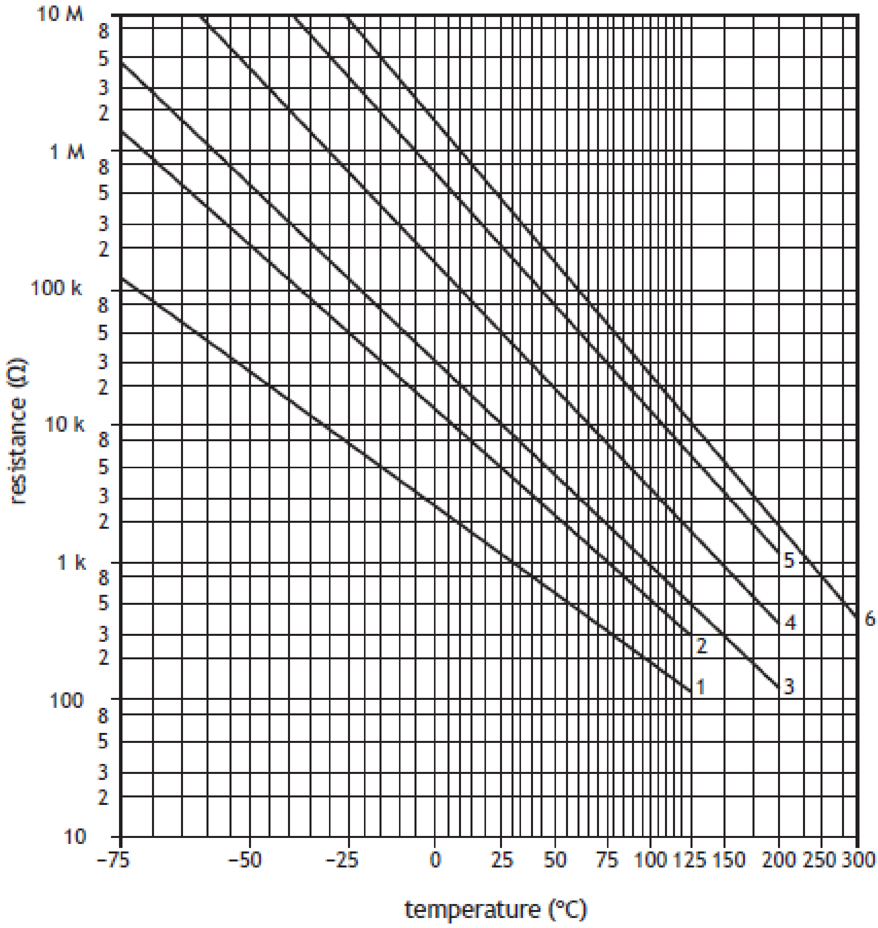
(c) Calculate the resistance of the thermistor. 3

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

10. (continued)

The operating characteristics of a range of thermistors are shown on the graph below.



(d) Determine (with reference to the graph above) the resistance of a type 3 thermistor when the temperature is 10 °C. 1

____

[Turn over

X823750115

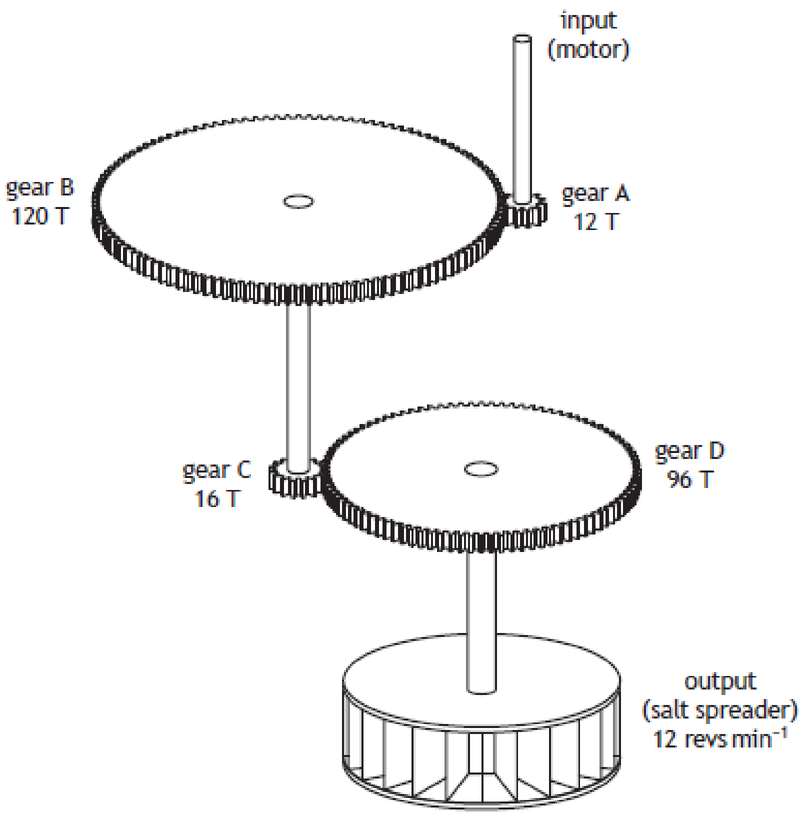
Back to Table

Back to Table

10. (continued)

MARKS | DO NOT WRITE IN THIS MARGIN

The gear train shown below is used to drive the salt spreading system.



(e) Calculate the input speed of the motor. 4

Back to Table

Back to Table

10.	(a)		*When the temperature decreases to a low temperature ...* The resistance (of the thermistor) will increase. This will cause the voltage (V_1) to increase. When the voltage V_1 increases the transistor/relay will switch on. ... turning on the LEDs and buzzer.	4	Descriptive response. 1 mark for resistance of thermistor increase. 1 mark for voltage V_1 increase. 1 mark for transistor switching on/ saturate or relay energising/switch on. 1 mark for both LEDs and the buzzer turning on. Apply FTE between each statement.
	(b)		The resistance of the variable resistor can be altered ...which will change the temperature that will give a warning.	2	1 mark for resistance can be adjusted (cause). Do not accept the resistance is different. 1 mark for a different temperature(s) to activate the circuit (effect).
10.	(c)		$\frac{V1}{V2} = \frac{R1}{R2}$ $\frac{0.84}{5.2} = \frac{R}{190}$ $R = 0.16154 \times 190$ $R = 30.6926$ R = 31 kΩ (2 sf) OR $V_R = IR$ $5.2 = I \times 190$ I = 0.027368 (mA) $V = IR$ $0.84 = 0.027368 \times R$ $R = \frac{0.84}{0.027368}$ $R = 30.6928$ R = 31 kΩ (2 sf)	3	 1 mark for substitution. 1 mark for transposition. 1 mark for correct answer from given working with unit. 1 mark for calculating current. 1 mark for transposition (allow FTE.) 1 mark for correct answer from given working with unit.
	(d)		20 kΩ	1	1 mark for correct answer with unit. Accept 20 000 Ω.

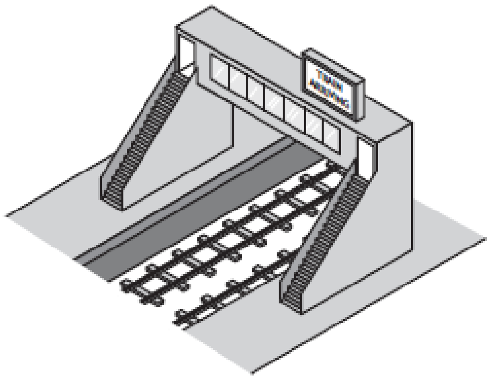
Back to Table

Back to Table

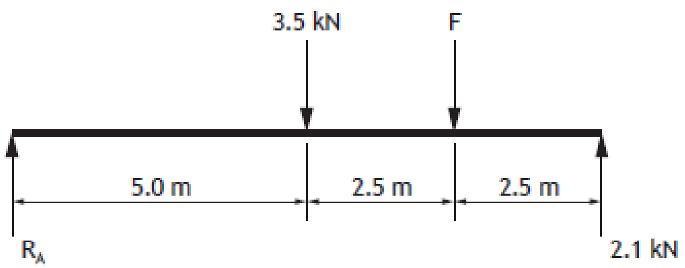
Question			Expected response	Max mark	Additional guidance
10.	(e)		$Input_{speed} \times in_{size} = output_{speed} \times out_{size}$ $12 \times 96 = \text{output speed} \times 16$ $\text{output speed} = \frac{1152}{16}$ output speed = 72 (revs min^{-1}) $12 \times \text{input speed} = 72 \times 120$ $\text{input speed} = \frac{8640}{12}$ Input speed = 720 revs min^{-1} (2 sf) OR $\frac{\text{output speed}}{\text{input speed}} = \frac{A}{B} \times \frac{C}{D}$ $\frac{12}{\text{input speed}} = \frac{12}{120} \times \frac{16}{96}$ $\text{input speed} = \frac{12}{\left(\frac{12}{120} \times \frac{16}{96}\right)}$ $\text{input speed} = \frac{12}{\left(\frac{1}{60}\right)}$ input speed = 720 revs min^{-1} (2 sf)	4	1 mark for substitution. 1 mark for correct answer from given working (unit not required). 1 mark for substitution. 1 mark for correct answer from given working with unit. Allow FTE. Do not accept RPM. 1 mark for first ratio (could be inverted). 1 mark for second ratio (same order as first ratio). Accept simplified ratios. 1 mark for transposition (12×60 if ratios inverted). 1 mark for correct answer from given working with unit.

MARKS DO NOT WRITE IN THIS MARGIN

11. A walkway linking two railway platforms is shown.



A simplified freebody diagram of the walkway and sign (force F) is shown below.



(a) (i) Calculate the force F by taking moments about R_A. 3

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

11. (a) (continued)

(ii) Calculate the reaction force R_A. 2

Lifts are installed at both ends of the walkway.

(b) (i) Describe one positive social impact of installing the lifts. 1

(ii) Describe one positive economic impact of installing the lifts. 1

(iii) Describe one negative economic impact of installing the lifts. 1

[Turn over

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

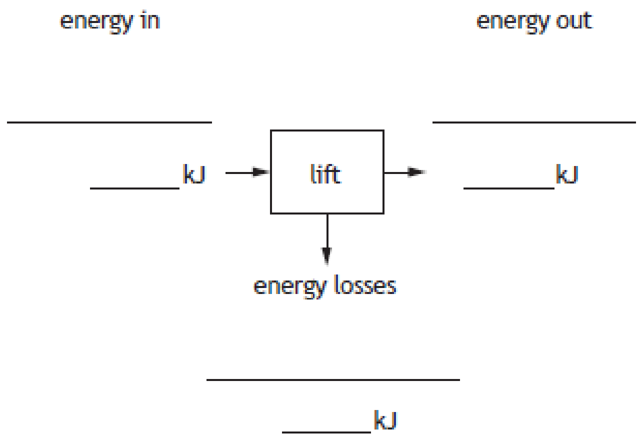
11. (continued)

The electrical energy supplied to raise one lift up to the walkway is 44 kJ.

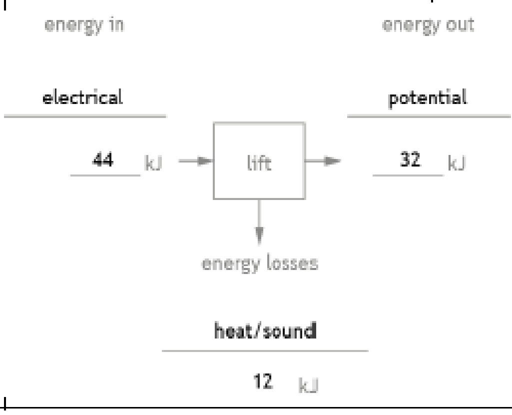
The lift has a potential energy of 32 kJ when it is at the top of the walkway.

(c) Complete the energy audit diagram below for the lift. **3**

Include the main forms of energy and their values.



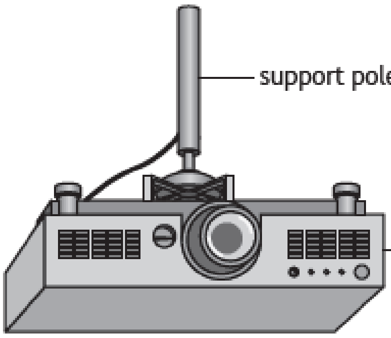
Question			Expected response	Max mark	Additional guidance
11.	(a)	(i)	$\Sigma CWM = \Sigma ACWM$ $(3.5 \times 5) + (F \times 7.5) = (2.1 \times 10)$ $17.5 + (F \times 7.5) = 21$ $F = \frac{3.5}{7.5}$ $F = 0.4666666667$ $F = 0.47$ kN (2 sf)	3	1 mark for substitution. 1 mark for transposition. 1 mark for correct answer from given working with unit.
		(ii)	$\Sigma F_{vertical} = 0$ $3.5 + 0.47 = R_A + 2.1$ $R_A = 3.97 - 2.1$ $R_A = 1.87$ $R_A = 1.9$ kN (2 sf)	2	1 mark for substitution. Allow FTE from part a(i). 1 mark for correct answer from given working with unit.
	(b)	(i)	More people will be able to use the station. Easier access/less effort for travellers to reach the platform/ walkway. Jobs created during installation/ maintenance.	1	Descriptive positive social response. Benefit must relate to the person/people - stated/implied and the context. Do not accept save people time/ jobs on its own.
		(ii)	Increase in profits by installing lifts. (Maintenance) jobs created giving income. (Easier access for everyone) so increased profit/customers in platform shops.	1	Descriptive positive economic response. Response must include cost/money benefit stated/inferred. Do not accept employment/increase in profit on its own.
		(iii)	The (lift) would be expensive to install/maintain. Increase in running costs.	1	Descriptive negative economic response. Response must include cost/money drawback stated/inferred. Do not accept employment/cost/ losses on its own.

Question			Expected response	Max mark	Additional guidance
11.	(c)			3	1 mark for input electrical energy and 44 (kJ). 1 mark for output potential energy and 32 (kJ). 1 mark for lost heat/sound energy and 12 (kJ). Allow FTE for energy losses value.

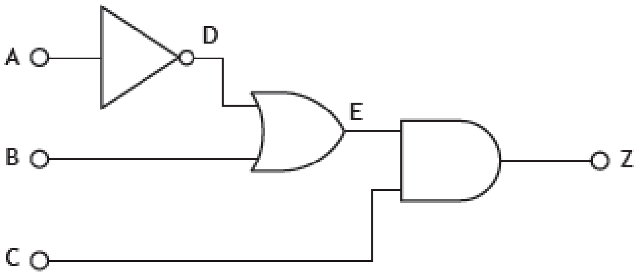
Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

12. A ceiling mounted data projector and support pole are shown.



Logic circuits are used to control the data projector. A logic diagram for one of the circuits is shown below.



(a) 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			

Back to Table

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

12. (continued)

The Boolean equation for a second logic circuit is given below.

$$(L \cdot M) + \overline{N} = Y$$

(b) Complete the logic diagram below for this Boolean equation. 3

(c) Describe two advantages of using computer simulation to test a logic circuit before constructing a prototype. 2

1 ____

____

____

2 ____

____

____

Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

12. (continued)

The support pole used to hold the data projector has a cross-sectional area of 190 mm^2 and a stress of 0.84 N mm^{-2}.

(d) (i) Calculate the force acting on the support pole. 3

(ii) State the nature of the force in the support pole as the data projector pulls down on it. 1

The pole supporting the data projector is replaced with one which has a larger cross-sectional area.

(e) Describe the effect this will have on the stress in the support pole. 1

[Turn over

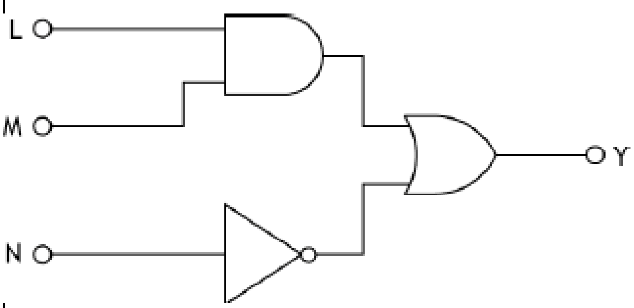
Back to Table

<table>
<tr><th colspan="3">Question</th><th>Expected response</th><th>Max mark</th><th>Additional guidance</th></tr>
<tr><td>12.</td><td>(a)</td><td></td><td>
<table>
<tr><th>D</th><th>E</th><th>Z</th></tr>
<tr><td>1</td><td>1</td><td>0</td></tr>
<tr><td>1</td><td>1</td><td>1</td></tr>
<tr><td>1</td><td>1</td><td>0</td></tr>
<tr><td>1</td><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td><td>0</td></tr>
<tr><td>0</td><td>0</td><td>0</td></tr>
<tr><td>0</td><td>1</td><td>0</td></tr>
<tr><td>0</td><td>1</td><td>1</td></tr>
</table>
</td><td>3</td><td>1 mark per correct complete column.

Column D = NOT A

Allow for FTE

Column E = B OR D

Column Z = C AND E</td></tr>
<tr><td></td><td>(b)</td><td></td><td>
</td><td>3</td><td>1 mark for L and M wired individually to AND gate.

1 mark for N wired to NOT gate.

1 mark for OR gate output wired to Y and inputs to NOT and AND.

FTE - 1 mark OR gate wired to N and/or L and M if a previous gate(s) omitted.</td></tr>
</table>

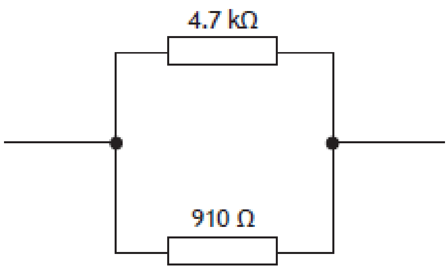
Question			Expected response	Max mark	Additional guidance
12.	(c)		Quicker to assemble the circuit Quicker to change the circuit Easier to see faults/issues with circuit Reduces cost as components will not be destroyed No risk of damage to actual components/user	2	Descriptive advantage. 1 mark for each relevant statement. Not speed, cost, safety, ease, on its own. Cost must relate to speed or no damaged components.
	(d)	(i)	$\sigma = \frac{F}{A}$ $0.84 = \frac{F}{190}$ $F = 0.84 \times 190$ $F = 159.6$ $F = 160$ N (2 sf)	3	1 mark for substitution. 1 mark for transposition. 1 mark for correct answer from given working with unit.
		(ii)	Tensile/Tension	1	Accept Tie. Do not accept pulling force/gravity.
	(e)		The stress will decrease	1	

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

13. A hoverboard is shown.

Part of the circuit used in the control of the hoverboard is shown below.



(a) (i) Calculate the total resistance of the circuit. 2

(ii) Draw the symbol for a voltmeter, connected on the circuit above, to measure the voltage across the 910 Ω resistor. 2

(iii) Indicate, with an X, on the circuit above where an ammeter would be connected to measure the total current. 1

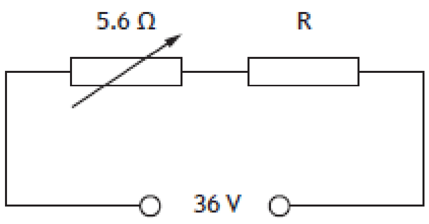
Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

13. (continued)

Part of a second circuit used in the hoverboard is tested using a 36 V supply.



(b) Calculate the value of resistor R to ensure that the circuit current is 2.0 A. 4

[Turn over

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

13. (continued)

The hoverboard and rider have a combined mass of 64 kg.

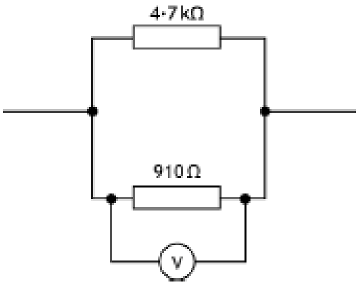
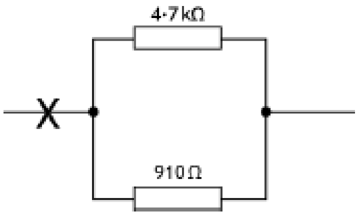
(c) Calculate the kinetic energy of the hoverboard and rider when they are travelling at 3.4 m s^{-1}. 2

The hoverboard is an established technology.

A driverless car is an emerging technology that is not yet established.

(d) Explain a possible impact of driverless cars on road safety. 2

Back to Table

Question			Expected response	Max mark	Additional guidance
13.	(a)	(i)	$RT = \frac{R1 \times R2}{R1 + R2}$ $RT = \frac{4700 \times 910}{4700 + 910}$ RT = 762.3885918 Ω RT = 760 Ω (2 sf) $\frac{1}{Rt} = \frac{1}{4700} + \frac{1}{910}$ Rt = 762.3885918 Ω Rt = 760 Ω (2 sf)	2	1 mark for substitution with the same unit. 1 mark for correct answer from given working with unit. 1 mark for substitution with the same unit. 1 mark for correct answer from given working with unit.
		(ii)		2	1 mark for correct symbol. 1 mark for correct wiring across the 910 Ω resistor branch.
		(iii)		1	1 mark for X (ammeter) in correct series position. Accept X on the wire at either side. Do not accept X on a node.

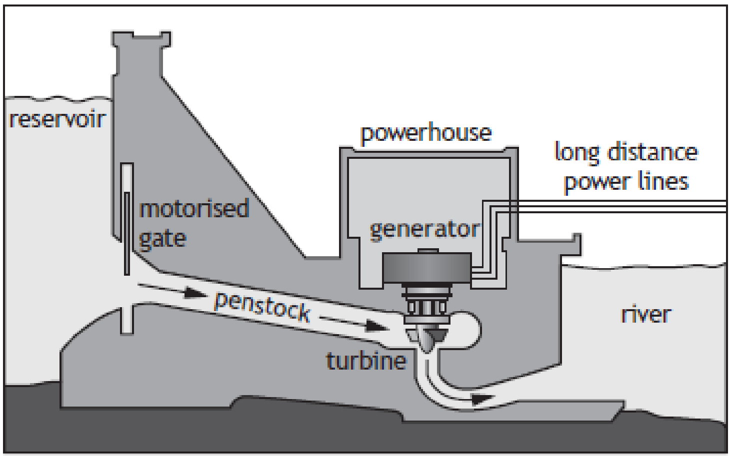
Back to Table

Question			Expected response	Max mark	Additional guidance
13.	(b)		$V = IR_T$ $36 = 2 \times R_T$ $RT = \frac{36}{2}$ $R_T = 18\ (\Omega)$ $R = 18 - 5{\cdot}6$ $R = 12.4$ $R = 12\ \Omega$ (2 sf) OR $V = IR$ $V = 2 \times 5.6$ $V = 11.2$ (V) $V_R = V_S - V$ $V_R = 36 - 11.2$ $V_R = 24.8$ (V) $V = IR$ $R = \frac{24.8}{2}$ $R = 12.4$ $R = 12\ \Omega$ (2 sf)	4	1 mark for substitution. 1 mark for transposition. 1 mark for correct answer from given working (units not required). 1 mark for correct answer from given working with unit. Allow FTE. 1 mark for voltage over 5.6 Ω resistor (units not required). 1 mark for voltage over R (units not required). 1 mark for transposition. 1 mark for correct answer from given working with unit. Allow FTE. If voltage divider ratio used mark as second guidance.

Question			Expected response	Max mark	Additional guidance
13.	(c)		$E_k = \frac{1}{2}mv^2$ $E_k = \frac{1}{2}64 \times 3.4^2$ Ek = 369.92 Ek = 370 J (2 sf)	2	1 mark for substitution. 1 mark for correct answer from given working with unit.
	(d)		Driverless cars have no human error …therefore safer Driverless cars may not be fully tested …which could cause an accident Cars can travel at an appropriate speed/distance between cars …resulting improved road safety	2	Explanation relating to road safety. 1 mark for cause. 1 mark for effect. Do not accept no driver as a cause on its own.

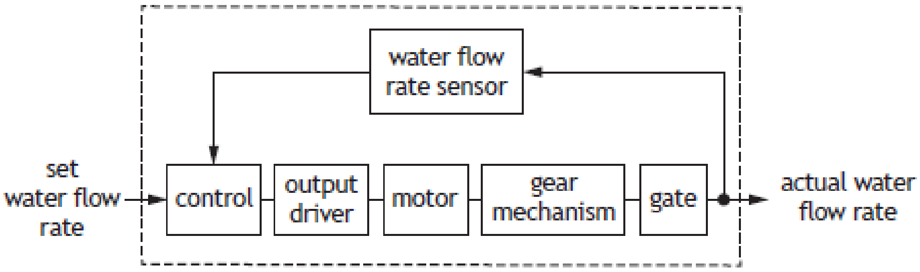
Back to Table

14. Hydropower is used to produce electricity from stored water in a reservoir.
A diagram of a hydropower station is shown.



A steady flow rate of water must move through the penstock to rotate the turbine. The water flow rate is adjusted by a motorised gate which can move up or down.

A sub-system diagram for the control of the motorised gate is shown.



(a) Describe (with reference to the sub-system diagram) the operation of the system. **5**

____

____

____

____

____

____

____

[Turn over

Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

14. (continued)

Part of the gear mechanism used to control the gate movement has a velocity ratio of 14:1 and an input speed of 870 revs min^{-1}.

(b) Calculate the output speed of this part of the gear mechanism. 3

A microcontroller is used in the control of the hydropower station.

(c) Describe one advantage of using a microcontroller instead of a hard wired circuit. 1

Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

14. (continued)

The hydropower station is 0.85 (85%) efficient and generates an output power of 15 MW.

(d) Calculate the input power. 3

(e) Explain the impact of using hydropower on climate change. 2

[Turn over

Back to Table

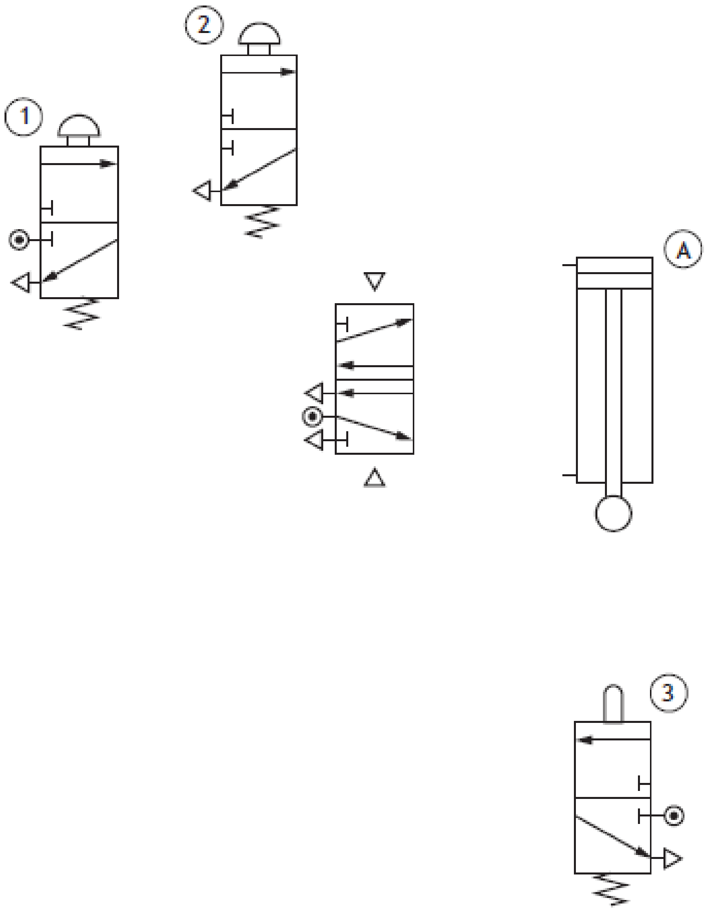
14.	(a)			5	Descriptive responses.
			The water flow rate is set (by the user)		1 mark for the external signal inputted/user setting of level.
			The sensor detects the (actual water) flow rate.		1 mark for description of the sensing action/feedback from sensor.
			The control unit compares both flow rate (values).		1 mark for description of the control (comparison/decision making).
			OR		
			The control unit decides if the rate is too low/high/correct.		1 mark for description of the control of the motor/gear/gate.
			The motor activates/the gear mechanism turns/the gate moves		
			The gate moves up/opens when the rate is too low		
			OR		
			The gate lowers/closes when the rate is too high		1 mark for description of the correct gate movement for the condition described.
			OR		
			The gate will not move when the rate is correct		

Question			Expected response	Max mark	Additional guidance
14.	(b)		Velocity Ratio $= \frac{\text{Speed of Input}}{\text{Speed of Output}}$ $14 = \frac{870}{\text{speed of output}}$ speed of output $= \frac{870}{14}$ speed of output = 62.14285 speed of output = 62 revs min^{-1} (2 sf)	3	1 mark for substitution. Accept 14:1 for VR in substitution. 1 mark for transposition. 1 mark for correct answer from given working with unit. Do not accept RPM.
	(c)		The program can be easily modified/ corrected It is reprogrammable Its more reliable because there are less components	1	Descriptive response relating to when in use. Do not accept cheaper/fewer components/reliable/quicker on its own. Do not accept easier/quicker to replace component.
	(d)		$\eta = \frac{\text{Power out}}{\text{Power in}}$ $0.85 = \frac{15}{\text{Power in}}$ Power in $= \frac{15}{0.85}$ Power in = 17.647 Power in = 18 MW (2 sf)	3	1 mark for substitution. 1 mark for transposition. 1 mark for correct answer from given working with unit.
	(e)		Once in use Hydro power does not emit any greenhouse gases ...therefore does not contribute to global warming When in use Hydro power reduces the need to use fossil fuels ...therefore reducing greenhouse gases/carbon footprint/impact on climate change.	2	Explanation must relate to climate change and the use of Hydro. Do not accept pollution related responses. Do not accept construction based responses. 1 mark for cause. 1 mark for effect.

MARKS | DO NOT WRITE IN THIS MARGIN

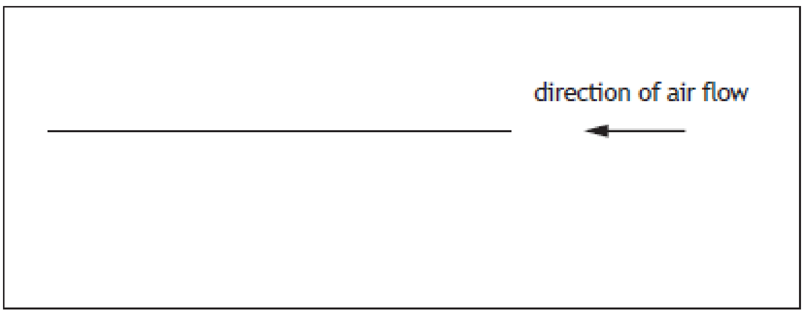
15. A pneumatic circuit is used in part of a manufacturing process.

(a) Complete the piping of the pneumatic circuit below to outstroke the piston in cylinder (A) when valve (1) and valve (2) are actuated. The piston will instroke when valve (3) is actuated. 5



The speed of the piston movement needs to be slowed down.

(b) Draw the symbol for a uni-directional restrictor to slow the air flow in the direction shown. 2



Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

15. (continued)

Cylinder (A) is supplied with an air pressure of 1.4 $N\,mm^{-2}$ and the piston has an outstroking force of 490 N.

(c) Calculate the area of the piston in cylinder (A). 3

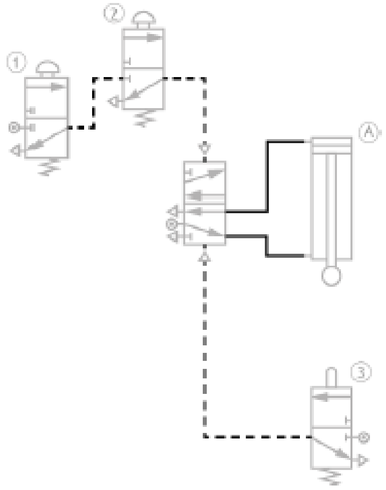
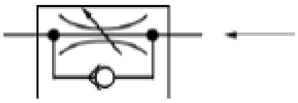
An engineer compared the size of the outstroke force and the instroke force of a double-acting cylinder when supplied with the same air pressure.

The result of the test showed that there was a difference in the size of the two forces.

(d) Explain the difference in the size of these two forces. 2

[END OF QUESTION PAPER]

Back to Table

Question			Expected response	Max mark	Additional guidance
15.	(a)			5	Pipe connections must be port to port. 1 mark for ANDing valve 1 to valve 2 and piping pilot actuator on top of the 5/2 valve. 1 mark for piping up valve 3 to pilot actuator on the bottom of 5/2 valve. 1 mark for a pilot air line type for given piping into the 5/2. 1 mark for top pipe to DAC from 5/2 valve. 1 mark for bottom pipe to DAC from 5/2 valve. Allow FTE if incorrect 5/2 state outputs port are used. 1 mark max for DAC piping.
	(b)			2	1 mark for correct symbol of a uni-directional restrictor. 1 mark for correct orientation of by-pass route. Symbol need not be drawn on the given pipe.
	(c)		$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$ $1.4 = \frac{490}{\text{Area}}$ $A = \frac{490}{1.4}$ $A = 350\ \text{mm}^2$ (2 sf)	3	 1 mark for substitution. 1 mark for transposition. 1 mark for correct answer from given working with unit.

page 17

Question			Expected response	Max mark	Additional guidance
15.	(d)		The area on the instroke is smaller (due to the piston rod), ...resulting in the instroking force being smaller The area on the outstroke is larger (due to no piston rod), ...resulting in the outstroking force being larger The two areas are different ... therefore the outstroke force is larger	2	1 mark for cause (difference in area - stated or inferred). 1 mark for effect (specific effect on difference in force in/outstroke). Do not accept size in place of area. Do not accept forces will be different. Allow FTE.

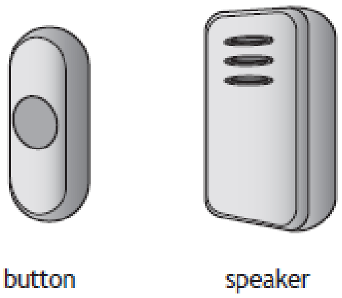
[END OF MARKING INSTRUCTIONS]

MARKS | DO NOT WRITE IN THIS MARGIN

SECTION 1 — 20 marks

Attempt ALL questions

1. The parts of a doorbell, consisting of a button and speaker, are shown.



(a) Complete the system diagram shown below for the doorbell by adding the missing output. 1

user input → doorbell → ____________

The doorbell operates without the use of feedback.

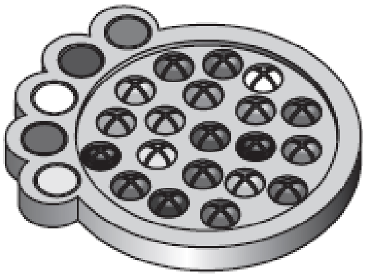
(b) State the type of control that uses feedback. 1

____

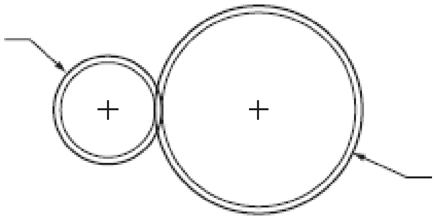
Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

2. A child's game is shown.



A diagram of the simple gear train inside the game is shown below.



Calculate the velocity ratio of this simple gear train. 2

[Turn over

Back to Table

Back to Table

3. A Boolean equation is shown.

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

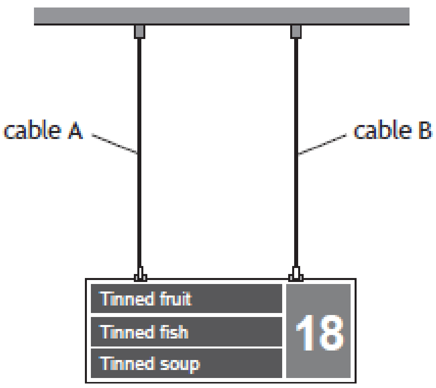
Draw the logic diagram for this Boolean equation. 2

A ○

○ Z

B ○

4. A sign hanging from a supermarket ceiling is shown.



A free body diagram of the sign is to be drawn.

(a) Describe one piece of information that should be included on a free body diagram. 1

____

Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

4. (continued)

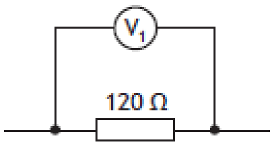
The sign hangs from the ceiling by two cables.

Cable A has an original length of 4.5 m and is stretched by 0.0013 m.

(b) Calculate the strain in cable A. 2

(c) State the nature of the force in cable A. 1

5. Part of a circuit is shown.



(a) Calculate the voltage V_1 across the 120 Ω resistor when the current flow is 0.0025 A. 2

The 120 Ω resistor is replaced by one with a larger resistance.

(b) State the effect on the current if the voltage V_1 remains the same. 1

[Turn over

Back to Table

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

6. A drill uses a 1.5 A, 18 V rated battery.

(a) Calculate the electrical energy supplied by the battery when the drill is used for 160 seconds. **2**

Grease is used to lubricate the gear system within the drill.

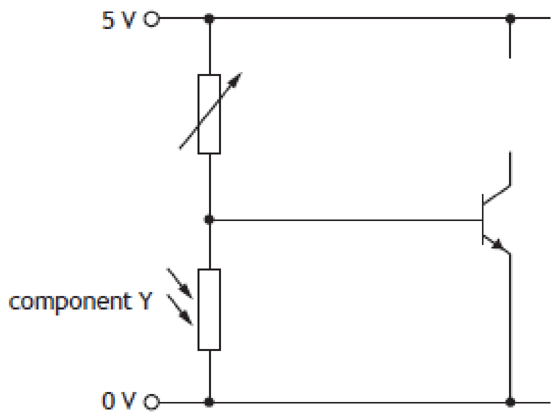
(b) Describe a reason for lubricating the gear system. **1**

Back to Table

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

7. A lamp in a child's night light will automatically switch on when the room is dark. The incomplete circuit diagram used to control the lamp is shown below.



(a) Complete this circuit diagram by adding the symbol for the lamp. **1**

(b) State the full name of component Y in this circuit. **1**

(c) Indicate, with a cross (X) on the circuit above, where an ammeter would be connected to measure the current flowing to the base connection of the transistor. **1**

(d) State the name of the component that could be used to protect the transistor from a large input current. **1**

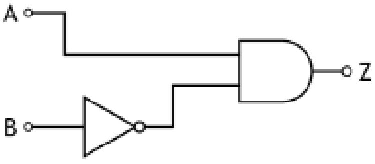
[Turn over

Back to Table

Back to Table

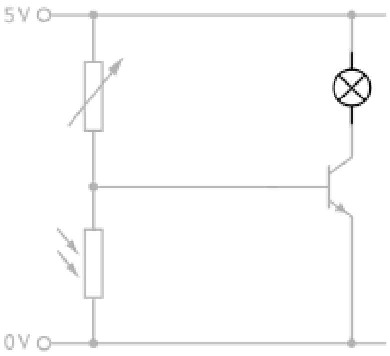
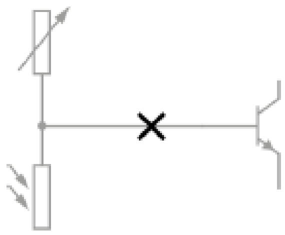
Marking instructions for each question

Section 1

Question			Expected response	Max mark	Additional guidance
1.	(a)			1	1 mark for sound at output. Accept noise/light.
	(b)		Closed loop (control)	1	Do not accept closed on its own.
2.			$\text{Velocity Ratio} = \frac{\text{Speed of Input}}{\text{Speed of Output}}$ $\text{Velocity Ratio} = \frac{360}{12}$ VR = 30 : 1	2	1 mark for substitution. 1 mark for correct answer from given working. Ignore any units. Ratio must be simplified. Accept 30.
3.				2	1 mark for B wired to NOT gate. 1 mark for AND gate with inputs and output connections.
4.	(a)		Size/direction/position of force(s).	1	Descriptive response. Do not accept: size/direction/forces/position on its own. Accept distance between cables.
	(b)		$\varepsilon = \frac{\Delta l}{l}$ $\varepsilon = \frac{0.0013}{4.5}$ $\varepsilon = 0.000288889$ $\varepsilon = 0.00029$ (2 sf)	2	1 mark for substitution. 1 mark for correct answer from given working. Ignore any units.
	(c)		Tensile	1	Accept tension/tie. Do not accept pulling force/gravity.

Back to Table

Question			Expected response	Max mark	Additional guidance
5.	(a)		$V = IR$ $V = 0.0025 \times 120$ $V = 0.30$ V (2 sf)	2	1 mark for substitution. 1 mark for answer from given working with unit.
	(b)		Decrease (in the current).	1	
6.	(a)		$E_e = ItV$ $E_e = 1.5 \times 160 \times 18$ $E_e = 4320$ $E_e = 4.3$ kJ (2 sf)	2	1 mark for substitution. 1 mark for correct answer from given working with unit. Alternative method using power: 1 mark for 27(W). 1 mark for energy (E = P × t) final answer with unit. Apply FTE.
	(b)		Reduce wear (on the gear system). Gears run smoother/quieter. Improve efficiency/battery life. Less heat/sound/energy losses.	1	Descriptive response. Accept reduces friction (stated or implied). Accept stops the gears rusting/ prevents losing torque.

Question			Expected response	Max mark	Additional guidance
7.	(a)			1	1 mark for lamp symbol and correct connections.
	(b)		Light Dependant Resistor	1	Do not accept LDR.
	(c)			1	1 mark for position of ammeter, indicated on the wire, to measure the base current. Accept ammeter symbol in correct position.
	(d)		(Fixed) Resistor	1	Accept variable resistor.

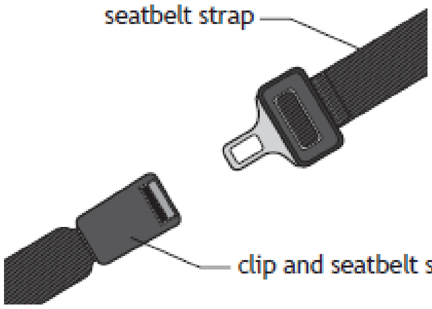
Back to Table

DO NOT WRITE IN THIS MARGIN

SECTION 2 — 90 marks

Attempt ALL questions

8. A car safety system detects when the driver's seatbelt is unfastened.



The safety system is operated by a microcontroller.

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

Input connections	Pin	Output connections
	7	warning lamp
	6	buzzer
seatbelt sensor	0	

The safety system operates using the following sequence:

- A warning lamp and a buzzer turn off.
- When the seatbelt sensor is on, the sequence will return to the start.
- If the seatbelt sensor is off, the warning lamp will turn on.
- The buzzer will then turn on and off three times over a total period of 1.8 seconds.
- The sequence will return to check the seatbelt sensor again.

Back to Table

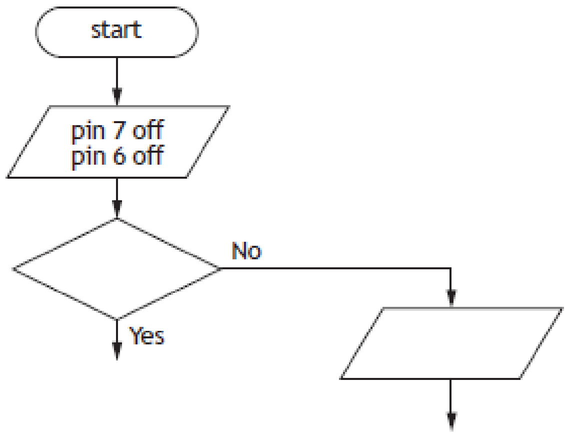
Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

8. (continued)

(a) Complete the flowchart for the sequence shown opposite, with reference to the Data Booklet and input/output connections.

Include all pin numbers and delay units in your flowchart. **10**



Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

8. (continued)

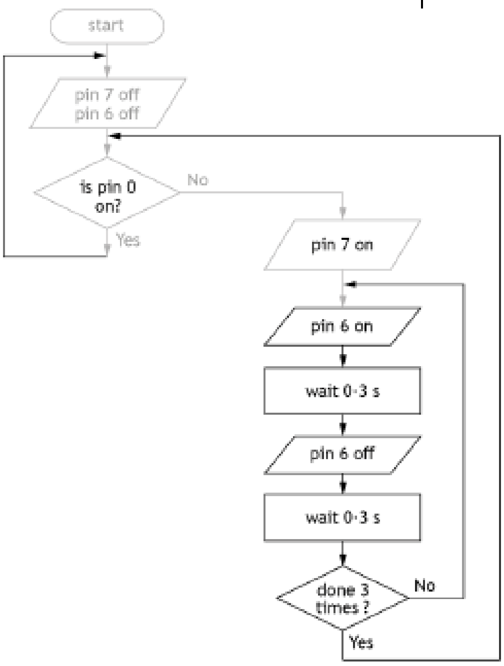
A force applied to the seatbelt strap results in a stress of 15 $N\,mm^{-2}$. The seatbelt strap has a cross-sectional area of 48 mm^2.

(b) Calculate the force applied. 3

Back to Table

Back to Table

Section 2

<table>
<tr><th colspan="3">Question</th><th>Expected response</th><th>Max mark</th><th>Additional guidance</th></tr>
<tr><td>8.</td><td>(a)</td><td></td><td>
</td><td>10</td><td>Pin 0 on ? decision - 1 mark.

Yes loop to start (arrow provided) - 1 mark.

Pin 7 on in correct position - 1 mark.

Pin 6 on and off in correct position - 1 mark.

Both delays in correct position - 1 mark.

Total delay time with unit = 0.6s - 1 mark.

x3 ? decision with Y/N - 1 mark.

Correct repeat sequence loop with arrow back to before pin 6 on - 1 mark.

Loop after sequence with arrow back to before pin 0 - 1 mark

Accept (on, off, delay) sequence repeated three times - 2 marks.

All symbols correct - 1 mark.

Ignore any additional steps.</td></tr>
</table>

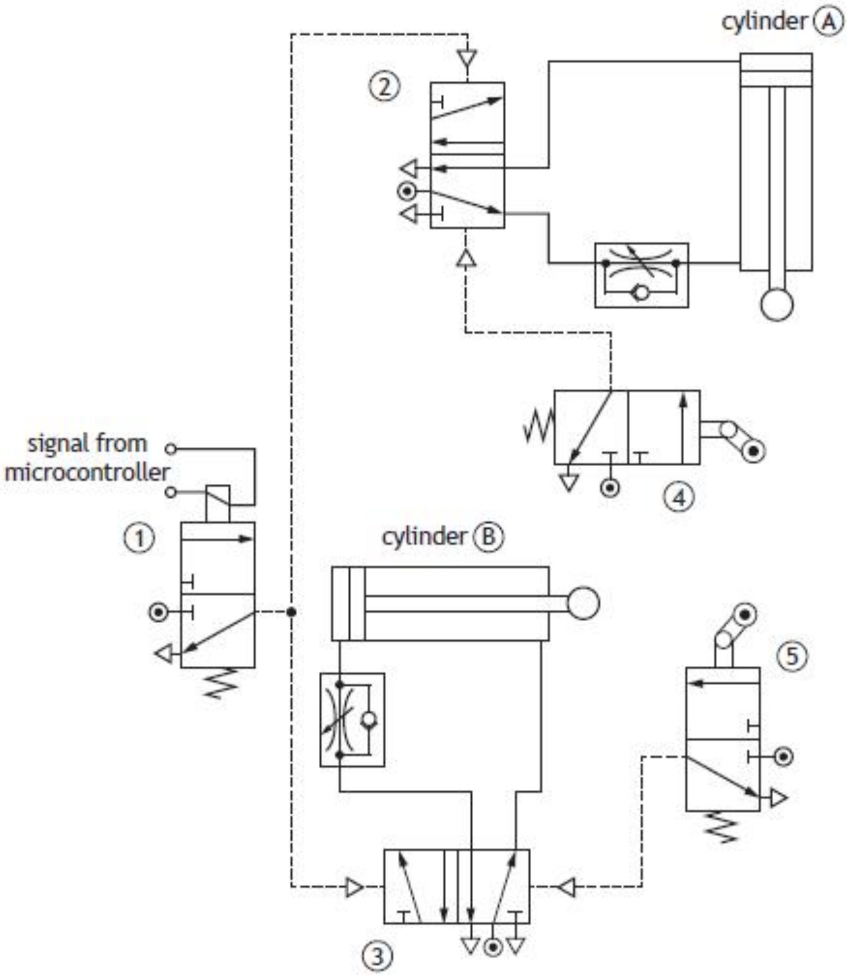
Question			Expected response	Max mark	Additional guidance
8.	(b)		$\sigma = \frac{F}{A}$ $15 = \frac{F}{48}$ $F = 15 \times 48$ $F = 720$ N (2 sf)	3	1 mark for substitution. 1 mark for transposition. 1 mark for correct answer from given working with unit.

[Back to Table]

DO NOT WRITE IN THIS MARGIN

9. A pneumatic circuit is used to arrange bottles ready for packaging in a production line.

The pneumatic circuit used to arrange the bottles is shown below.



[Back to Table]

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

9. (continued)

(a) Describe the operation of the circuit shown opposite. 5

When a signal is received from the microcontroller . . .

[Turn over

Back to Table

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

9. (continued)

Air at a pressure of $0.32\ N\,mm^{-2}$ is supplied to cylinder Ⓑ. This results in an outstroking force of 620 N.

(b) (i) Calculate the area of the piston. 3

(ii) Calculate the diameter of the piston. 3

Back to Table

9. (continued)

A microcontroller based system is used to detect the bottles.

The program used to count six bottles is shown below.

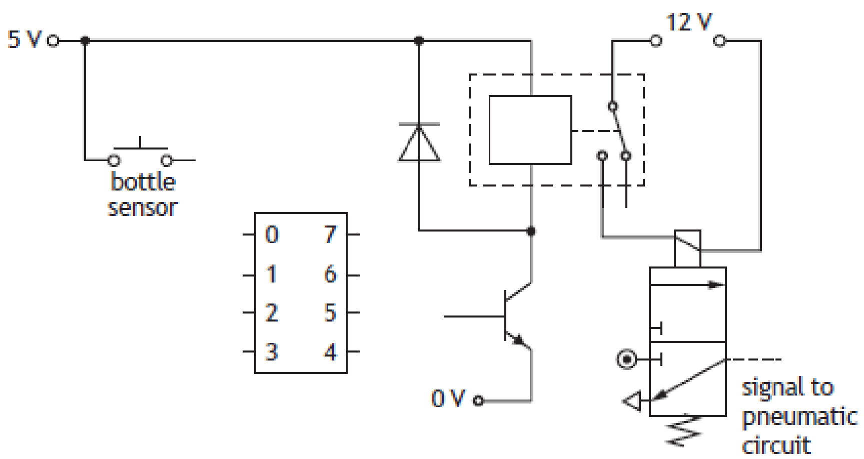
```
line  program
1     main:      let count = 0
2     check:         if input2 is off then check
3                    let count = count + 1
4                if count = 6 then label_1
5                goto check
6     label_1:   switch on 7
7                pause 500
8                switch off 7
9                goto main
```

(c) State the line number that contains a time delay. **1**

____

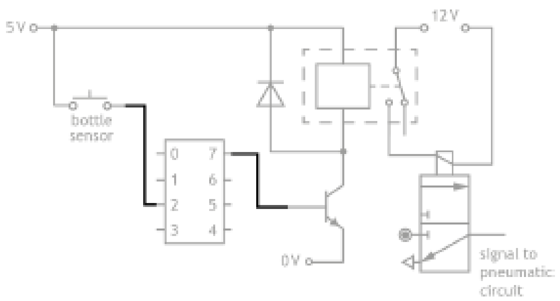
An incomplete diagram for the microcontroller based system is shown below.

(d) Complete, with reference to the program above, the wiring of the bottle sensor and the transistor to the microcontroller. **2**



Question			Expected response	Max mark	Additional guidance
9.	(a)		*When a signal is received from the microcontroller ...* valve 1 actuates and pilot air switches valve 2 and piston A outstrokes. ..piston A actuates valve 4 which sends pilot air to reset valve 2 causing piston A to instroke. valve 1 actuates and pilot air switches valve 3 and piston B outstrokes. ..piston B actuates valve 5 which sends pilot air to reset valve 3 causing pistion B to instroke. Piston A outstrokes slowly and piston B instrokes slowly.	5	Descriptive response. 1 mark for valve 1/2 causing piston A to outstroke. 1 mark for valve 4 and 2 to cause piston A to instroke. 1 mark for valve 1/3 causing piston B to outstroke. 1 mark for valve 5 and 3 causing piston B to instroke. 1 mark for piston A outstroking slowly and piston B instroking slowly. If response describes valve 1 (or both 5/2 valves) causing both pistons to outstroke then 2 marks can be awarded. Instroking conditions must clearly link both named valves to the correct cylinder.
	(b)	(i)	$P = \frac{F}{A}$ $0.32 = \frac{620}{A}$ $A = \frac{620}{0.32}$ $A = 1937.5$ $A = 1900\ \text{mm}^2$ (2 sf)	3	 1 mark for substitution. 1 mark for transposition. 1 mark for correct answer from given working with unit.

page 08

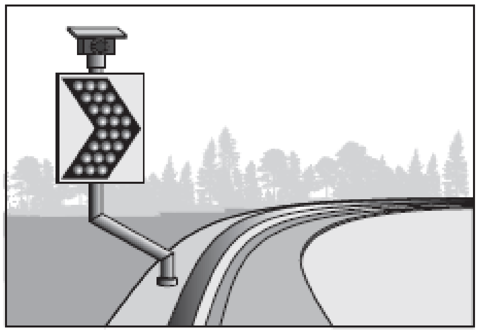
Question			Expected response	Max mark	Additional guidance
9.	(b)	(ii)	$A = \frac{\pi d^2}{4}$ $1900 = \frac{\pi d^2}{4}$ $d = \sqrt{\frac{1900 \times 4}{\pi}}$ $d = 49.1849$ $d = 49$ mm (2 sf)	3	1 mark for substitution. Allow FTE from (b)(i). 1 mark for transposition. 1 mark for correct answer from given working with unit. If radius is given as the final answer then max 2 marks.
	(c)		(Line) 7	1	
	(d)			2	Bottle sensor correctly wired to pin 2 - 1 mark. Pin 7 correctly wired to base of transistor - 1 mark. Do not accept any additional pins wired to bottle sensor/transistor.

page 09

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

10. A warning sign used on a road is shown.



The warning sign uses a number of LEDs powered by solar energy.

(a) Describe a task an electronic engineer would complete when designing the warning sign. 1

(b) Describe an economic impact of using LEDs instead of lamps in the warning sign. 1

(c) Explain an impact on the environment of using solar powered LEDs in the warning sign. 2

[Turn over

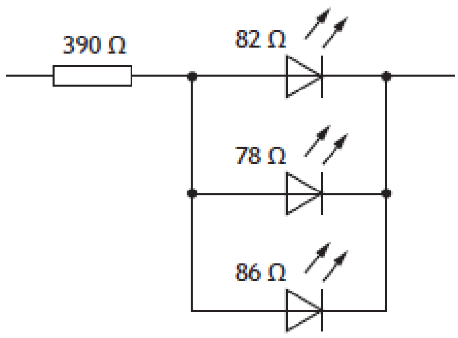
Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

10. (continued)

Part of the circuit used in the warning sign is shown below.



(d) (i) Calculate the resistance of the three LEDs in parallel. 3

(ii) Calculate the total resistance of the circuit shown above. 1

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

10. (continued)

The warning sign is rated at 12 V, 1.8 W.

(e) Calculate the current supplied to the warning sign. 3

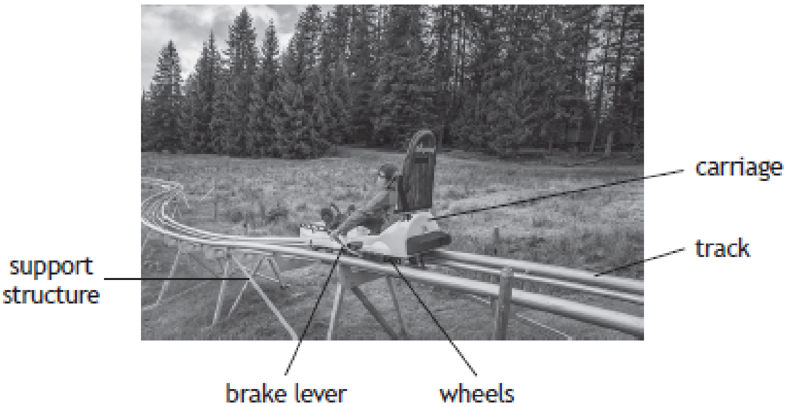
[Turn over

Question			Expected response	Max mark	Additional guidance
10.	(a)		Design the LED/charging/sensing circuit. Write the control program. Simulate/test/prototype the LEDs circuit. Calculate the voltage/current/power required for all LEDs. Selecting components to be used to drive/protect the LEDs.	1	Descriptive electronic based response relating to the design phase. 1 mark for any appropriate response of an engineer's activity and specific electronic aspect. Building must relate to prototype. Do not accept circuit/circuit diagram/warning sign on its own as an electronic aspect.
	(b)		Reduction in running costs. Longer lasting so repair/replacement costs less.	1	Descriptive response relating to financial impact (positive/negative) using LEDs. 1 mark for an economic impact (positive/negative). Do not accept LEDs are cheaper on its own.
	(c)		LEDs are long lasting ... resulting in less materials going to landfill. It is a renewable source/does not use fossil fuel ...so it does not pollute/damage the environment. Solar does not produce CO_2 ...reducing climate change/global warming. Solar powered LEDs do not need mains electricity ...so no need to dig up the ground to lay cabling.	2	Explanation based on environmental impact (positive/negative) of using solar powered LEDs. 1 mark for cause. 1 mark for effect.

Question			Expected response	Max mark	Additional guidance
10.	(d)	(i)	$\frac{1}{RT} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3}$ $\frac{1}{RT} = \frac{1}{82} + \frac{1}{78} + \frac{1}{86}$ $RT = \frac{1}{0.03664354175}$ $R_T = 27.28994$ $R_T = 27\ \Omega$ (2 sf)	3	1 mark for substitution. 1 mark for transposition. 1 mark for correct answer from given working with unit.
		(ii)	$R_T = 27 + 390$ $R_T = 417\ \Omega$ $R_T = 420\ \Omega$ (2 sf)	1	Allow FTE from part (i). 1 mark for correct answer with unit.
	(e)		$P = VI$ $1.8 = 12 \times I$ $I = \frac{1.8}{12}$ $I = 0.15$ A (2 sf)	3	1 mark for substitution. 1 mark for transposition. 1 mark for correct answer from given working with unit.

MARKS DO NOT WRITE IN THIS MARGIN

11. The mountain coaster shown below allows riders to travel downhill in an unpowered carriage. The rider can control the speed of the carriage by using a braking system.



A number of different engineers were involved during the development and construction of the mountain coaster.

(a) (i) Describe a task that a mechanical engineer would carry out during the development of the carriage. **1**

(ii) Describe a task that a civil engineer would carry out during the development of the mountain coaster. **1**

(iii) Describe a task that an environmental engineer would carry out during the construction of the track. **1**

MARKS DO NOT WRITE IN THIS MARGIN

11. (continued)

At the start of the ride, 6.2 m above the ground, the carriage and rider have a combined potential energy of 13 kJ.

(b) (i) Calculate the combined mass of the carriage and rider. 3

(ii) Calculate the kinetic energy of the carriage and rider when released and travelling at a velocity of $2.7\ m\ s^{-1}$. 2

[Turn over

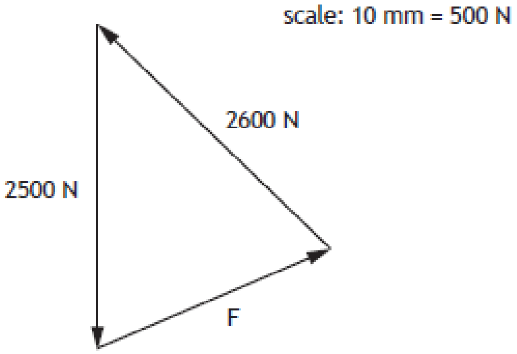
Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

11. (continued)

A structural engineer analyses the forces acting through part of the support structure for the track.

A triangle of forces diagram used in the analysis is shown below.



(c) Determine, with reference to the triangle of forces diagram, the size of unknown force F. 1

F = ______________ N

The properties of the four metals considered for the support structure are shown in the table below.

Metal	Corrosion resistant	Durability
A	no	low
B	yes	high
C	yes	low
D	no	high

(d) Select the most suitable metal (A–D) from the table above to be used for the support structure and justify your choice. 2

Choice of metal ______________________________

Justification ______________________________

____

____

____

Back to Table

Question			Expected response	Max mark	Additional guidance
11.	(a)	(i)	Design the brake lever. Design the wheels to spin freely. Simulate the brake mechanism. Select an appropriate material for the wheel axle. Calculate the braking force.	1	Descriptive mechanical response relating to the design phase and carriage. 1 mark for any appropriate response of an engineer's activity and specific mechanical aspect of the carriage. Do not accept design the wheel/ gears/mechanism on its own. Building must relate to prototype.
		(ii)	Survey/test the ground on the hillside. Plan the route/site of the mountain coaster track. Design the position of the access roads to the coaster track.	1	Descriptive civil response relating to the design phase and mountain coaster. 1 mark for any appropriate response of an engineer's activity and specific civil aspect.
		(iii)	Monitor the (impact on) local wildlife/area. Measure the noise/pollution level.	1	Descriptive environmental response relating to the construction phase. 1 mark for any appropriate response of an engineer's activity and specific environmental aspect of the construction. Must be a monitoring based activity.
	(b)	(i)	$E_p = mgh$ $13 \times 10^3 = m \times 9.8 \times 6.2$ $m = \dfrac{13000}{9.8 \times 6.2}$ $m = 213.9566$ $m = 210$ kg (2 sf)	3	1 mark for substitution. 1 mark for transposition. 1 mark for correct answer from given working with unit.

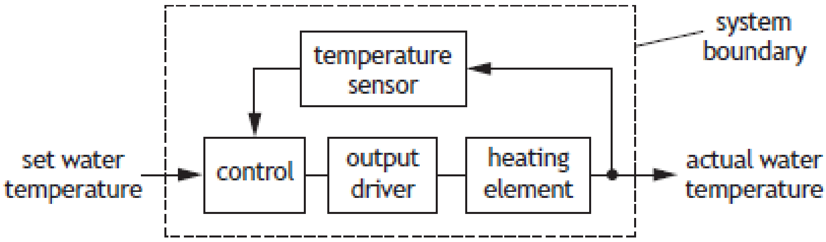
Question			Expected response	Max mark	Additional guidance
11.	(b)	(ii)	$E_k = ½\,mv^2$ $E_k = ½ \times 210 \times 2.7^2$ $E_k = 765.45$ $E_k = 770$ J (2 sf)	2	1 mark for substitution. Allow FTE from (b)(i). 1 mark for correct answer from given working with unit.
	(c)		2000 - 2100 (N)	1	Unit not required.
	(d)		B Metal B is corrosion resistant and is (more) durable. Metal B because the structure will be used outside and it is corrosion resistant. Metal B because it is durable and so parts will not need to be replaced often.	2	1 mark for metal B. 1 mark for corrosion resistant and durable. OR 1 mark for a property with valid rationale based on selection. Apply FTE from metal selection.

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

12. A washing machine is shown.

A sub-system diagram showing the control of the water temperature in the washing machine is shown below.



(a) Describe the reason for including a system boundary in a sub-system diagram. 1

____

____

(b) Describe, with reference to the sub-system diagram above, the control of the water temperature. 3

The water temperature is set . . .

____

____

____

____

____

____

____

____

Back to Table

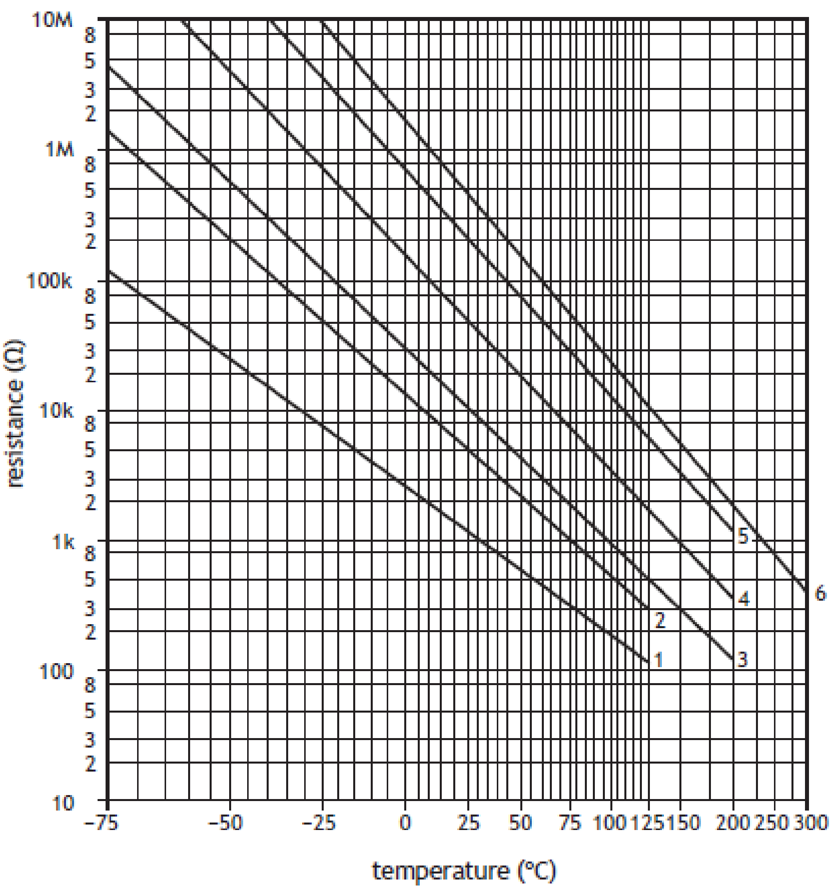
Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

12. (continued)

A thermistor is used in the temperature sensor.

The operating characteristics of six thermistors are shown on the graph below.



(c) State the thermistor number from the graph above that has a resistance of 1 kΩ when the temperature is 30 °C. **1**

____

* X 8 2 3 7 5 0 1 2 4 *

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

12. (continued)

(d) Explain why using a low temperature wash cycle can affect climate change. 2

The washing machine's heating element is tested using 8.6 kg of water.

(e) Calculate the heat energy when the water temperature is raised by 15 °C. 2

[Turn over

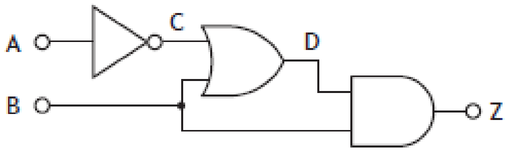
Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

12. (continued)

The logic diagram for part of a circuit used in the washing machine is shown.



(f) Complete the truth table for this logic diagram. 3

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

The truth table for another logic circuit in the washing machine is shown below.

F	G	H	Y
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	1
1	1	0	1
1	1	1	0

(g) Complete the Boolean equation for output Y in terms of inputs F, G and H. 3

Y = ______________________________

Back to Table

Question			Expected response	Max mark	Additional guidance
12.	(a)		To separate an (external) input/ output from a sub-systems/ process. To contain all the sub-systems that are in a system. To show what goes in/out of a system. To separate the outside environment from a system.	1	Response describing containment/ separation of system and external influences.
	(b)		*The water temperature is set ...* The temperature sensor (detects the actual temperature and) sends a signal to the control. The control will compare the set temperature with the actual temperature. If the water is too cold the heater will switch on. OR If the water is at/above the set temperature the heater will switch off.	3	1 mark for feedback description. 1 mark for control comparison description. 1 mark for description of the heating element switching on when too cold/switching off when correct temperature.
	(c)		(Type) 1	1	
	(d)		Less energy will be needed to heat the water ... so there will be fewer greenhouse gasses given off/reducing climate change/carbon footprint.	2	Explanation must relate to climate change. 1 mark for cause (energy reduced). 1 mark for effect (greenhouse gas emission). Apply FTE.

Back to Table

<table>
<tr><th colspan="3">Question</th><th>Expected response</th><th>Max mark</th><th>Additional guidance</th></tr>
<tr><td>12.</td><td>(e)</td><td></td><td>$E_h = cm\Delta T$

$E_h = 4180 \times 8.6 \times 15$

$E_h = 539220$

$E_h = 540$ kJ (2 sf)</td><td>2</td><td>1 mark for substitution.

1 mark for correct answer from given working with unit.</td></tr>
<tr><td></td><td>(f)</td><td></td><td><table><tr><th>A</th><th>B</th><th>C</th><th>D</th><th>Z</th></tr><tr><td>0</td><td>0</td><td>1</td><td>1</td><td>0</td></tr><tr><td>0</td><td>1</td><td>1</td><td>1</td><td>1</td></tr><tr><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td></tr><tr><td>1</td><td>1</td><td>0</td><td>1</td><td>1</td></tr></table></td><td>3</td><td>1 mark for column C (NOT A).

1 mark for column D (C OR B). Allow FTE.

1 mark for column Z (D AND B). Allow FTE.</td></tr>
<tr><td></td><td>(g)</td><td></td><td>$Y = (F \bullet \overline{G} \bullet H) + (F \bullet G \bullet \overline{H})$

Alternative

$Y = F \bullet ((\overline{G} \bullet H) + (G \bullet \overline{H}))$

$Y = F \bullet (G \oplus H)$</td><td>3</td><td>1 mark for $(F \bullet \overline{G} \bullet H)$.

1 mark for $(F \bullet G \bullet \overline{H})$.

If only one statement is given then bracket is not required.

1 mark for OR-ing all statements. Do not accept F/G/H on its own as a statement.

Alternative

1 mark for F AND

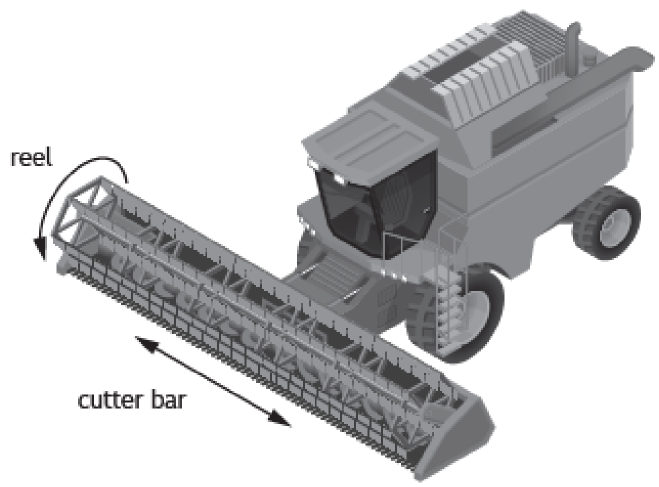
1 mark for both $(\overline{G} \bullet H)$ and $(G \bullet \overline{H})$ with brackets.

1 mark for OR-ing G/H statements.

If Exclusive OR used then 2 marks for (G EOR H) with bracket.</td></tr>
</table>

MARKS | DO NOT WRITE IN THIS MARGIN

13. A combine harvester used to gather crops is shown below.

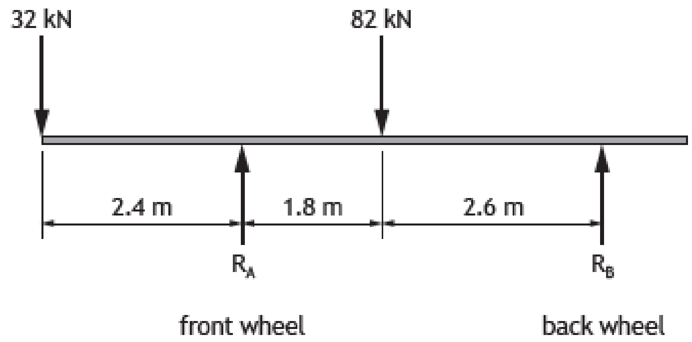


(a) State the type of motion shown above at the: 2

reel ______________________________

cutter bar ______________________________

A simplified diagram for the combine harvester is shown.



X823750128

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

13. (continued)

(b) (i) Calculate the reaction force R_A by taking moments about R_B. 3

(ii) Calculate the reaction force R_B. 2

[Turn over

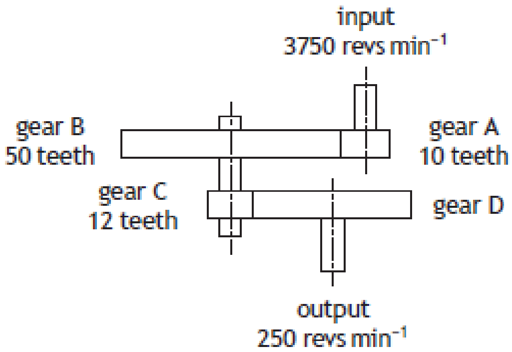
Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

13. (continued)

Part of a drive mechanism used in the combine harvester is shown.



(c) Calculate the number of teeth on gear D. 4

Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

13. (continued)

The combine harvester uses a Global Positioning System (GPS) when cutting the crop. This is an established technology.

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

(d) Explain a possible impact of an emerging technology which you are familiar with. 2

Emerging technology ______________________________

Impact ______________________________

____

____

____

____

[Turn over

Back to Table

Question			Expected response	Max mark	Additional guidance
13.	(a)		reel: rotary cutter bar: reciprocating	2	1 mark for reel motion. Accept rotational/rotating. 1 mark for cutter bar motion. Accept reciprocal.
	(b)	(i)	$\Sigma CWM = \Sigma ACWM$ $(R_A \times 4.4) = (82 \times 2.6) + (32 \times 6.8)$ $R_A = \dfrac{430.8}{4.4}$ $R_A = 97.909$ $R_A = 98$ kN (2 sf)	3	1 mark for substitution. 1 mark for transposition. 1 mark for correct answer from given working with unit.
		(ii)	$\Sigma F_{vertical} = 0$ $\quad\quad \Sigma F_{up} = \Sigma F_{down}$ $R_B + 98 = 32 + 82$ $R_B = 16$ kN (2 sf)	2	1 mark for substitution. Allow FTE from part(b)(i). 1 mark for correct answer from given working with unit.

Back to Table

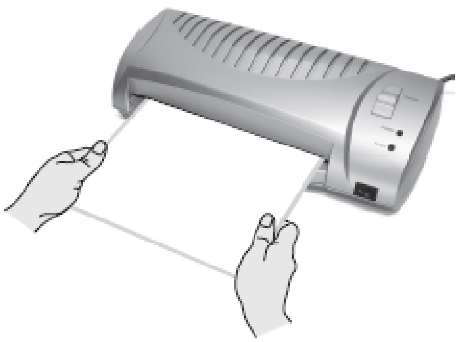
Question			Expected response	Max mark	Additional guidance
13.	(c)		$3750 \times 10 = \text{Output speed} \times 50$ $Outputspeed = \frac{37500}{50}$ Output speed = 750 (revs min^{-1}) $750 \times 12 = 250 \times \text{gear } D$ $gearD = \frac{9000}{250}$ gear D = 36 (teeth) **Alternative method** $VR = \frac{3750}{250}$ $VR = 15{:}1$ $\frac{15}{1} = \frac{50}{10} \times \frac{D}{12}$ $D = \frac{15 \times 12 \times 10}{50}$ gear D = 36 (teeth)	4	1 mark for substitution. 1 mark for correct answer from given working (unit not required). 1 mark for substitution. Allow FTE. 1 mark for correct answer from working (ignore any units). **Alternative method** 1 mark for velocity ratio (does not need to be simplified). 1 mark 50:10 gear ratio (ratios could be inverted). 1 mark for transposition. 1 mark for correct answer from working (ignore any units).
	(d)		Graphene. Conducts electricity quickly. ...this would result in batteries charging quicker/circuits working quicker. Fully autonomous car. Will not be fully tested. ...so, there could be faults/could cause an accident.	2	Accept impact for any emerging technology. 1 mark for cause. 1 mark for effect. If no technology named or the given example is clearly established/ developing; 1 mark maximum for having both cause and effect.

Back to Table

Back to Table

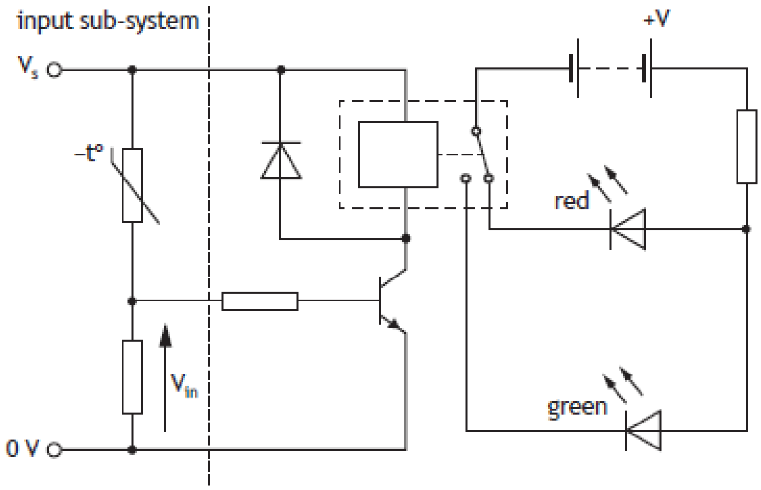
MARKS DO NOT WRITE IN THIS MARGIN

14. A laminator is used to cover a sheet of paper in a plastic sleeve.



The plastic sleeve is heated by the laminator as it passes through.

The circuit used to indicate when the laminator is at the correct temperature is shown below.



(a) Describe the operation of the input sub-system as the temperature increases. Make reference to the resistance of the thermistor and the voltage V_{in}. 2

As the temperature increases . . .

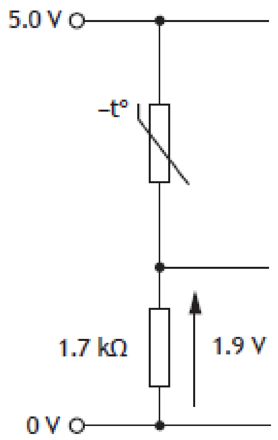
Back to Table

Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

14. (continued)

The input sub-system is shown below.



(b) Calculate the resistance of the thermistor for the condition shown above. 4

(c) Describe, with reference to the circuit shown opposite, the effect on the red LED and the green LED when the transistor first activates the relay. 2

When the transistor activates the relay . . .

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

[Turn over

Back to Table

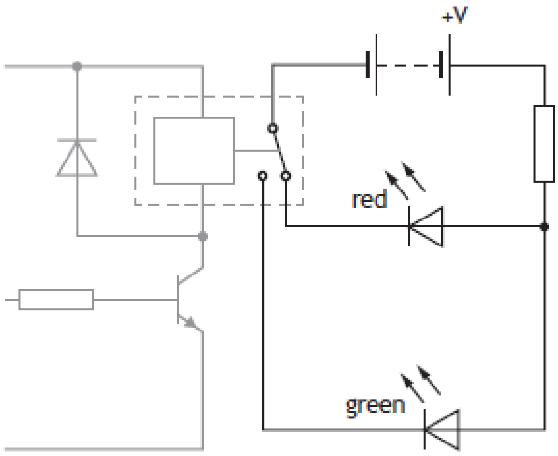
Back to Table

MARKS | DO NOT WRITE IN THIS MARGIN

14. (continued)

A possible modification to the circuit is to include an audible alert when the laminator is at the correct temperature.

(d) Draw, in the circuit below, the symbol for a buzzer connected in parallel with the green LED. 2



Back to Table

Back to Table

MARKS DO NOT WRITE IN THIS MARGIN

14. (continued)

An electronic engineer used computer simulation to test the modified circuit.

(e) Describe an advantage of using computer simulation compared to building a circuit for testing purposes. **1**

A large reduction in speed is required for a feed roller to slowly move the plastic sleeve and paper through the laminator.

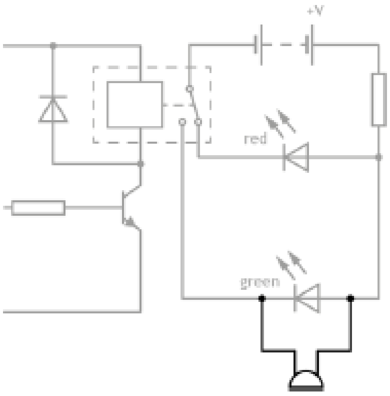
(f) Explain why a compound gear train is more suitable than a simple gear train to create this large reduction in speed in the laminator. **2**

[END OF QUESTION PAPER]

Back to Table

Question			Expected response	Max mark	Additional guidance
14.	(a)		*As the temperature increases ...* The (thermistor) resistance will decrease. The voltage (V_{in}) will increase.	2	Descriptive response. 1 mark for thermistor resistance decreasing. 1 mark for V_{in} based on resistance response. If V_{in} increasing stated without reference to thermistor resistance - 1 mark only.
	(b)		5 - 1.9 = 3.1 (V) $\frac{3.1}{1.9} = \frac{R}{1.7}$ $R = \frac{3.1 \text{x} 1.7}{1.9}$ R = 2.77368 R = 2.8 kΩ (2 sf) Alternative method 5 - 1.9 = 3.1 (V) $V_R = IR$ 1.9 = $I \times$ 1.7 I = 1.1176 (mA) $V = IR$ 3.1 = 1.1176 x R $R = \frac{3.1}{1.1176}$ R = 2.7738 R = 2.8 kΩ (2 sf)	4	1 mark for voltage across variable resistor. Units not required. 1 mark for substitution. Apply FTE and accept 5.0 V if V_1 is not calculated. 1 mark for transposition. 1 mark for correct answer from given working with unit. Alternative method 1 mark for voltage across variable resistor. Units not required. 1 mark for calculating current. Units not required. Apply FTE and accept 5.0 V if V_1 is not calculated. 1 mark for transposition. Allow FTE. 1 mark for correct answer from given working with unit.

Back to Table

Question			Expected response	Max mark	Additional guidance
14.	(c)		*When the transistor activates the relay ...* the red LED will switch off and the green LED will switch on.	2	Descriptive response relating to LEDs individually. LED colour needs to be stated/implied by position. 1 mark for red LED switching off. 1 mark for green LED switching on. Apply FTE for second description.
	(d)			2	1 mark for correct symbol of the buzzer. 1 mark for wiring connected anywhere in parallel with green LED.
	(e)		Quicker to develop solution. Saves money as no replacement components needed. Components will not be destroyed/ wasted. Easier to change circuit during testing. No risk to the user due to fault/failure.	1	Descriptive response relating to an advantage of simulation testing. 1 mark for a relevant description. Not faster, cheaper, easier or safer to simulate on its own. Component cost must relate to replacement of parts.
	(f)		A compound gear train will use smaller gears ...which makes it able to fit inside the small space/laminator.	2	1 mark for cause (smaller gears/ train). Do not accept high velocity ratio as a cause or effect. 1 mark for effect (compact space). Accept responses explaining the disadvantage of a simple gear train.

[END OF MARKING INSTRUCTIONS]