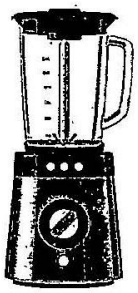
Candidate 1 evidence

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

Mechanical Engineer

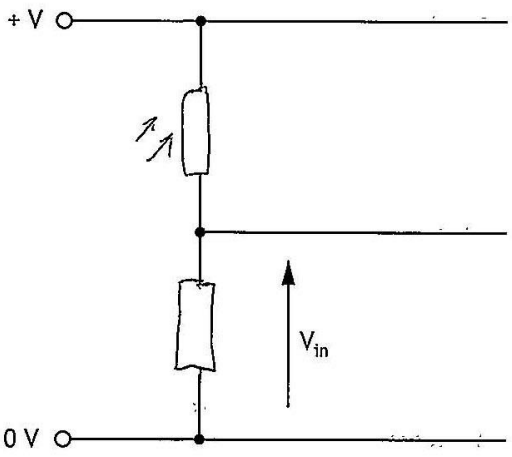
(b) State the type of engineer that would simulate the speed control circuit in the kitchen blender. 1

Electronic Engineer

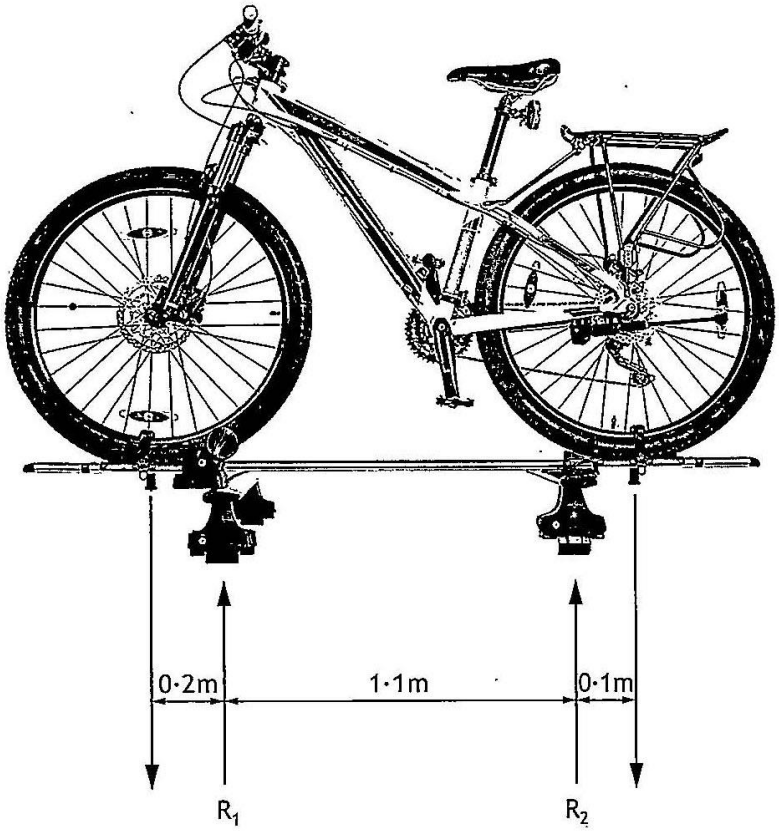
2. An electronic circuit is being designed to meet the following specification:

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

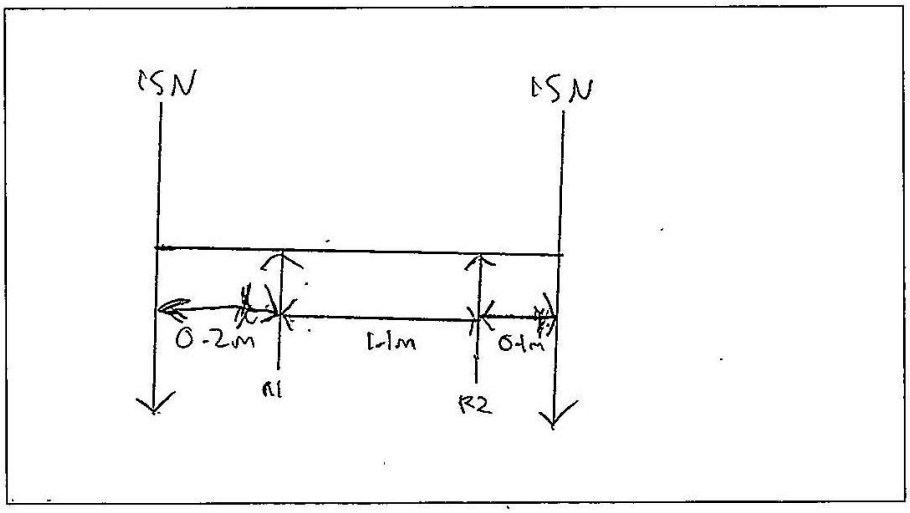
Complete the circuit diagram below to include an LDR and a fixed resistor so that the circuit meets the required specification. 3



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

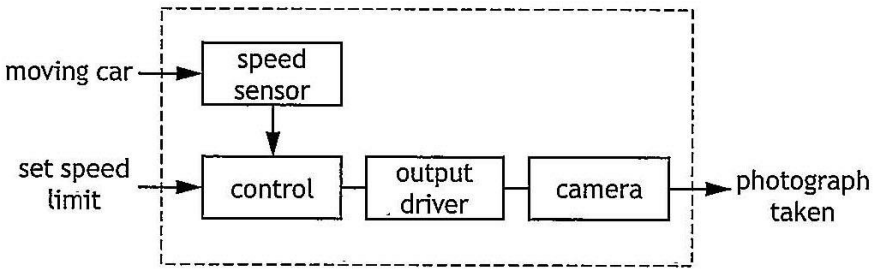


Draw a free body diagram for the bike and carrier shown above. **2**



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**

Closed Loop

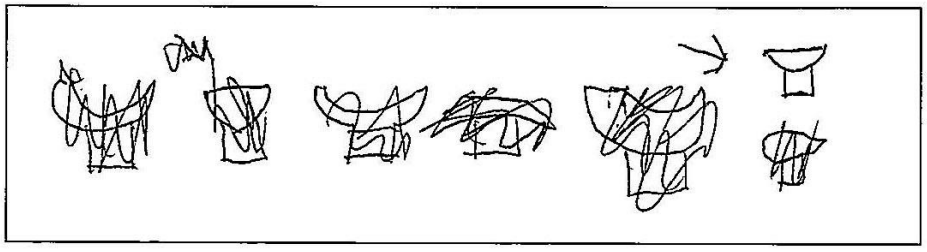
(b) Describe the operation of the motorway speed camera. **3**

The speed limit is set.

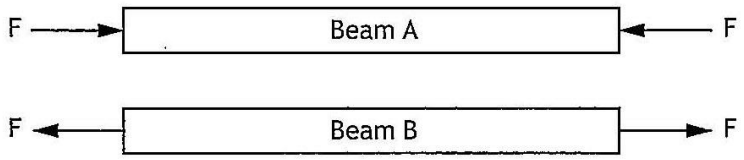
The control unit checks the ser value with the real value of the car. If the real value of the car is greater than the ser speed limit, the control unit sends a signal to the output driver which amplifies the signal to power the camera which takes a photo of the speeding car.

5. A buzzer is a commonly used electronic component.

Draw the symbol for a buzzer. **1**



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

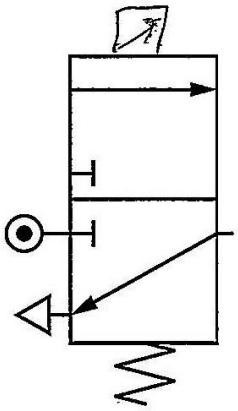


State the nature of the force acting on: 2

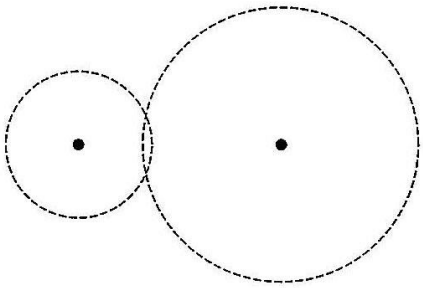
Beam A Compression

Beam B Tension

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



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



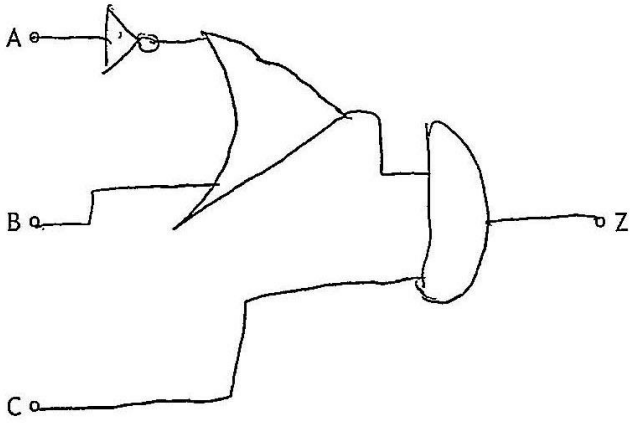
Describe two errors that were made when drawing this simple gear train. 2

Error 1 The gears overlap instead of touching & and they have been drawn as circles instead of rectangles.

Error 2 Dashed lines have been used to draw the gears instead of full lines.

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

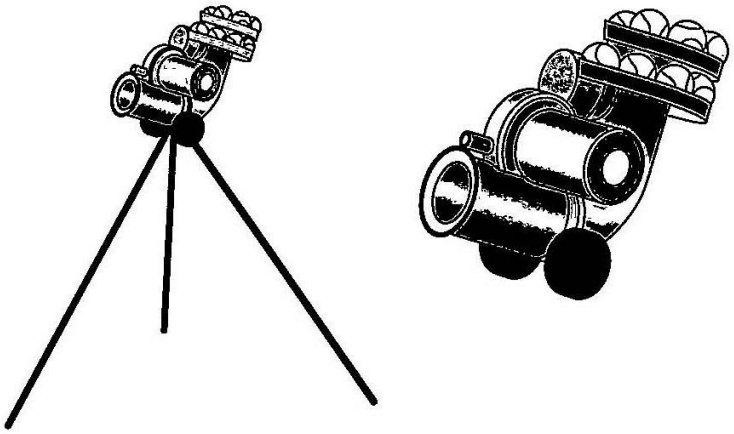
$$Z = (\overline{A} + B) \bullet C$$



SECTION 2 — 90 marks

Attempt ALL questions

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.

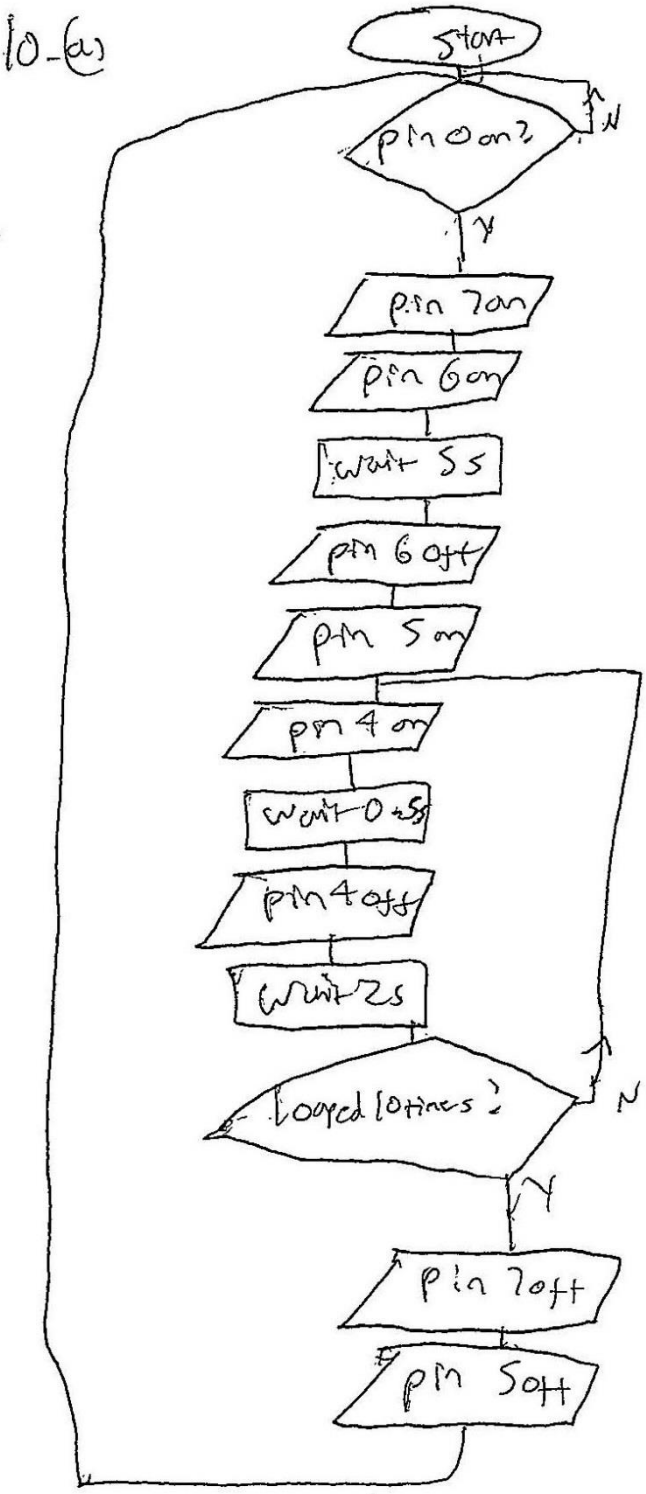
Input connections	Pin	Output connections
	7	ball firing motor
	6	red light
	5	green light
	4	ball release
start button	0	

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.

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**



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**

$\epsilon = \frac{\Delta L}{L}$

$0.0016 = \frac{\Delta L}{1200}$

$\Delta L = 1200 \times 0.0016$

$\Delta L = 1.92\,mm$

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

Oscilating

(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

$E_p = mgh$

$E_p = 69 \times 9.8 \times 6.8$

$E_p = 4598.16\,J$

11. (b) (continued)

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

$E_K = \frac{1}{2}mv^2$

$970 = \frac{1}{2} \times 69 \times v^2$

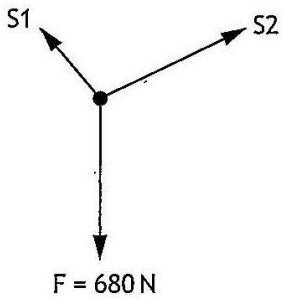
$v^2 = \frac{970}{34.5}$

$v^2 = 28.12$

$v = \sqrt{28.12}$

$v = 5.3 ms^{-1}$

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

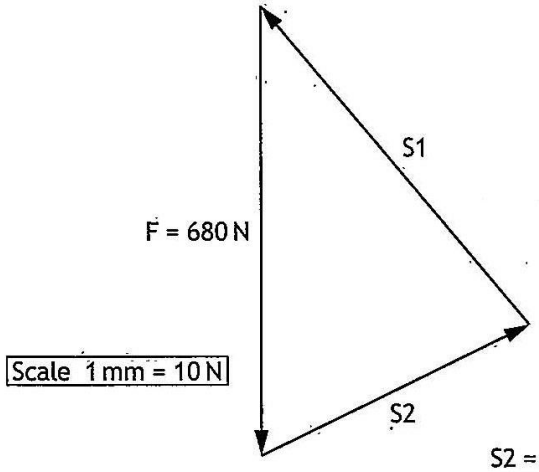


(i) State, with reference to the Data Booklet, the condition of equilibrium which does **not** need to be considered when studying forces acting at a single point. 1

ΣF_h

11. (c) (continued)

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



S2 = 460 N

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

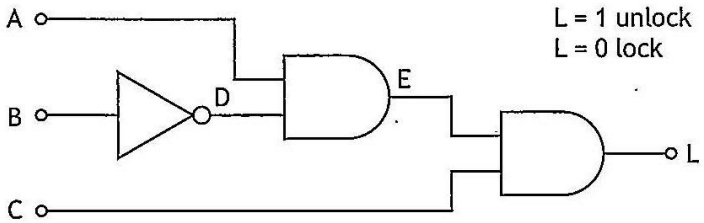
Select the most suitable material (A-D) from the table above to be used for the support wires and justify your choice. **2**

Choice of material C

Reason for choice They have high durability so can resist wear and tear, and are strong enough to be able to withstand the 1300N and 930N tensile loads.

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

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

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

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

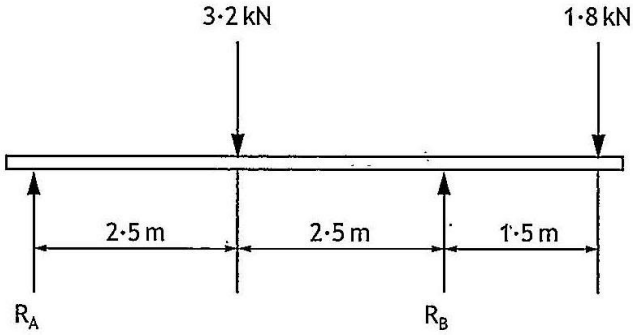
The microcontroller can easily be re-programmed to have multiple purposes instead of the difficulty of replacing components in a circuit. The microcontroller has less ports and can be fitted more easily.

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

When a micro-controller is done with its initial purpose it can be reprogrammed to have a new purpose, so one can be used multiple times for many things instead of having to form brand new logic circuits, using up materials. Microcontrollers do not have to be thrown away due to their re-usability.

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**

$\Sigma CW M = \Sigma ACW M$

$(1.5 \times 1.8) + (2.5 \times 3.2) = 5 R_A$

$R_A = \frac{(1.5 \times 1.8) + (2.5 \times 3.2)}{5}$

$R_A = 2.14 kN$

13. (a) (continued)

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

$\Sigma F_{up} = \Sigma F_{down}$

$R_A + R_B = 3.2 + 1.8$

$R_B = 5 - 2.14$

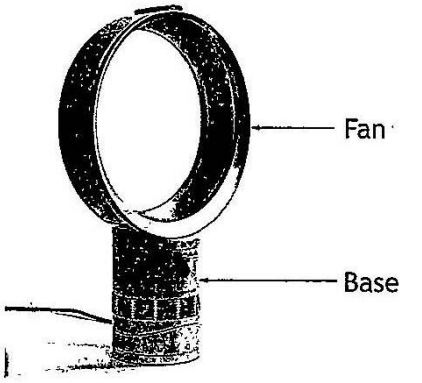
$R_B = 2.86\,kN$

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

1 He would have designed the hull with materials that can withstand the force of the waves.

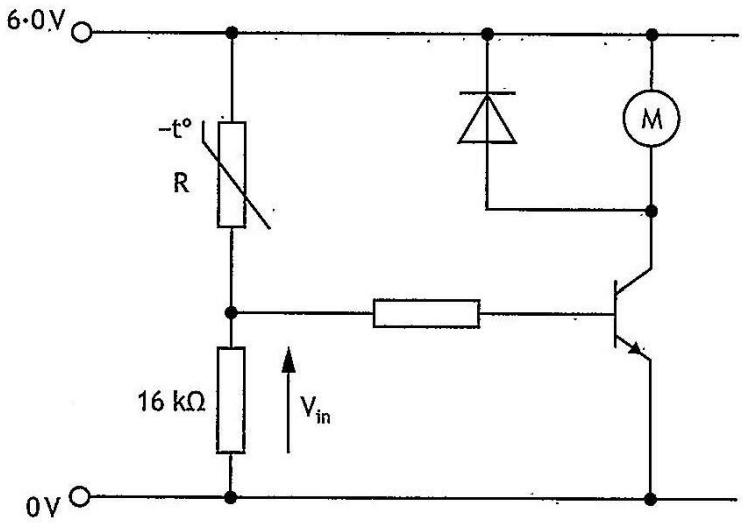
2 They would have designed the structure of the mast so it is stable and can withstand the force of the wind, and not break under pressure.

14. A desktop fan is shown.



ymgerman/shutterstock.com

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



14. (continued)

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

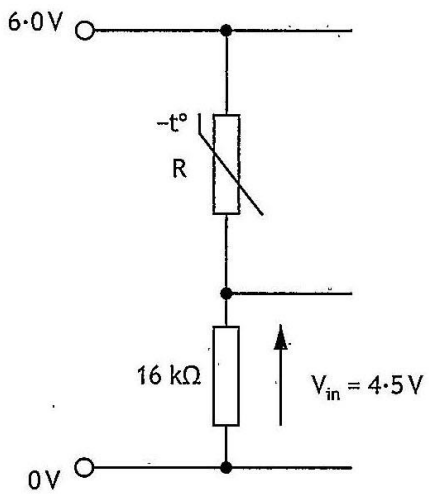
Include reference to the resistance of the thermistor and the voltage V_{in}.

As the temperature increases...

the resistance of the thermistor decreases. The voltage of the thermistor decreases. The voltage of the resistor increases as it has a larger share of the resistance. When Vin is equal to the threshold of the transistor, it switches on. The transistor allows current to flow, and when current flows, the motor of the fan turns on.

14. (continued)

The input sensing circuit of the fan is shown below.



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

$V_1 = 6 - 4.5 = 1.5V$

$V_2 = 4.5V$

$R_1 = ?$

$R_2 = 16k\Omega$

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

$$\frac{1.5}{4.5} = \frac{R_1}{16}$$

$$R_1 = \frac{1.5 \times 16}{4.5}$$

$R_1 = 5.3k\Omega$

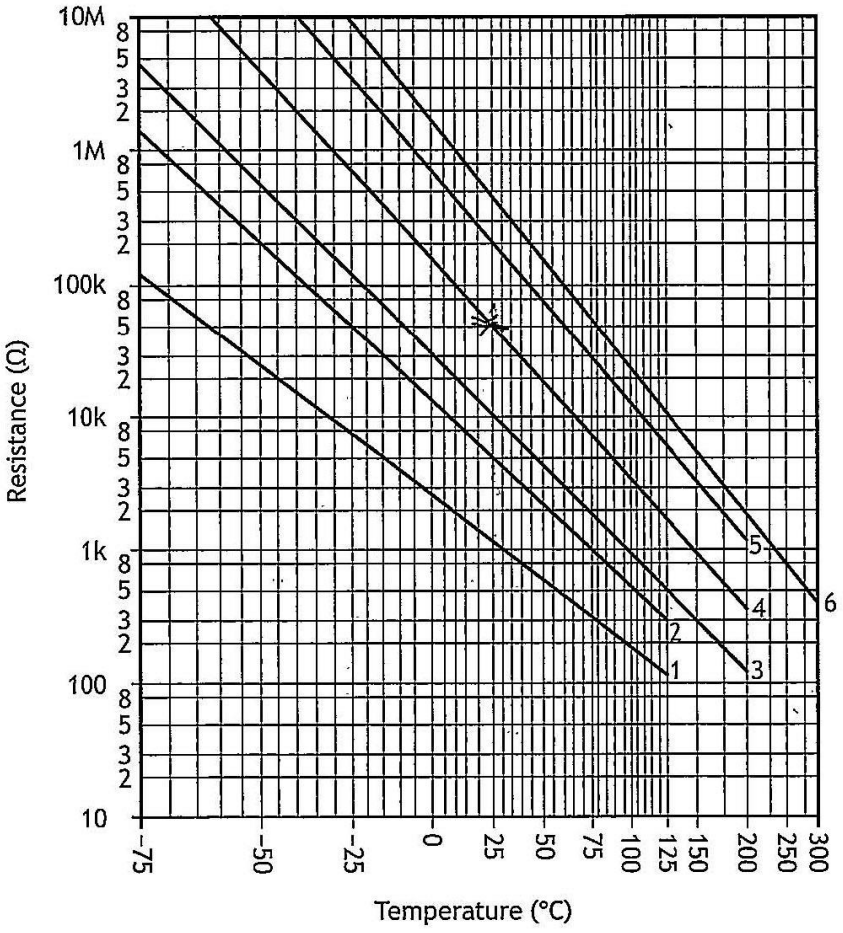
(c) Describe how the input sensing circuit could be modified so that the user can alter the temperature at which the fan motor switches on. 1

The fixed resistor should be replaced by a variable resistor, which can then modify resistance.

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**

50kΩ 500kΩ



14. (continued)

(e) The base of the fan has a force of 25 N applied to it and a stress of 0·029 Nmm^{-2}.

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

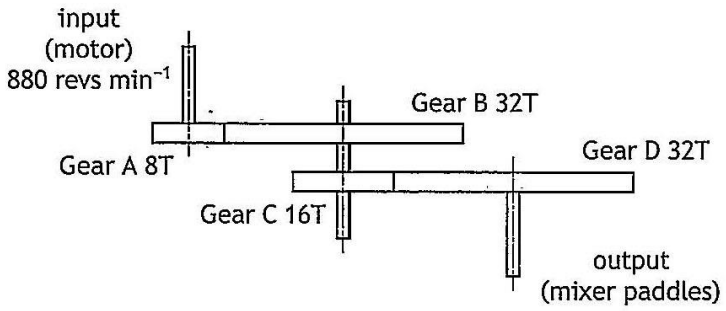
$$\sigma = \frac{F}{A}$$

$$0.029 = \frac{25}{A}$$

$$A = \frac{25}{0.029}$$

$$A = 862 mm^2$$

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**

$VR = \frac{\text{output size}}{\text{input size}} \times \frac{\text{output size}}{\text{input size}}$

$= \frac{32}{8} \times \frac{32}{16}$

$VR = 8$

$VR = \frac{\text{input speed}}{\text{output speed}}$

$8 = \frac{880}{\text{output speed}}$

$\text{output speed} = \frac{880}{8}$

output speed = 110 revs min^{-1}

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

$VR = \frac{\text{output size}}{\text{input size}} \times \frac{\text{output size}}{\text{input size}}$

$VR = \frac{32}{8} \times \frac{32}{16}$

$VR = 4 \times 2$

$VR = 8$

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

~~Gear B could be made larger to increse the VR by having more teeth added~~

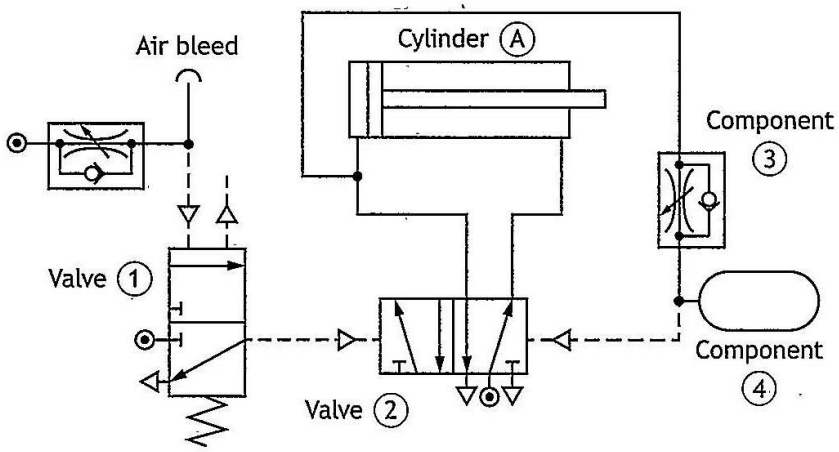
15.(b)

Gear B could be made to reduce the VR by having some teeth removed.

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.

This sends a pilot air signal to valve 2, causing it to change state. This causes cylinder A to Outstroke. When the air bleed is no longer covered a signal is sent with a time delay to valve 2, causing it to change state, and the cylinder A to instroke.

15. (continued)

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

When the air bleed is covered there is a way of sensing the pastry, and wherever the pastry is sensed the cylinder can outstroke and press them into the pie casings.

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

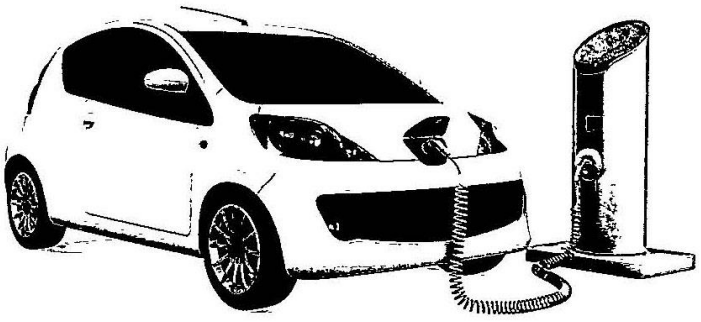
Calculate the pressure supplied to outstroke the piston. 2

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

$$P = \frac{73}{810}$$

$$P = 0.09\ N mm^{-2}$$

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

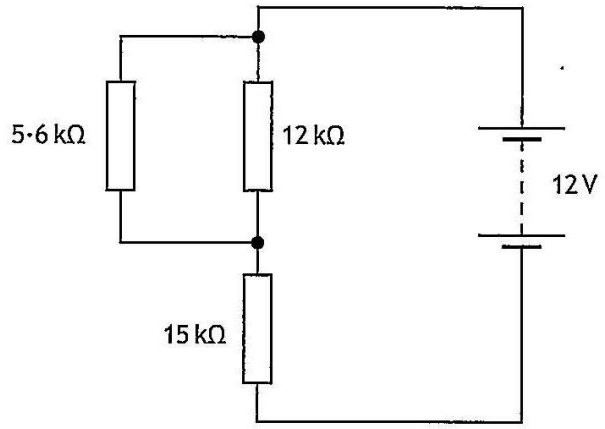
They do not use fossil fuels, and do not produce CO_2 gases that cause climate change and air pollution.

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

It may put manufacturers of diesel and petrol cars out of business as less and less people buy their vehicles.

16. (continued)

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



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

$R_p = \frac{R_1 \times R_2}{R_1 + R_2}$

$= \frac{12 \times 5.6}{12 + 5.6}$

$R_p = 3.8\,k\Omega$

$R_t = R_1 + R_2$

$= 3.8 + 15$

$R_t = 18.8\,k\Omega$

16. (continued)

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

$V = IR$
$V = 0{\cdot}6 \times 10^{-3} \times 15 \times 10^{3}$
$V = 9V$

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

$V_S = 12V$ $V_1 = V_S - V_2$
$V_2 = 9V$ $= 12 - 9$
$V_1 = ?$ $V_1 = 3V$

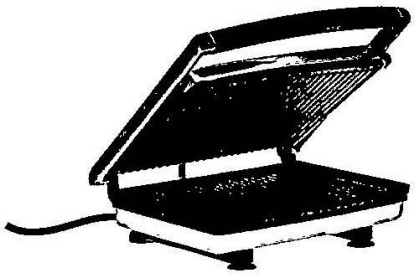
$V = IR$
$3 = I \times 5{\cdot}6$
$I = \frac{3}{5{\cdot}6}$
$I = 0{\cdot}54 mA$

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

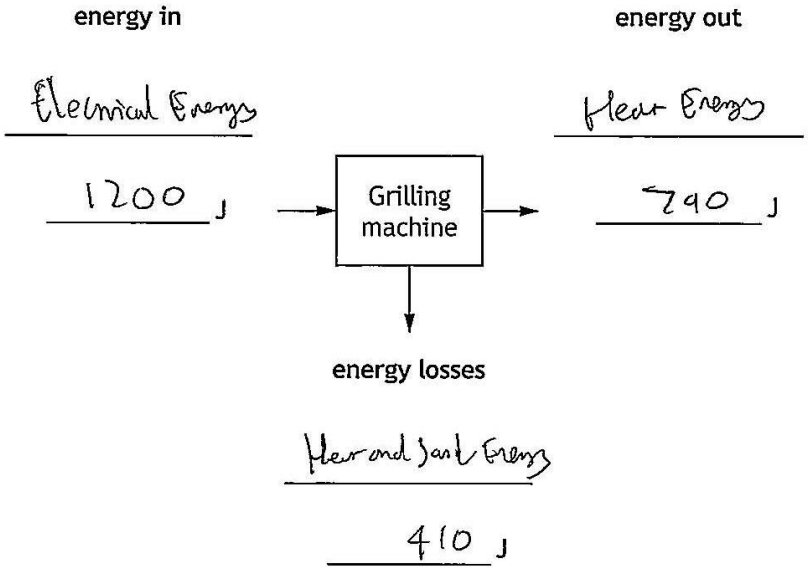
Amazon will use drones for delivering packages. This may put delivery drivers out of jobs. This will create new jobs for people to fly drones to customers.

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**



Space for rough working

1200 − 790 = 410J

17. **(continued)**

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

$\eta = \frac{E_{out}}{E_{in}}$

$\eta = \frac{790}{1200}$

$\eta = 0.66$

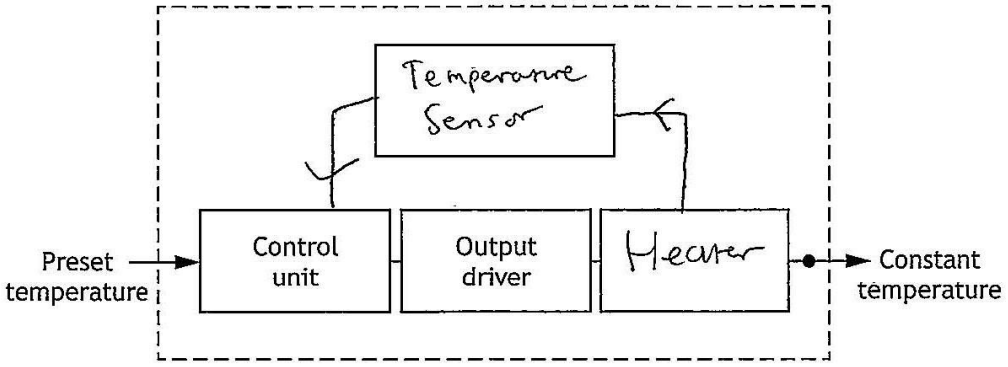
66% efficient

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

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

Closed loop

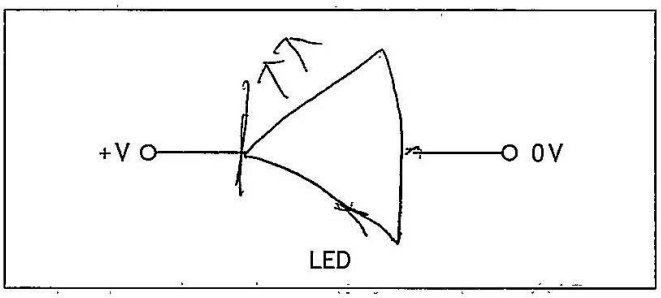
(ii) Complete the sub-system diagram below for the grilling machine. 3



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**

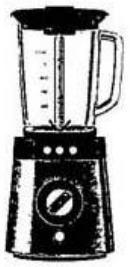
A resistor can be paired in series with the L.E.D to stop it being overloaded with current and destroyed.

Candidate 2 evidence

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

Mechanical engineer

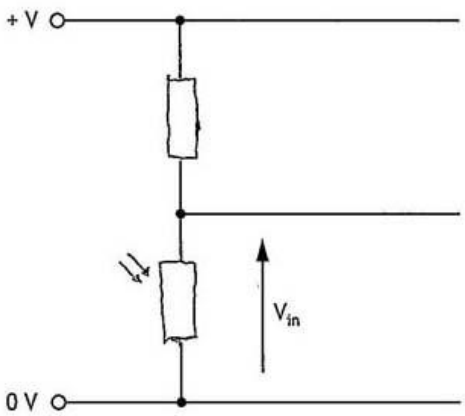
(b) State the type of engineer that would simulate the speed control circuit in the kitchen blender. 1

electronic engineer

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

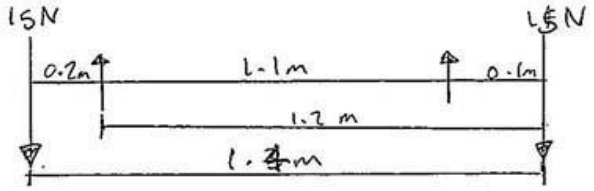
- V_{in} should increase as the light level detected increases.

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



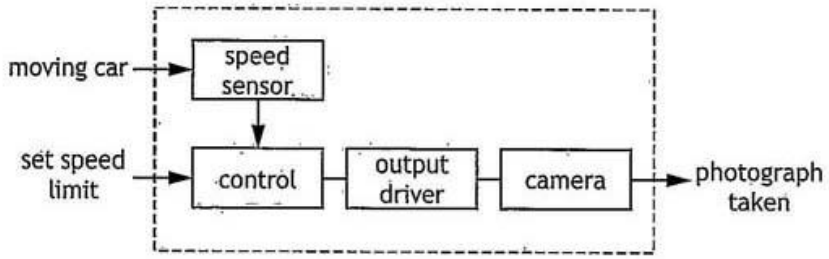
3. A bike and carrier are shown below. Each bike wheel applies a force of 15 N onto the carrier.

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



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

automatic closed loop

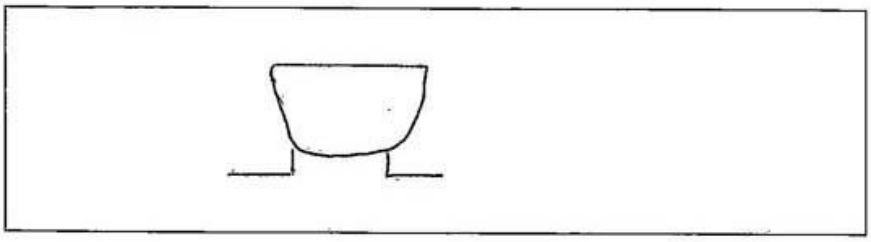
(b) Describe the operation of the motorway speed camera. 3

The speed limit is set.

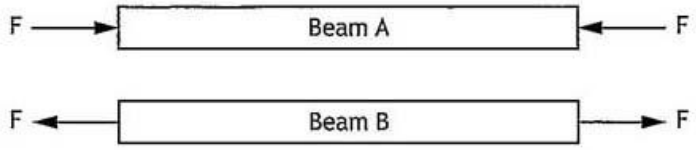
When the speed sensor detects a car moving above the set limit, it triggers the output driver to take a photograph with the camera.

5. A buzzer is a commonly used electronic component.

Draw the symbol for a buzzer. 1



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

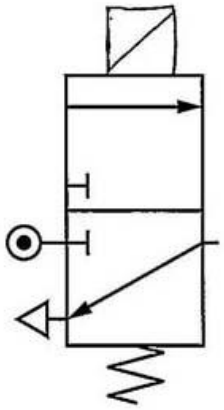


State the nature of the force acting on: 2

Beam A strain

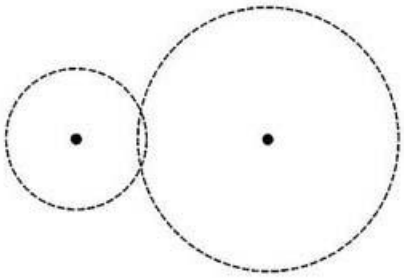
Beam B tension

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



[Turn over

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



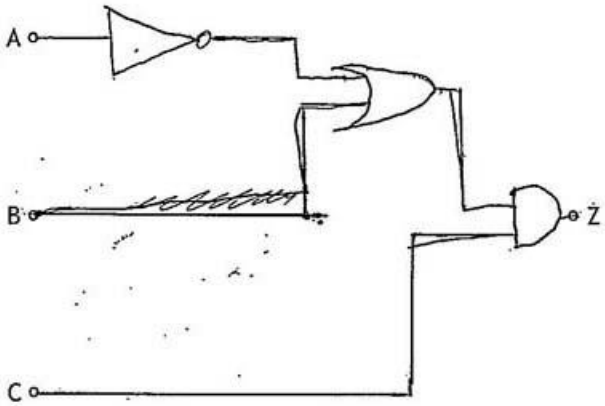
Describe two errors that were made when drawing this simple gear train. 2

Error 1 The gears overlap

Error 2 the shafts are too close to gether

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

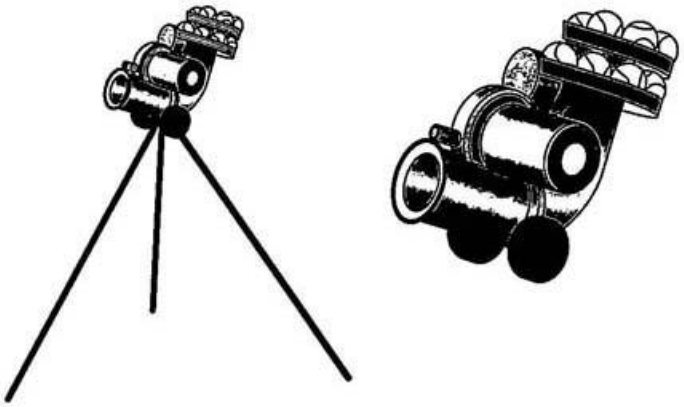
$$Z = (\overline{A} + B) \bullet C$$



SECTION 2 — 90 marks

Attempt ALL questions

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.

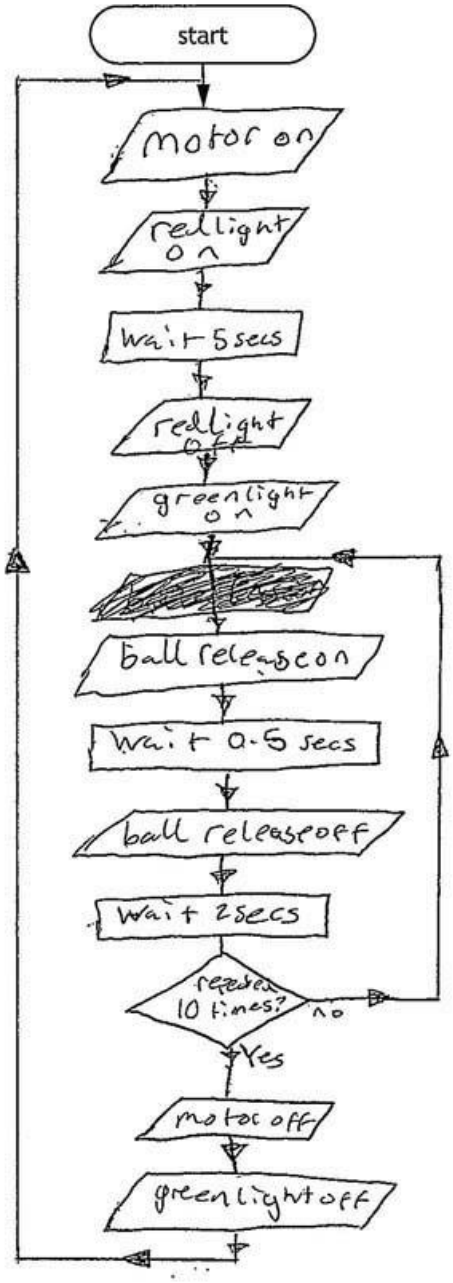
Input connections	Pin	Output connections
	7	ball firing motor
	6	red light
	5	green light
	4	ball release
start button	0	

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.

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**



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

$\Delta l = \epsilon L$

$= 0.0016 \times 1200$

$= 1.92\,mm$

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

reciprocating

(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

$E_p = mgh$

$= 69 \times 9.8 \times 6.8$

$= 4598.16$ J

[Turn over

11. (b) (continued)

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

$v^2 = \frac{Ek}{\frac{1}{2}m}$

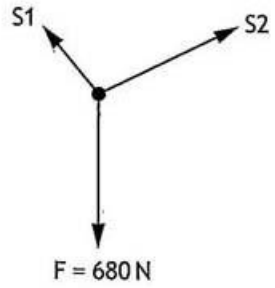
$= \frac{970}{\frac{1}{2} \times 69}$

$= 28.12$

$v = \sqrt{28.12}$

$= 5.3 \text{ m s}^{-1}$

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

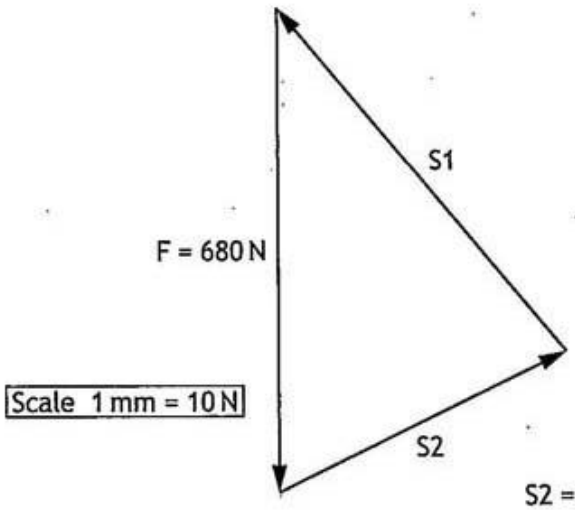


(i) State, with reference to the Data Booklet, the condition of equilibrium which does not need to be considered when studying forces acting at a single point. 1

$\Sigma M = 0$

11. (c) (continued)

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



S2 = 450 N

[Turn over

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

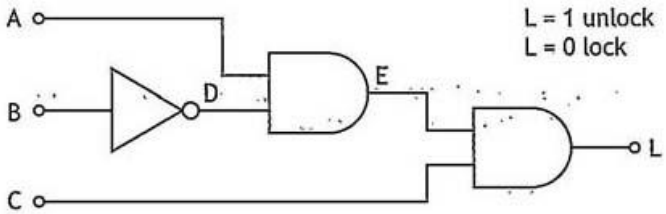
Select the most suitable material (A-D) from the table above to be used for the support wires and justify your choice. 2

Choice of material Material D

Reason for choice It is the only material that can hold the combined weight of the acrobats.

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

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

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

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

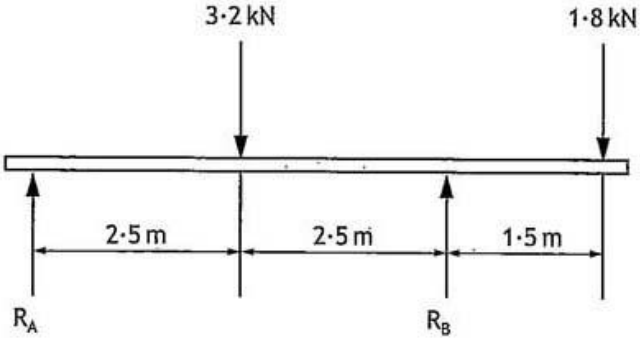
It is reprogrammable, meaning that instead of needing new parts, the micro controller can just be adjusted.

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

because fewer parts are required for a micro controller, it means less factories produce harmful fumes making parts

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

$\Sigma cwm = \Sigma acwm$

$F_1 d_1 = (F_2 d_2) + (F_3 d_3)$

$1.8 \times 1.5 = (3.2 \times 4) + (F_3 \times 6.5)$

$2.7 = 12.8 + F_3 \times 6.5$

$F_3 \times 6.5 = \frac{2.7}{12.8}$

$F_3 = \frac{2.7}{6.5 \times 12.8}$

$F_3 = 5.32$

$F_1 = 1.8N$

$F_2 = 3.2N$

$F_3 = ?$

$d_1 = 1.5m$

$d_2 = 4m$

$d_3 = 6.5m$

RA = 5.32N

13. (a) (continued)

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

$\Sigma M = 0$

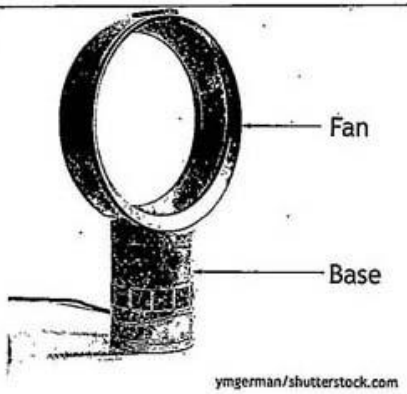
(b) Describe two specific roles a **structural** engineer may have had in the **development** of the catamaran. 2

1 the design of the frame of the ~~boat~~ catamaran

2 testing the catamaran through computer simulation.

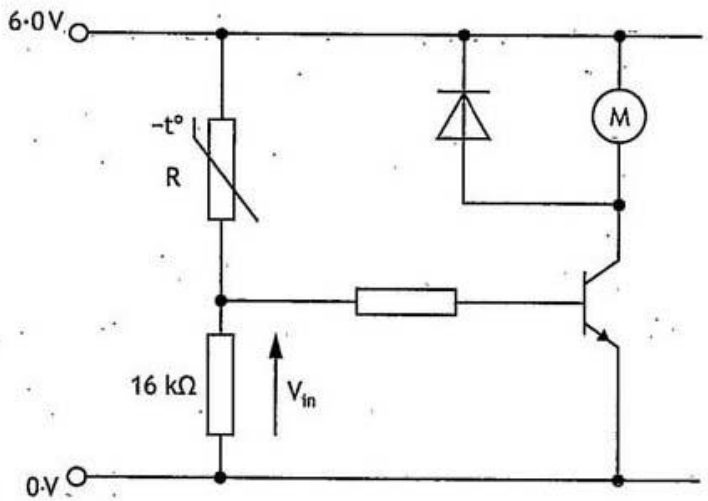
[Turn over

14. A desktop fan is shown.



ymgerman/shutterstock.com

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



14. (continued)

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

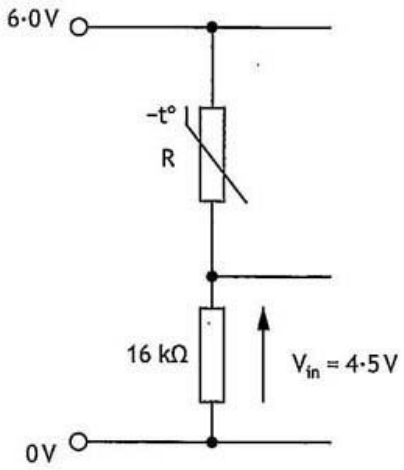
Include reference to the resistance of the thermistor and the voltage V_{in}.

As the temperature increases...

the resistance increases, the motor is switched on as well as the LED, which then goes through the collector of the transmitter and out the emitter.

14. (continued)

The input sensing circuit of the fan is shown below.



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

$V_{out} = 1.5\,V$

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

$\frac{4.5}{1.5} = \frac{16000}{R_2}$

$R_2 = \frac{16000 \times 1.5}{4.5}$

$R = 5.3\,K\Omega$

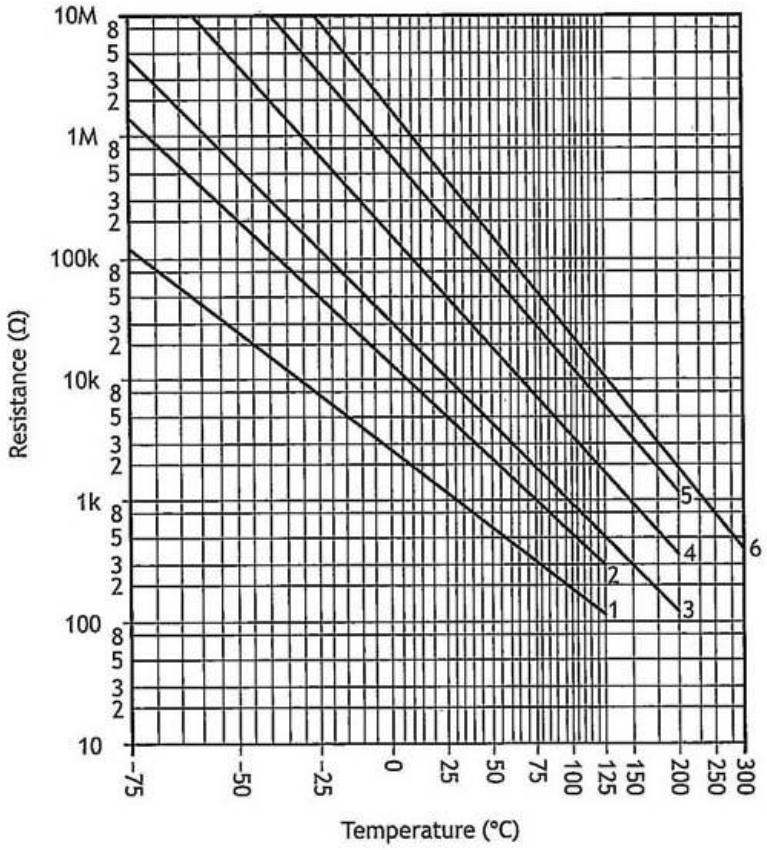
(c) Describe how the input sensing circuit could be modified so that the user can alter the temperature at which the fan motor switches on. 1

by adding a variable resistor

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

1 K Ω



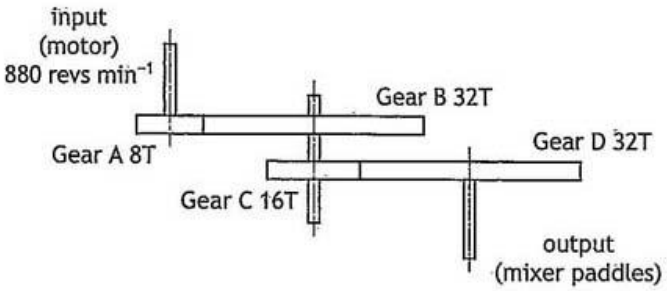
14. (continued)

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

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

$$A = \frac{F}{P}$$
$$= \frac{25}{0.029}$$
$$= 862.1\ mm^2$$

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

$\frac{32}{8} = 4$ $\frac{880}{4}$

$\frac{32}{16} = 2$ $= 220$

$\frac{220}{2}$

$= 110$ revs min^{-1}

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

$VR = \frac{\text{speed of input}}{\text{speed of output}}$

$= \frac{880}{110}$

$= 8:1$

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

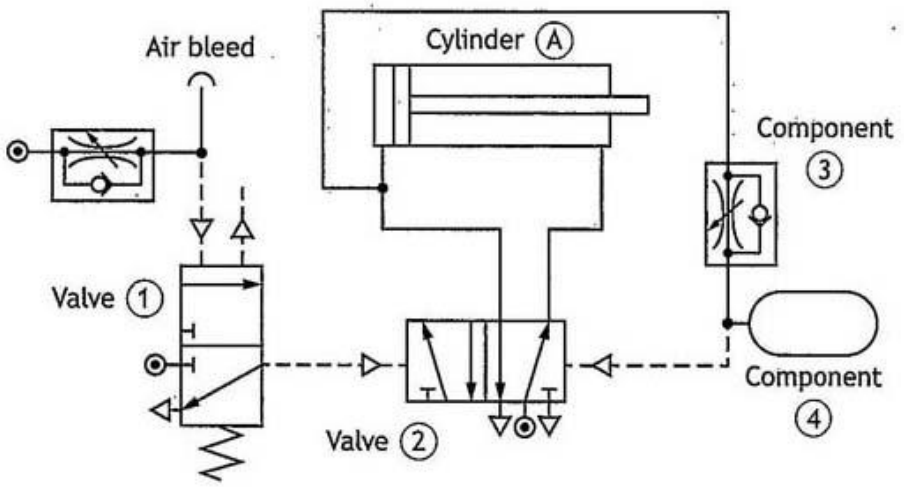
decrease the number of teeth

[Turn over

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.

Valve 1 then flows to valve 2, which actuates cylinder A. The time delay created by the uni directional restrictor and reservoir makes the piston lose air slowly.

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

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

$= \frac{73}{810}$

$= 0.09\ N\,mm^{-2}$

[Turn over

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

less pollution emitted by the gas from petrol/diesel

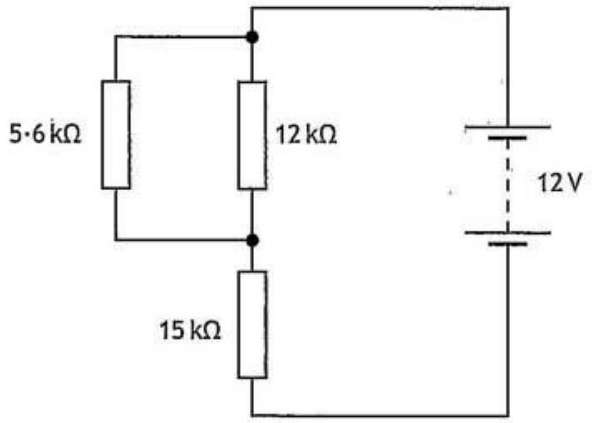
(ii) Describe one **negative economic** impact of the increasing use of electric cars. 1

~~electricity is more expensive~~

Jobs are lost creating petrol/diesel

16. (continued)

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



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

$R_t = \frac{R_1 \times R_2}{R_1 + R_2}$

$= \frac{5.6 * 12}{5.6 + 12}$

$= 24\,k\Omega$

$R_t = R_1 + R_2$

$= 24 + 15$

$R_t = 39\,k\Omega$

16. (continued)

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

$V = I R$

$= 0.0006 \times 15000$

$= 9$ V

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

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

$= \frac{1.5}{5.6}$

$I = 0.27$ A

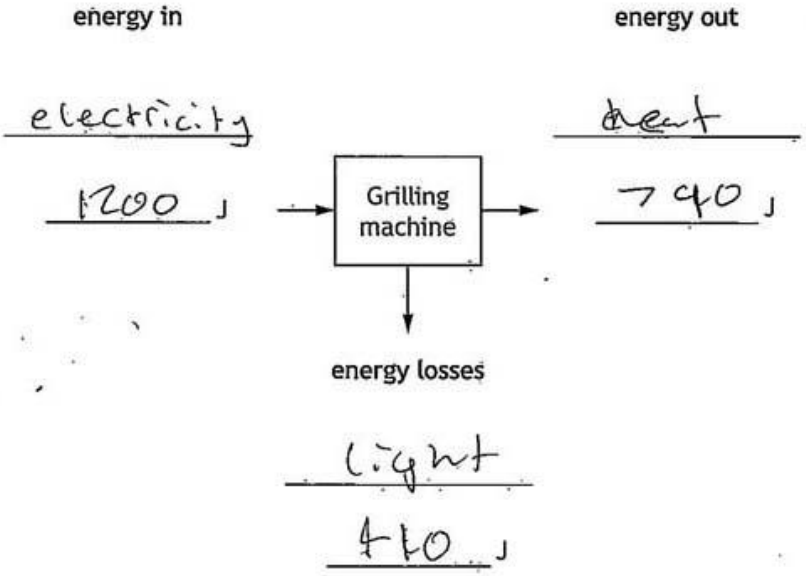
Electric vehicles are now considered to be an established technology. An **emerging technology** is one that has still to be tried commercially within a product or system.

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

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**



Space for rough working

1200 − 790 = 410 J

17. (continued)

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

efficiency = $\frac{\text{output}}{\text{input}}$

$= \frac{740}{1200} \times 100$

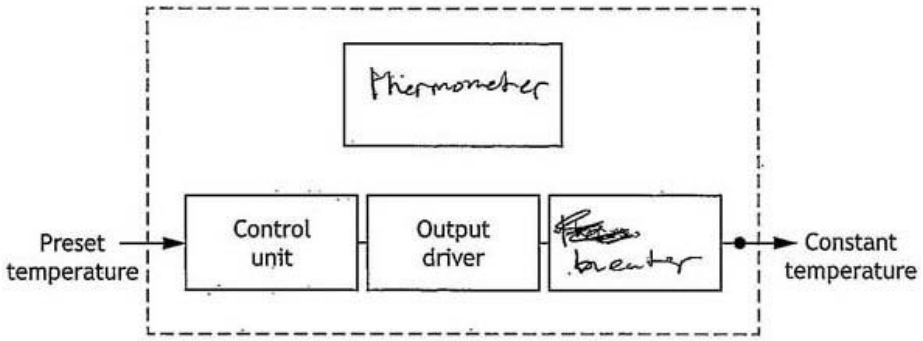
$= 66\%$

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

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

Closed Loop

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

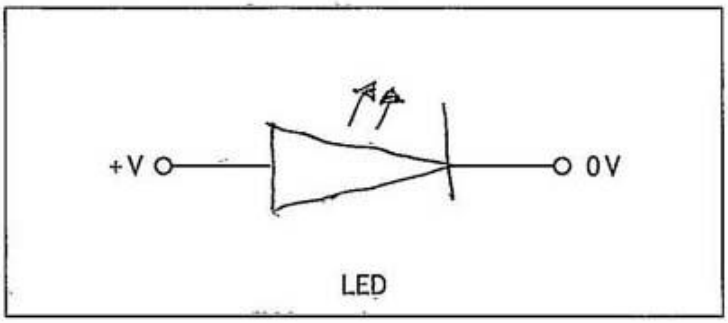


[Turn over for next question

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

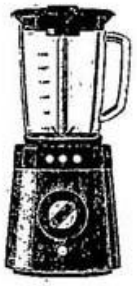
add a resistor before it

Candidate 3 evidence

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

mecanical engineer

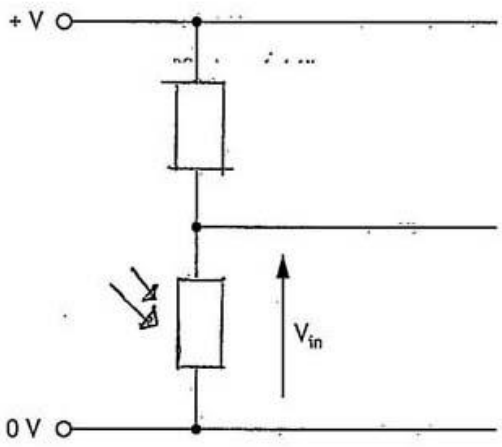
(b) State the type of engineer that would simulate the speed control circuit in the kitchen blender. 1

electrical engineer

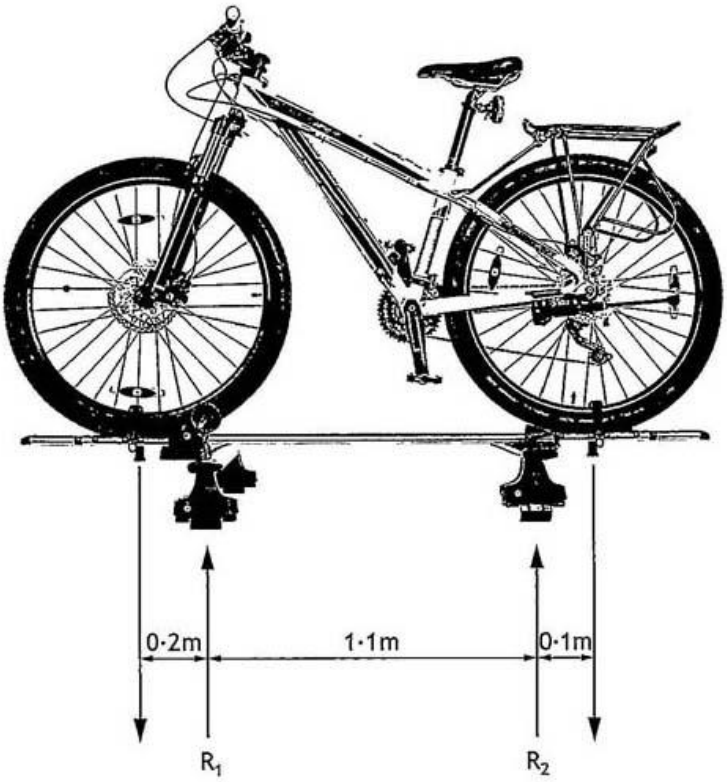
2. An electronic circuit is being designed to meet the following specification:

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

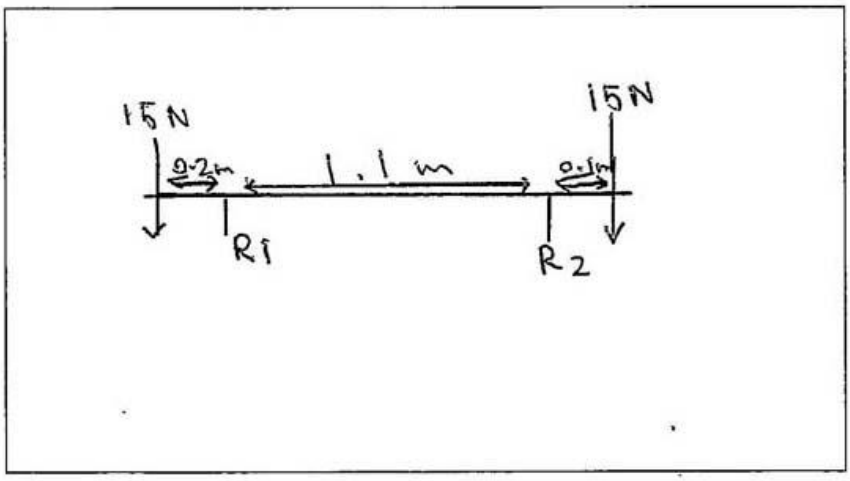
Complete the circuit diagram below to include an LDR and a fixed resistor so that the circuit meets the required specification. 3



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

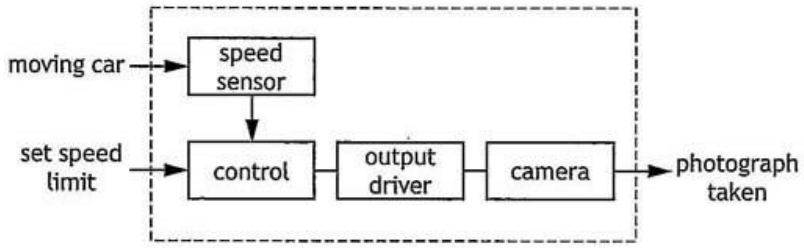


Draw a free body diagram for the bike and carrier shown above. 2



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

open loop controll

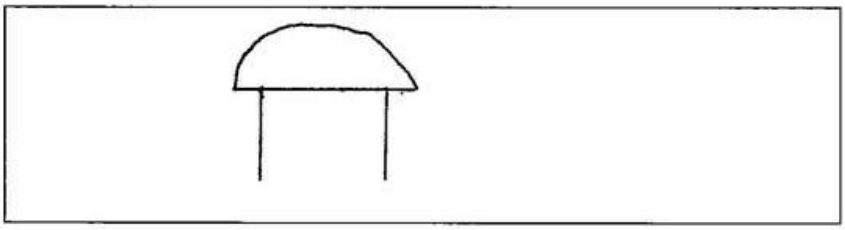
(b) Describe the operation of the motorway speed camera. 3

The speed limit is set.

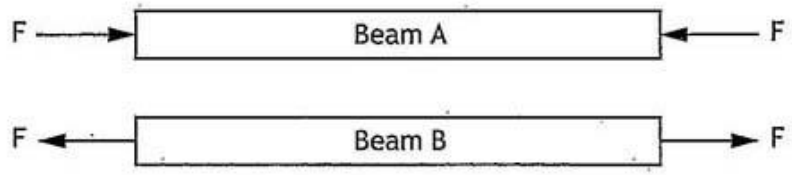
When a car drives past the speed camera, the speed sensor will detect the moving cars speed and if the speed is above the set speed limit then the control will send a signal to the act pot driver making the camera to a photograph of the moving car

5. A buzzer is a commonly used electronic component.

Draw the symbol for a buzzer. 1



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

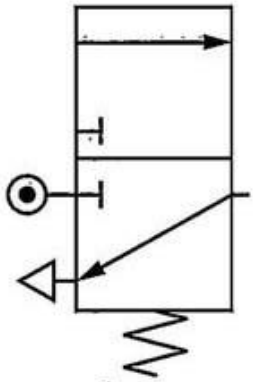


State the nature of the force acting on: 2

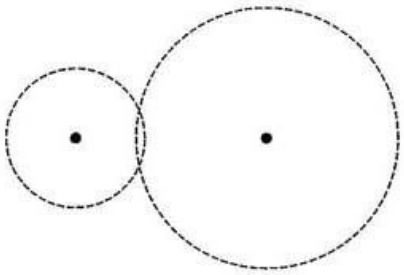
Beam A Stress

Beam B Strain

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



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



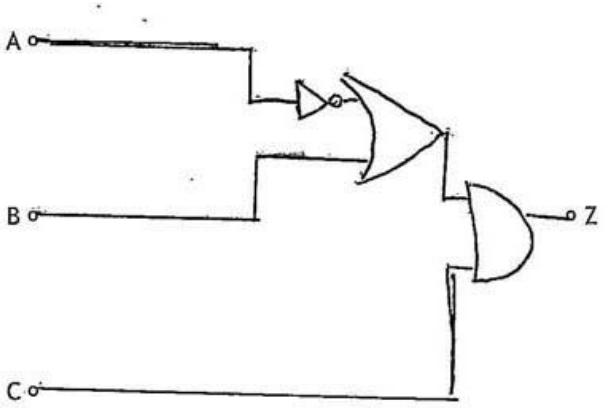
Describe two errors that were made when drawing this simple gear train. **2**

Error 1 the lines not visible

Error 2 the gear is drawn as a dotted line

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

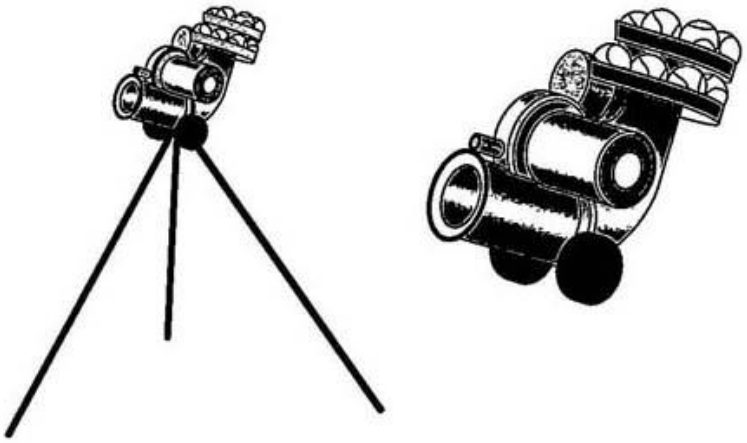
$$Z = (\overline{A} + B) \bullet C$$



SECTION 2 — 90 marks

Attempt ALL questions

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.

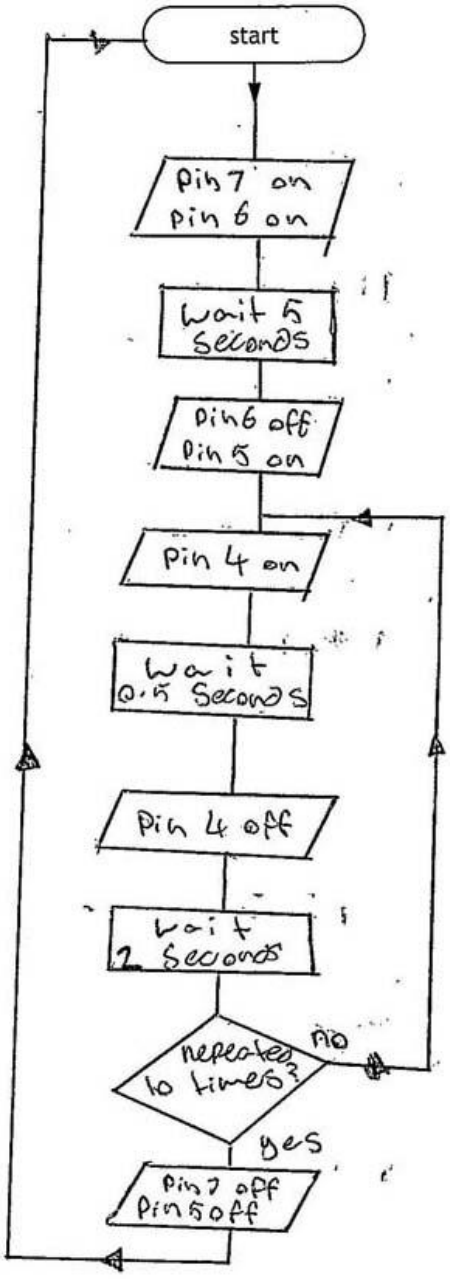
Input connections	Pin	Output connections
	7	ball firing motor
	6	red light
	5	green light
	4	ball release
start button	0	

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.

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**



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**

$$\epsilon = \frac{\Delta L}{L}$$

$$0.0016 = \frac{\Delta L}{1200}$$

$\times 1200$ $\times 1200$

$$1.92 = \Delta L$$

$$\Delta L = 1.92 \text{ mm}$$

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

rotary

(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

$E_p = m\ g\ h$

$= 69 \times 9.8 \times 6.8$

$= 4598.16\ J$

[Turn over

11. (b) (continued)

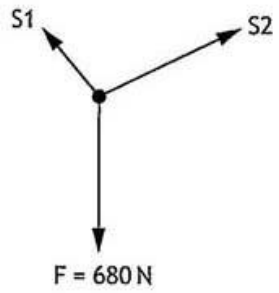
(ii) calculate their velocity when their kinetic energy is 970 J. 3

$$VR = \frac{\text{speed of input}}{\text{speed of output}}$$

$$= \frac{45 \quad 98.16}{970}$$

$$= 4.74 \text{ ms}^{-1}$$

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

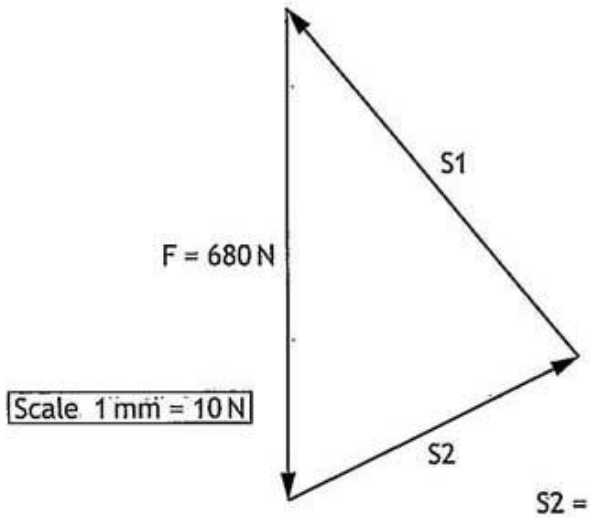


(i) State, with reference to the Data Booklet, the condition of equilibrium which does **not** need to be considered when studying forces acting at a single point. 1

$\Sigma Fv = 0$

11. (c) (continued)

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



S2 = 460 N

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

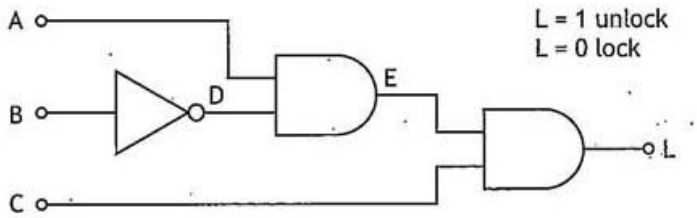
Select the most suitable material (A-D) from the table above to be used for the support wires and justify your choice. 2

Choice of material C

Reason for choice it can hold a lot of load (3250 N) and also has a high durability so will last a long time.

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

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

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

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

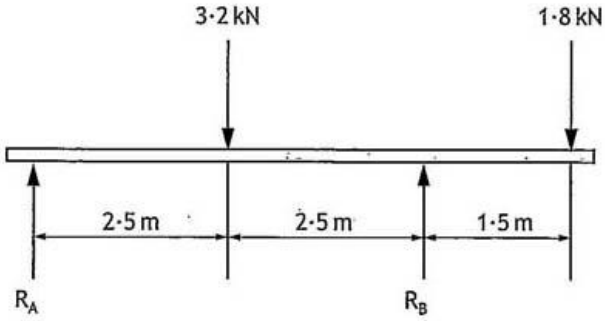
it is reprogramable

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

it is smaller so it takes less materials to make meaning less manufacturing in factories meaning less fuels used.

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**

CWM = ACWM
RA × 2 = (3.2 × 2.5) + (1.8 × 1.5)
RA × 2 = 10.7
RA = $\frac{10.7}{2}$ = 5·35 kN

13. (a) (continued)

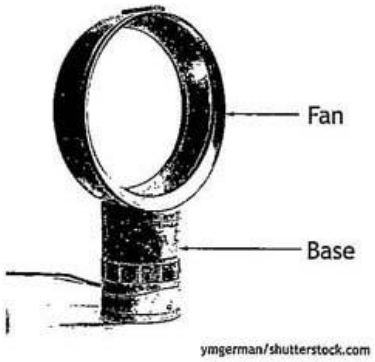
(ii) Calculate the size of reaction force R_B. 2

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

1 the size and shape of the catamaran and its sails

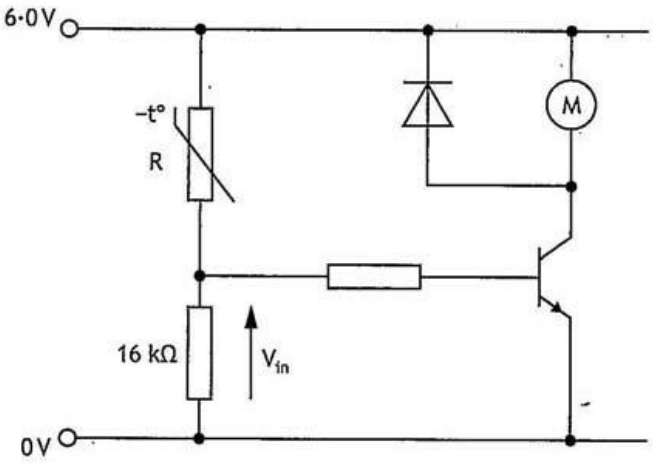
2 the materials the catamaran is made from.

14. A desktop fan is shown.



ymgerman/shutterstock.com

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



14. (continued)

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

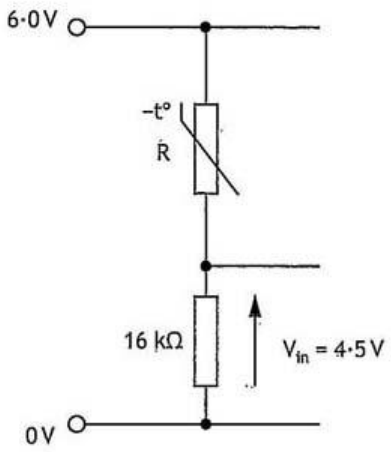
Include reference to the resistance of the thermistor and the voltage V_{in}.

As the temperature increases...

the thermistor reduces the resistance in the circuit making the motor turn faster, creating more movement for the fan cooling the room.

14. (continued)

The input sensing circuit of the fan is shown below.



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

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

$\frac{4.5}{1.5} = \frac{16}{R_2}$

$3 = \frac{16}{R_2}$ $\times R_2$ $\times R_2$

$3R_2 = 16$

$R_2 = \frac{16}{3} = 5.34\text{k}\Omega$

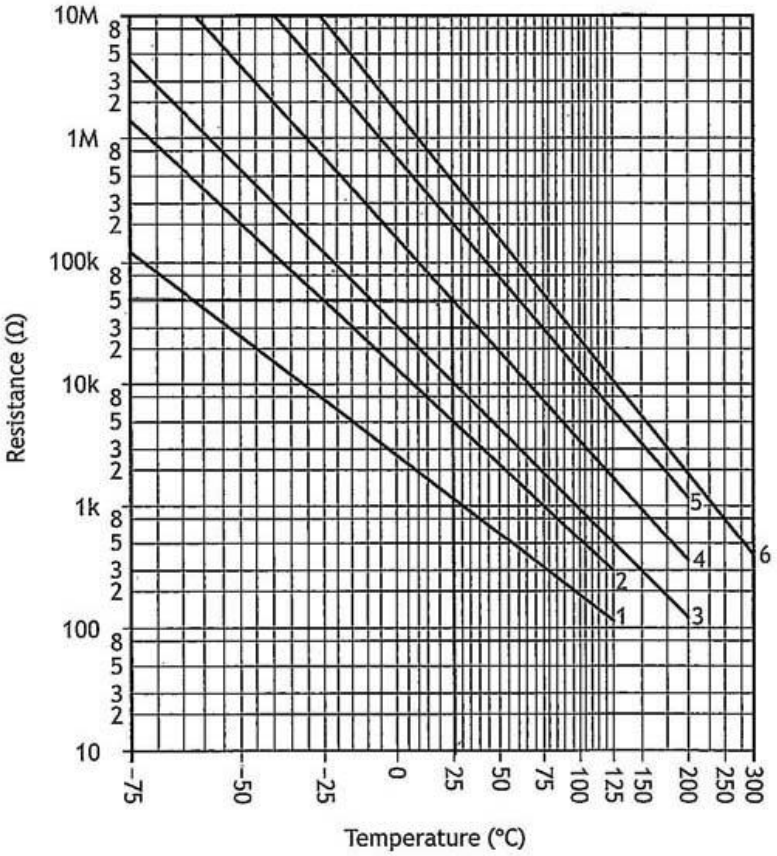
(c) Describe how the input sensing circuit could be modified so that the user can alter the temperature at which the fan motor switches on. 1

They could add a dial to manually change the temperature

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

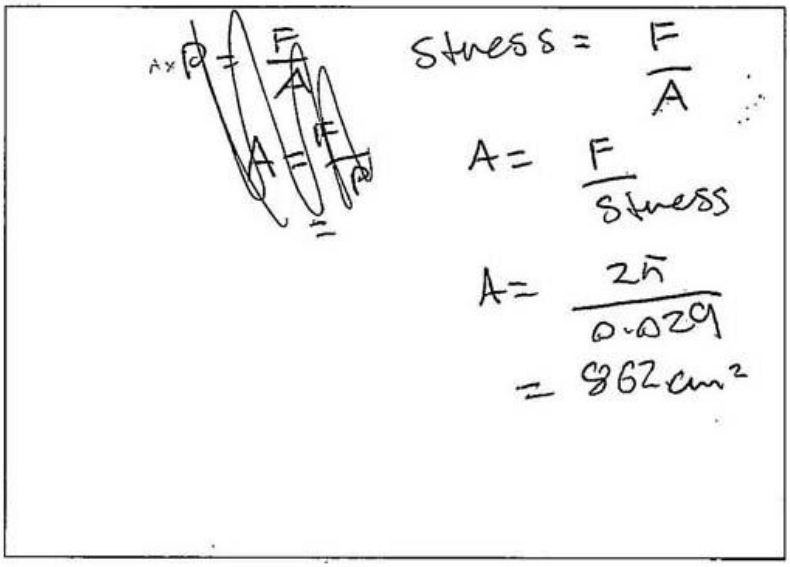
50k Ω



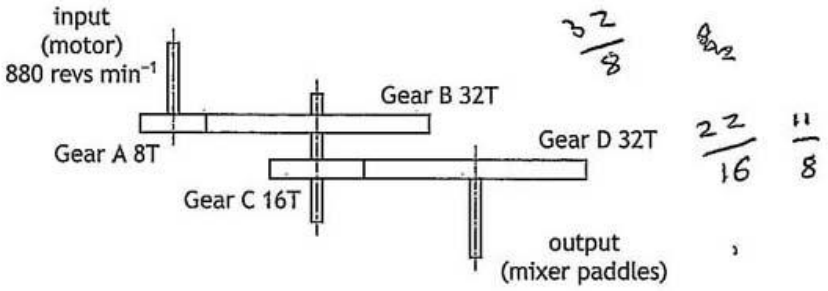
14. (continued)

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

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



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

$880 \div \frac{11}{2} = 160 \text{ rm}^{-1}$

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

velocity ratio = speed of input / speed of output

$= \frac{880}{160} = \frac{11}{2}$ or 11 : 2

15. (continued)

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

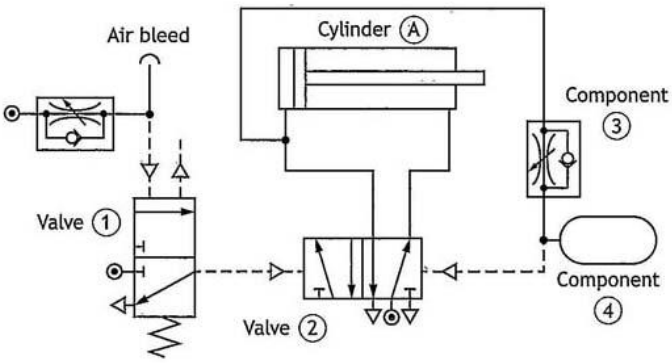
Describe one change that could be made to Gear B in order to increase the speed of the mixing paddles. 1

give gear B less teeth.

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.

3/2 Valve 1 when actuated sends air to 5/3 valve 2 which actuates cylinder A making it actstroke. air from valve 2 is also sent to component 3 and some is stored in resivour. Cylinder A will downstroke after air from the resivour goes back into 5/3 valve 2 making Cylinder A instroke

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

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

$$= \frac{73}{810}$$

$$= 0.09 \ N mm^{-2}$$

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

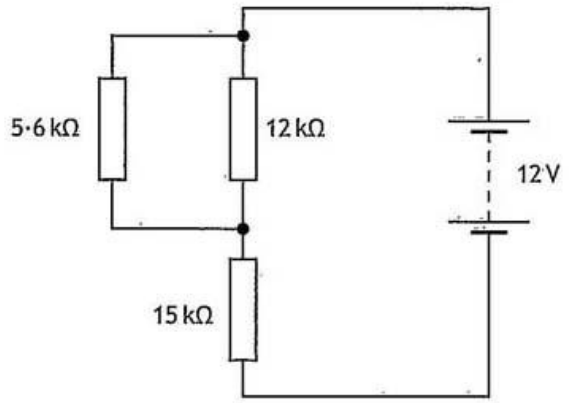
reduced use of fossil fuels like petrol

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

it takes a lot of electricity to charge the cars so it is hard to find a place to charge and could cause congestion on roads if one runs out of charge

16. (continued)

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



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

$R_T = R_1 + R_2 + R_3$

$= 0.8 + 1 + 2.7$

$= 4.5\ k\Omega$

$\frac{R_1 \times R_2}{(R_1 + R_2)}$

$= \frac{12 \times 4.8}{12 + 4.8}$

$= \frac{57.6}{16.8} = 3.8$

16. (continued)

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

$V = IR$
$V = 0.8 \times 15$
$V = 12\ V$

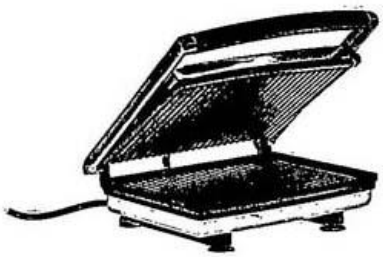
(ii) Calculate the current flowing through the 5·6 kΩ resistor. 4

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

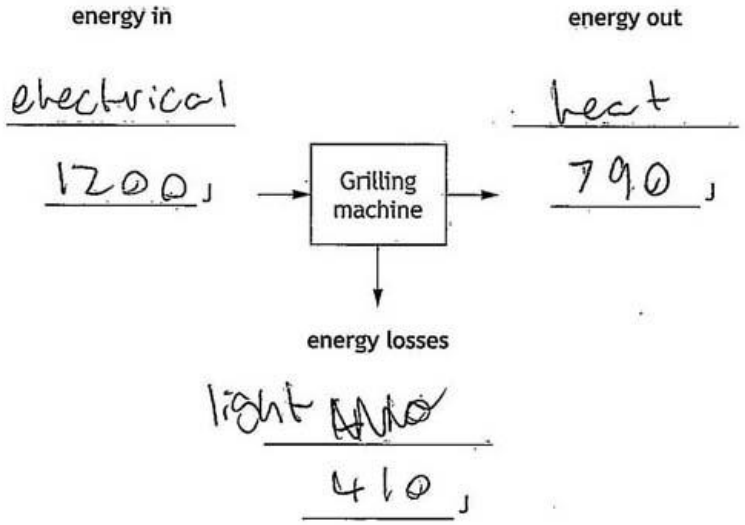
the ability to upload your thoughts and mind could if done correctly let your consciousness live forever.

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



Space for rough working

17. (continued)

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

efficency = 790 / 1200

= 0.658

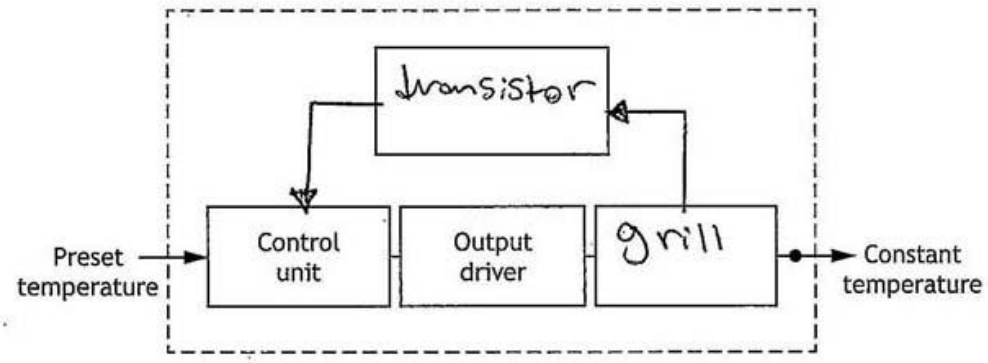
= 65.8 %

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

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

Closed loop

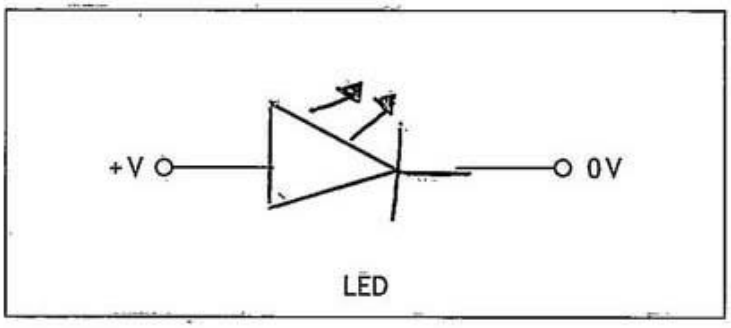
(ii) Complete the sub-system diagram below for the grilling machine. 3



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

put the LED in parallel so that it doesnt fail if others fail.

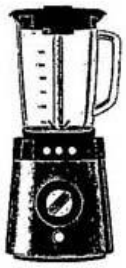
[END OF QUESTION PAPER]

Candidate 4 evidence

~~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

Mechanical engineer

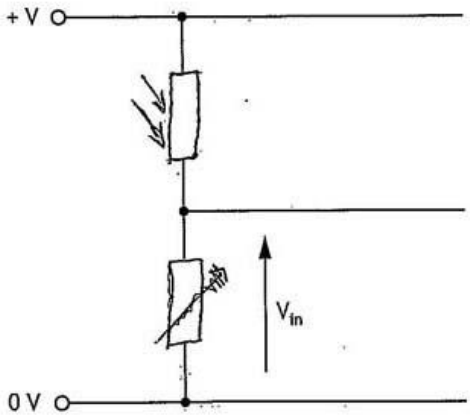
(b) State the type of engineer that would simulate the speed control circuit in the kitchen blender. 1

design / electrical engineer

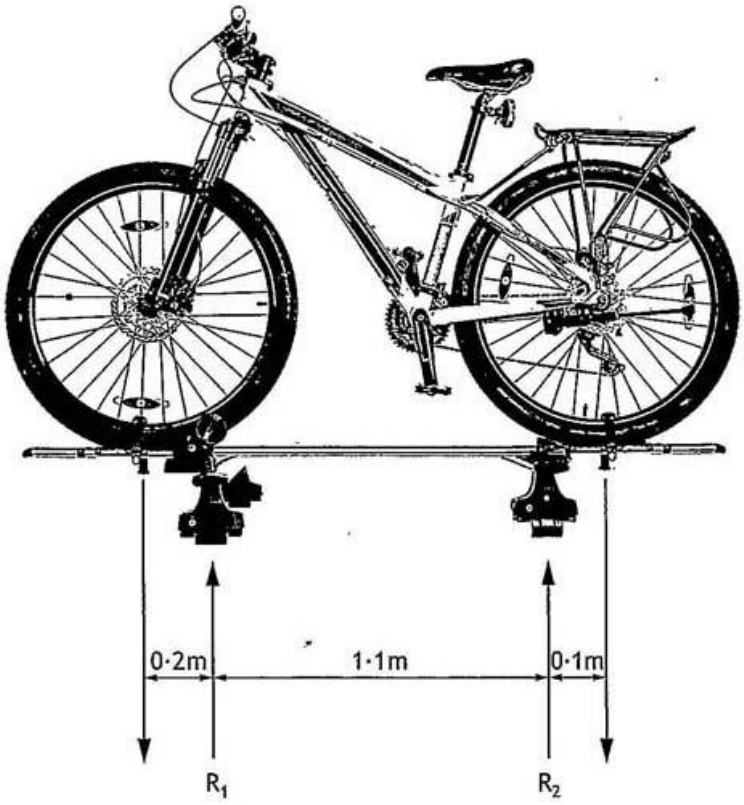
2. An electronic circuit is being designed to meet the following specification:

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

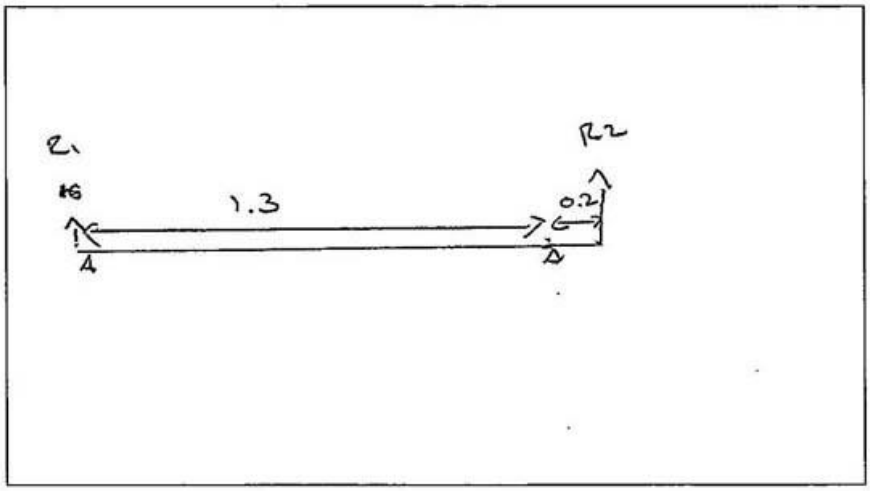
Complete the circuit diagram below to include an LDR and a fixed resistor so that the circuit meets the required specification. 3



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

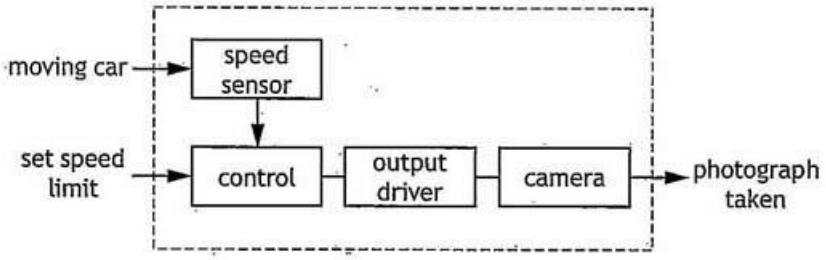


Draw a free body diagram for the bike and carrier shown above. 2



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

Open Loop

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

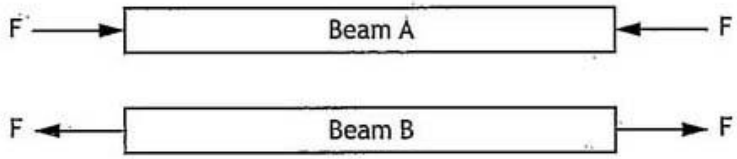
The speed limit is set.

once a car has passed the speed camera and is doing over the set speed limit this send a signal to the control system therefore sending a signal to the camera to retrive a photo of the licence plate

5. A buzzer is a commonly used electronic component.

Draw the symbol for a buzzer. 1

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

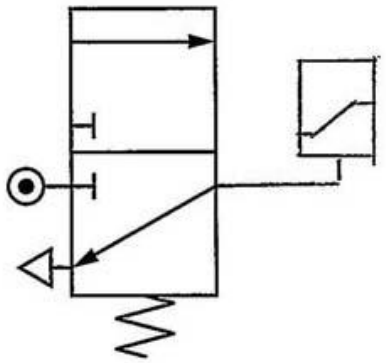


State the nature of the force acting on: 2

Beam A Compression

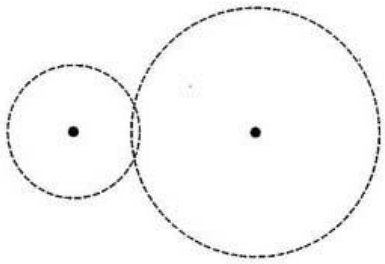
Beam B Tension

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



[Turn over

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



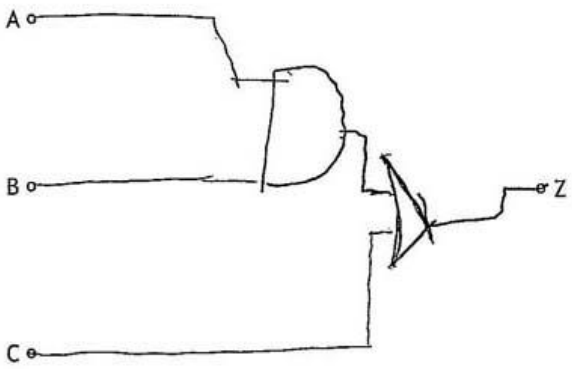
Describe two errors that were made when drawing this simple gear train. 2

Error 1 the gears overlap not showing which gears gear is infront

Error 2 Should be a solid line instead of a dashed line

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

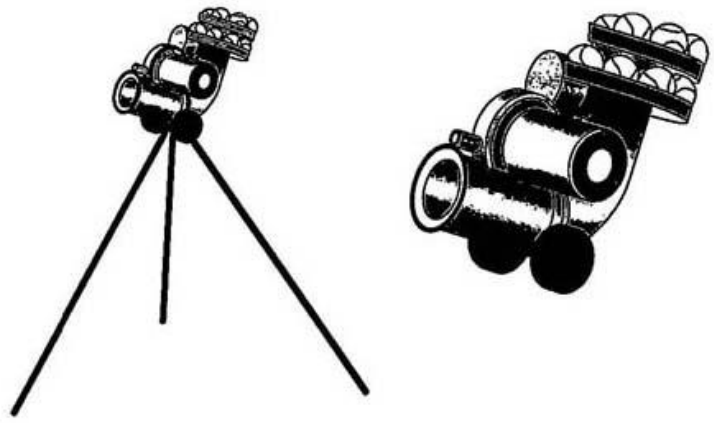
$$Z = (\overline{A} + B) \bullet C$$



SECTION 2 — 90 marks

Attempt ALL questions

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.

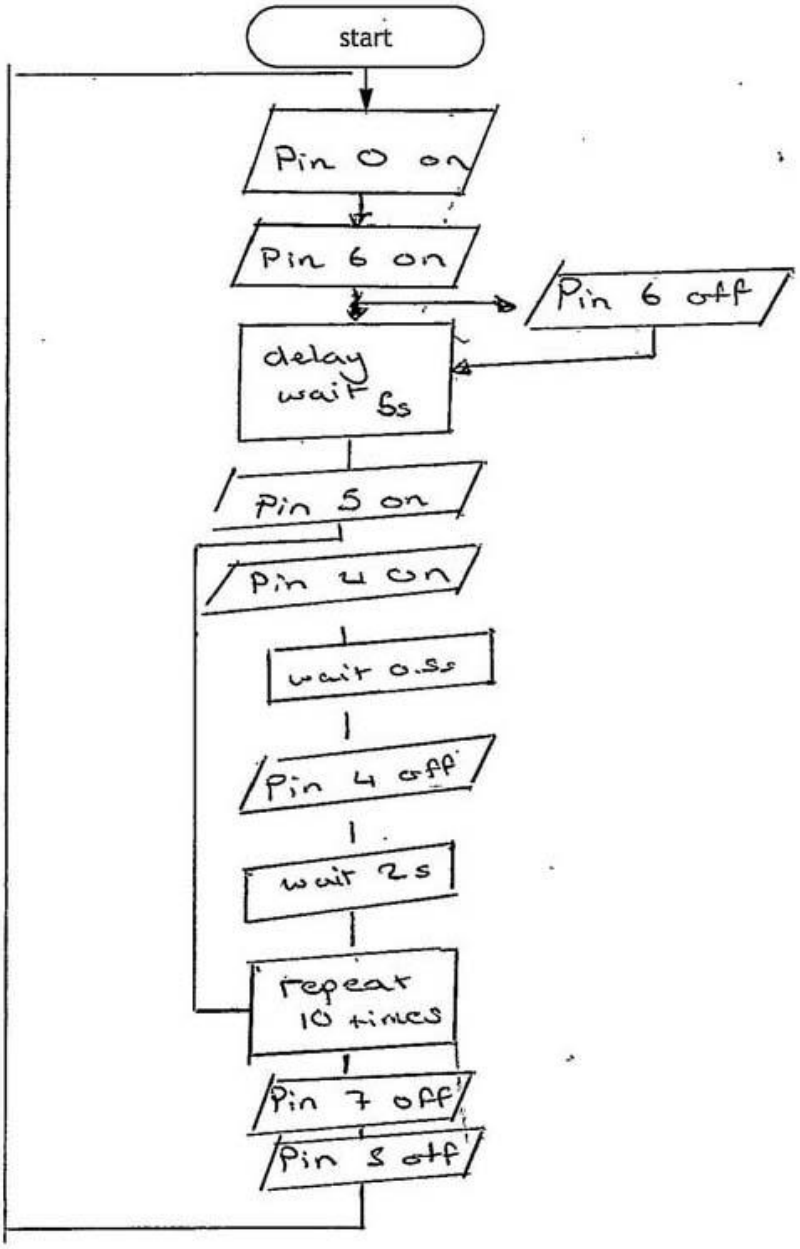
Input connections	Pin	Output connections
	7	ball firing motor
	6	red light
	5	green light
	4	ball release
start button	0	

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.

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**



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**

$\epsilon = \frac{\Delta L}{L}$

$0.0016 = \frac{\Delta L}{1200}$

$\Delta L = 0.0016 \times 1200$

$= 1.92\text{mm}$

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

Oscillating

(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

$Gp = mgh$

$= 69 \times 9.8 \times 6.8$

$= 4695.36$

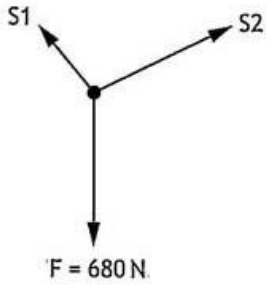
11. (b) (continued)

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

$E_k = \frac{1}{2}mv^2$

=

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

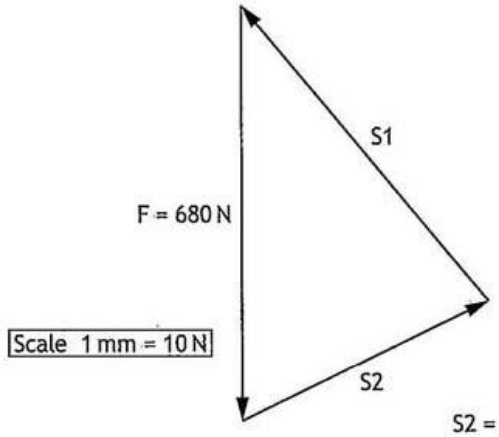


(i) State, with reference to the Data Booklet, the condition of equilibrium which does not need to be considered when studying forces acting at a single point. 1

gravity

11. (c) (continued)

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



S2 = 450 N

[Turn over

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

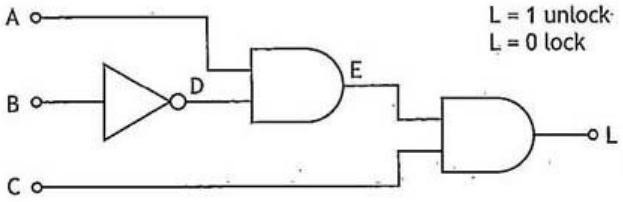
Select the most suitable material (A-D) from the table above to be used for the support wires and justify your choice. 2

Choice of material Material C

Reason for choice Max. tensile load is higher but also balances out with the high durability.

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 = (A+B).C (A.B)+C

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

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

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

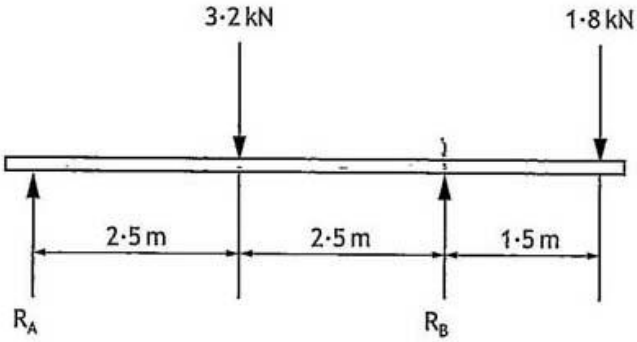
Reprogrammable Microcontrollers are more efficient and if a problem occured it would be a lot easier to sort out

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

Less heat, more eco friendly, less use of unneed waste materials

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

$M = F_x$

13. (a) (continued)

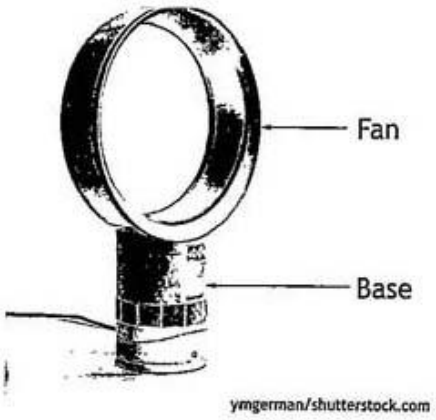
(ii) Calculate the size of reaction force R_B. 2

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

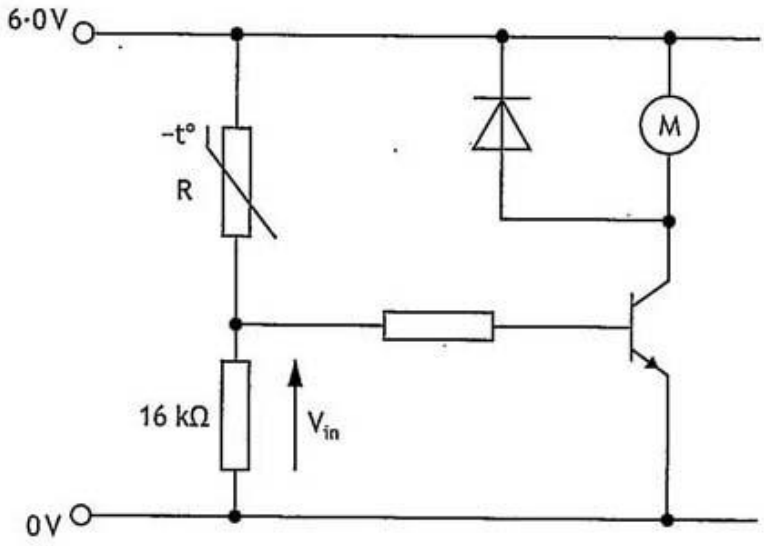
1 The select materials to make it light as possible

2 Simulation to ensure the product is as best as can be.

14. A desktop fan is shown.



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



14. (continued)

(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}.

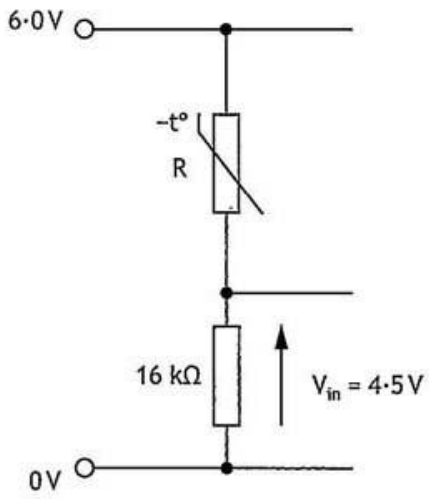
As the temperature increases...

As the temperature increases the resistance decreases across the circuit producing a rush of colder air

[Turn over

14. (continued)

The input sensing circuit of the fan is shown below.



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

$V = IR$ $V = 6 - 4.5$ $= 1.5V$ $V = IR$

$4.5 = I \times 16000$

$I = \frac{4.5}{16000}$

$I = 2.8 \times 10^{-4}$

$1.5 = 2.8 \times 10^{-4} \times R$

$R = \frac{1.5}{2.8 \times 10^{-4}}$

$= 3125\ \Omega$

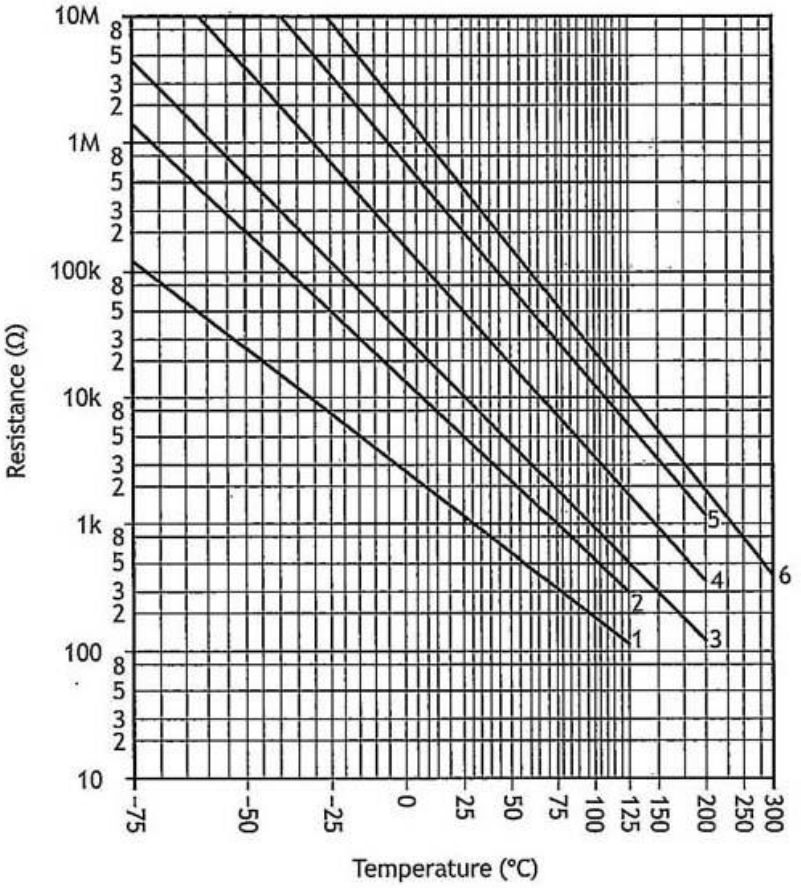
(c) Describe how the input sensing circuit could be modified so that the user can alter the temperature at which the fan motor switches on. 1

by placing an NTC thermistor for a set reading.

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

1000 Ω



[Turn over

14. (continued)

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

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

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

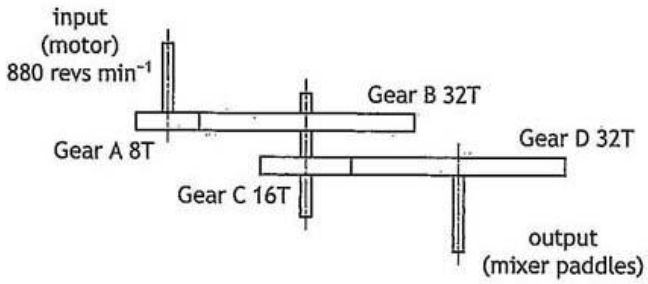
$$A = \frac{F}{\sigma}$$

$$= \frac{25}{0.029}$$

$$= 862.1\ \text{mm}^2$$

$$= 862\text{mm}^2$$

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

VR = Speed of input / Speed of output

32 = 880 / S.O

= 880 / 32

= 27.5 revs min^{-1}

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

VR = 80i / 500

= 880 / 27.5

= 32 ms^{-1}

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

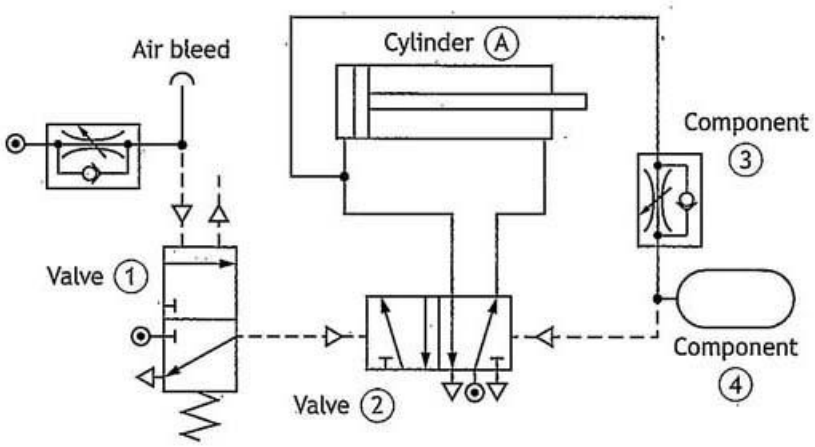
decrease size of cog

[Turn over

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.

Pushing the pilot air into the 5/2 valve which releases pressure to the double acting cylinder causing to outstroke once passed the unidirectional restrictor and fills the reservoir the air returns to the 5/2 valve and causes the cylinder to instroke.

15. (continued)

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

as soon as the air was completely gone a sensor would trigger stating that a pressures been released

(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

$P = fa$

$= 73 \times 810$

$= 59130\ N$

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

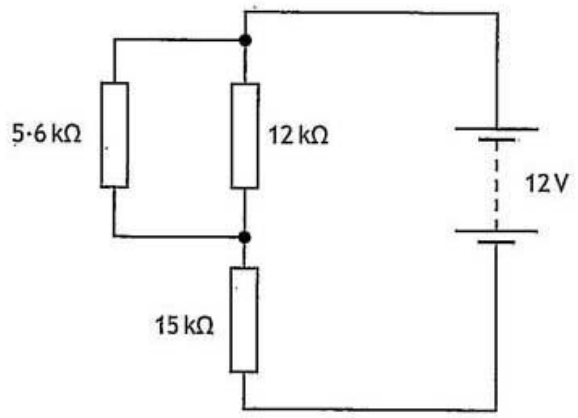
no fuel emission

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

more time to charge less places to charge

16. (continued)

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



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

$R_T = R_1 + R_2$

$= 15000 + 12000$

$= 27000\ \Omega$

$R_T = \frac{R_1 \times R_2}{(R_1 + R_2)}$

$= \frac{5600 \times 12000}{5600 + 12000}$

$= \frac{67200000}{17600}$

$= 3818.18\ \Omega$

27000

$+ 3818$

$= 30818\ \Omega$

$V_O = \frac{R_2}{(R_1 + R_2)} \times V_S$

$= \frac{15000}{(5600 + 12000)} \times 12$

$=$

16. (continued)

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

$V = IR$
$= 0.6 \times 10^{-3} \times 15000$
$= 9V$

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

$V = IR$
$IR = I \times 5600$
$\frac{IR}{5600}$
$= 2.14 \times 10^{-3} A$

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.

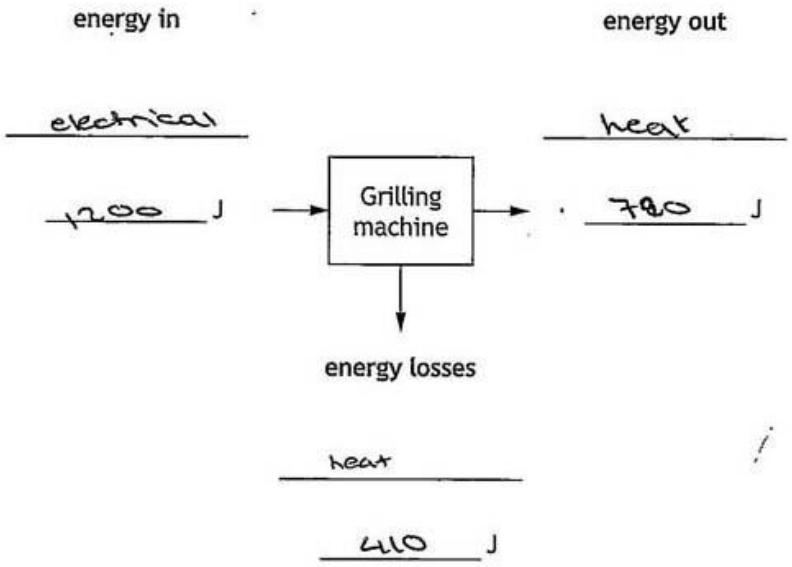
(d) Explain the possible impact of an **emerging technology** that you are familiar with. 2

- people may not attract to the technology
- issues may occur within the product early.

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



Space for rough working

1200 - 790
= 410 J

17. (continued)

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

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

$= \frac{1200}{790}$

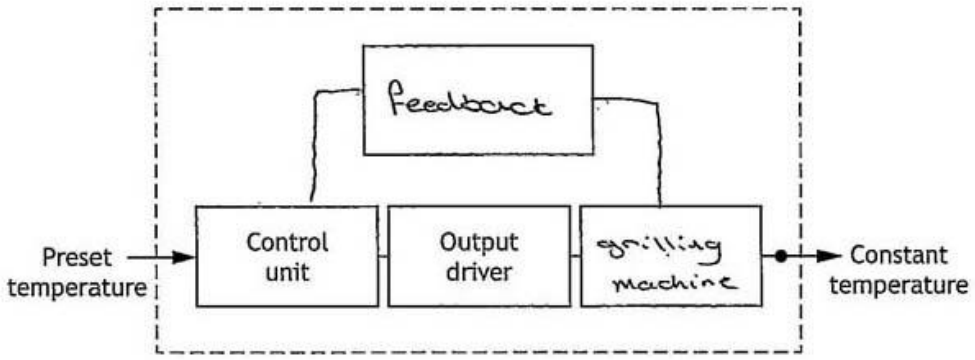
$= 1.5$

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

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

closed loop

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

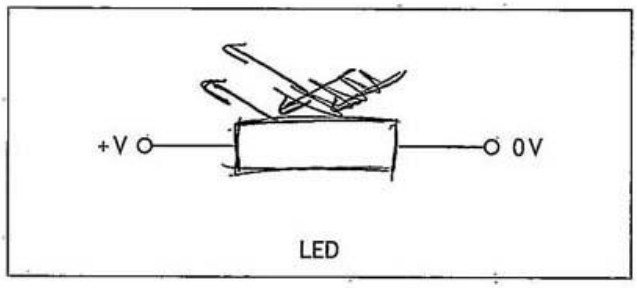


[Turn over for next question

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

adding a diode or a relay switch

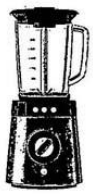
[END OF QUESTION PAPER]

Candidate 5 evidence

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

mechanical engineer

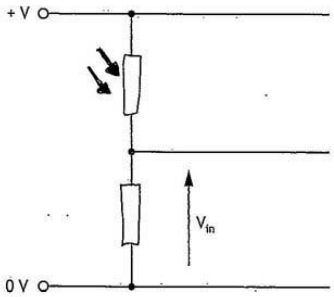
(b) State the type of engineer that would simulate the speed control circuit in the kitchen blender. 1

electrical engineer

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



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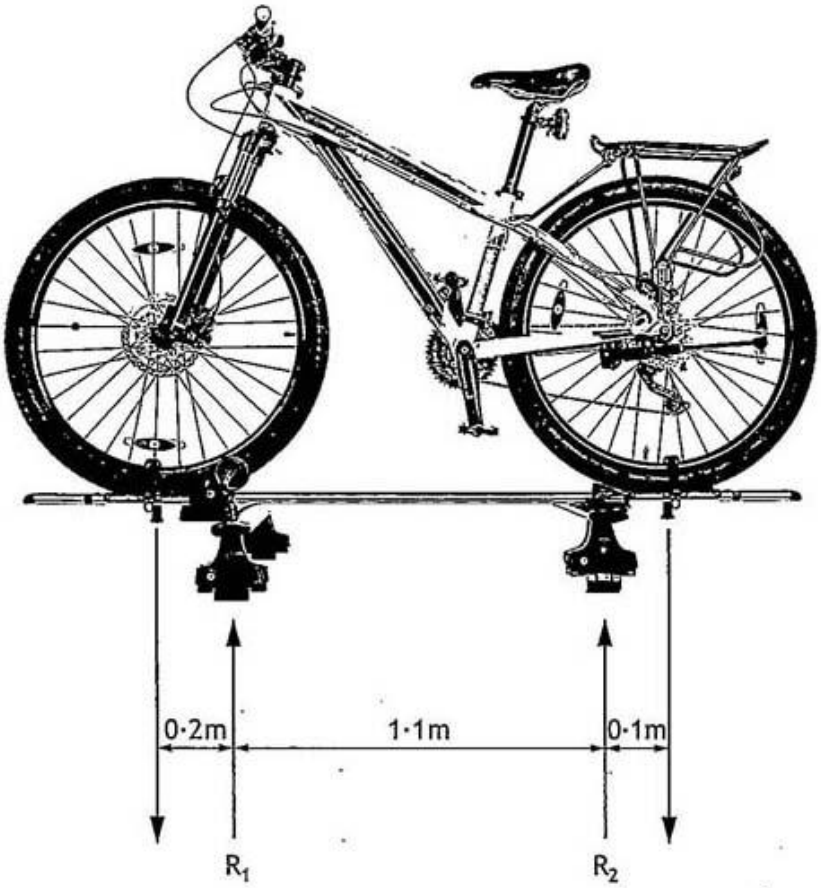
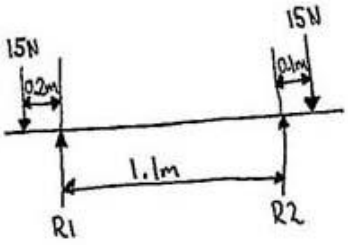
page 02

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

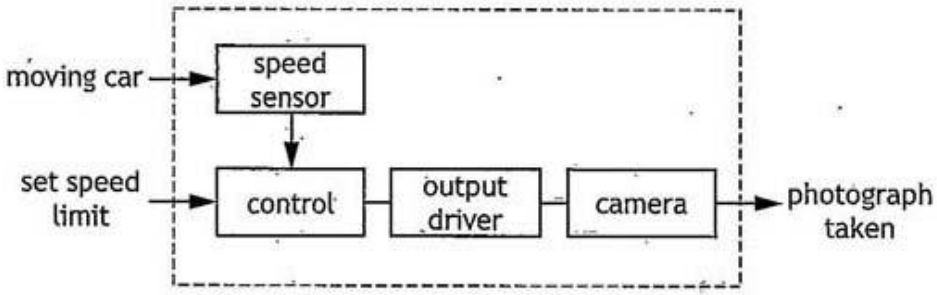


Draw a free body diagram for the bike and carrier shown above. 2



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

Open loop control

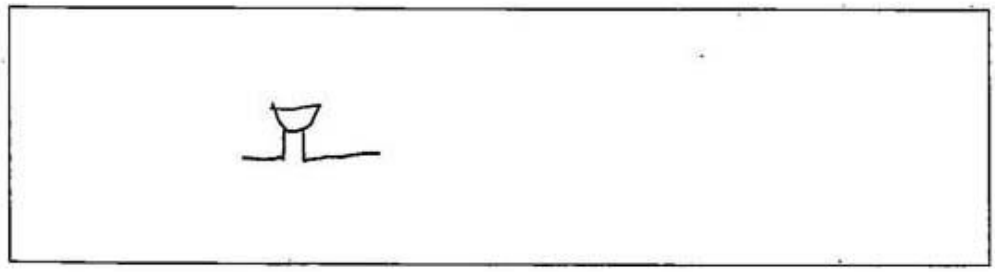
(b) Describe the operation of the motorway speed camera. 3

The speed limit is set.

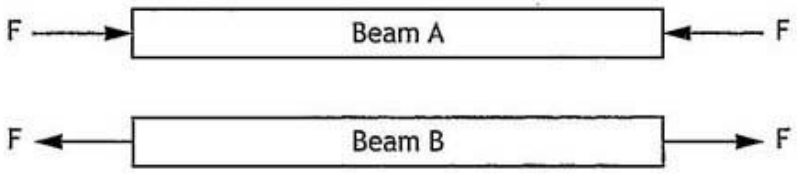
The speed sensor detects the moving car, If the car is not speeding the sensor waits for the next car. If the car is speeding the sensor triggers the contol unit which then activates the camera and a photo is taken.

5. A buzzer is a commonly used electronic component.

Draw the symbol for a buzzer. 1



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

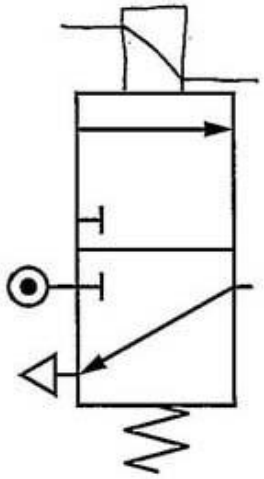


State the nature of the force acting on: 2

Beam A Compression

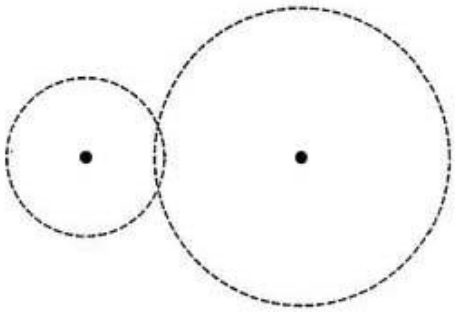
Beam B tension

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



[Turn over

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



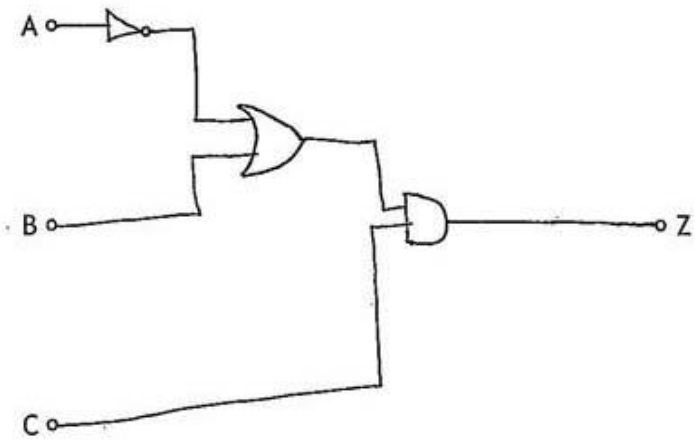
Describe two errors that were made when drawing this simple gear train. 2

Error 1 the lines should not be dotted.

Error 2 there should be 2 circles to represent 1 gear.

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

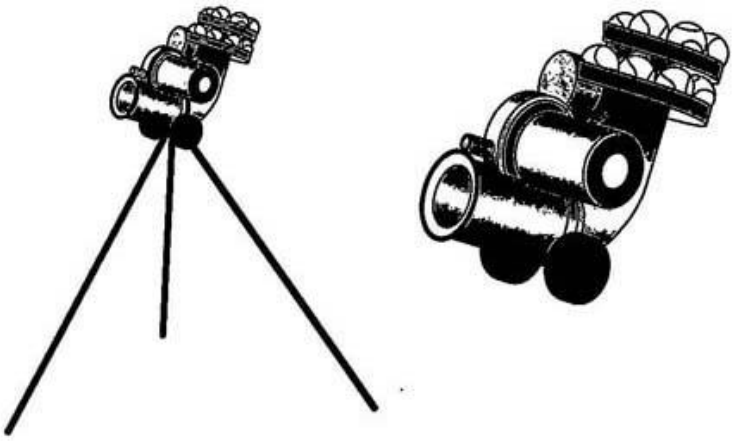
$$Z = (\overline{A} + B) \bullet C$$



SECTION 2 — 90 marks

Attempt ALL questions

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.

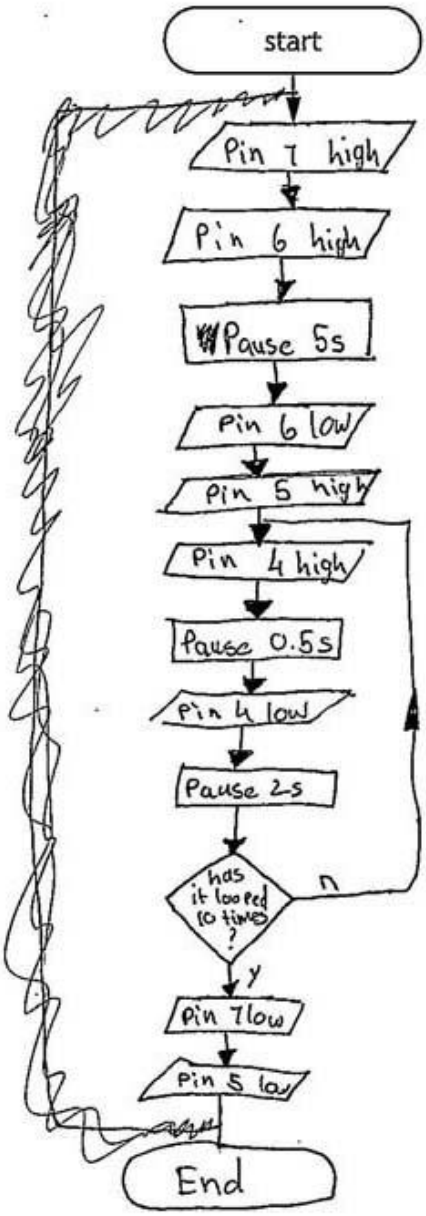
Input connections	Pin	Output connections
	7	ball firing motor
	6	red light
	5	green light
	4	ball release
start button	0	

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.

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**



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

$\epsilon = \frac{\Delta L}{L}$

$0.0016 = \frac{\Delta L}{1200}$

$0.0016 \times 1200 = \Delta L$

$\Delta L = 1.92\text{mm}$

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

Rotational

(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

$E_p = mgh$

$E_p = 69 \times 9.8 \times 6.8$

$E_p = 4598.16$ J

[Turn over

11. (b) (continued)

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

$E_K = \frac{1}{2} m v^2$

$970 = \frac{1}{2} \times 69 \times v^2$

$\frac{970}{0.5 \times 69} = v^2$

$v^2 = \frac{970}{34.5}$

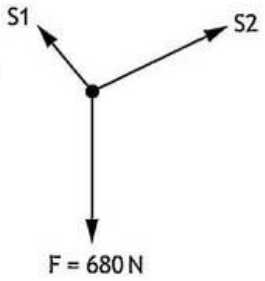
$v^2 = 28.11594203$

$v = \sqrt{28.11594203}$

$V = 5.302446796$

$v = 5.3$

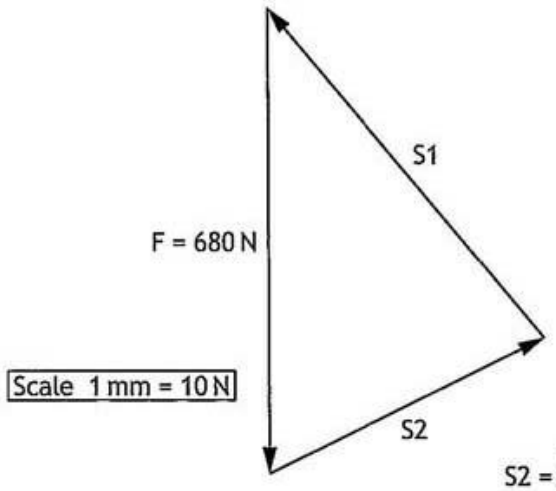
(c) Part of the supporting structure for the trapeze swing is shown below.



(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

11. (c) (continued)

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



S2 = 450 N

[Turn over

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

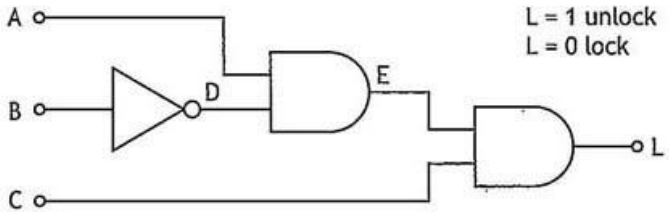
Select the most suitable material (A-D) from the table above to be used for the support wires and justify your choice. 2

Choice of material C

Reason for choice This material is strong enough to hold the wait and is durable

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 = $(A.\overline{B}).C$

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

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

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

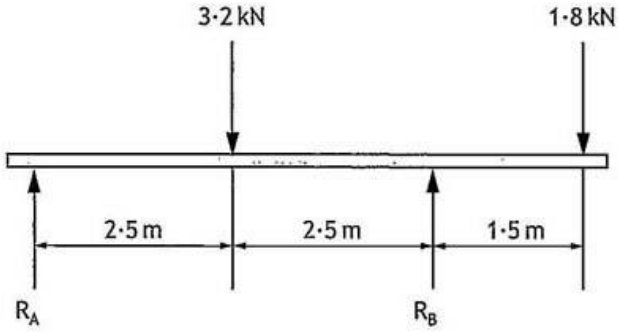
the micro controller is very small

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

it takes up less material meaning not as much machines are used to manufacture the product which means less fumes in the air

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

$\Sigma cwm = \Sigma acwm$

$(1.8 \times 1.5) + (a \times 5) = 3.2 \times 2.5$

$2.7 + 5a = 8$

$5a = 8 - 2.7$

$5a = 5.3$

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

$a = 1.06$

$R_A = 1.06\,kN$

13. (a) (continued)

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

$\Sigma\uparrow = \Sigma\downarrow$

$1.06 + R_B = 3.2 + 1.8$

$R_B = 5$

$R_B = 5 - 1.06$

$R_B = 3.94\text{kN}$

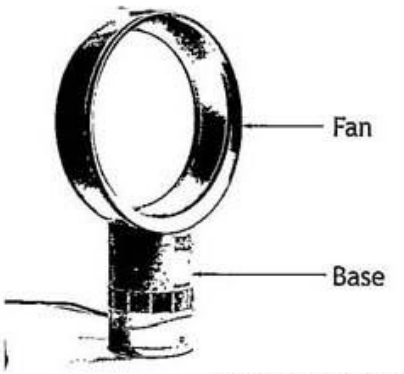
(b) Describe two specific roles a **structural** engineer may have had in the **development** of the catamaran. 2

1 Think of forces and where forces are being applied.

2 Source the correct material.

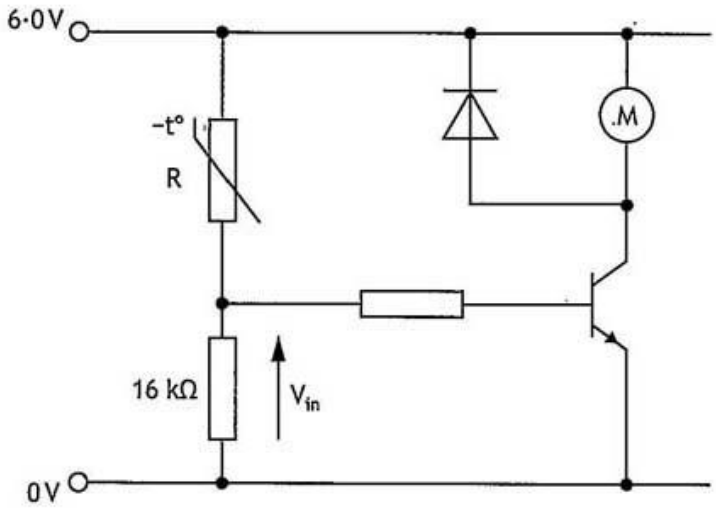
[Turn over

14. A desktop fan is shown.



ymgerman/shutterstock.com

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



14. (continued)

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

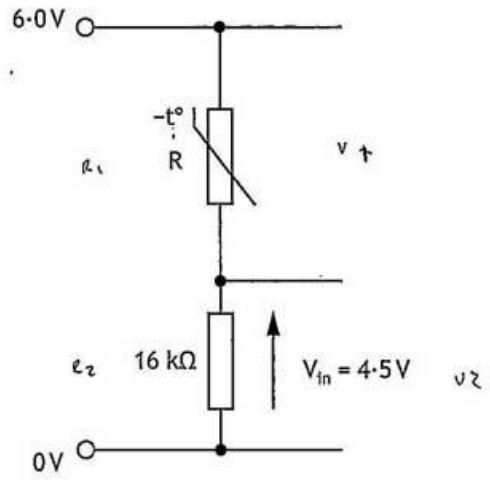
Include reference to the resistance of the thermistor and the voltage V_{in}.

As the temperature increases...

the resistance decreases across the thermistor. This allows current to flow through the set. resistor and through the NPN transistor and towards the motor causing the motor to turn on.

14. (continued)

The input sensing circuit of the fan is shown below.



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

$\frac{V1}{V2} = \frac{R1}{R2}$

$\frac{1.5}{4.5} = \frac{R1}{16}$

$\frac{1.5}{4.5} \times 16 = R1$

$R1 = \frac{1.5}{4.5} \times 16$

$R1 = 5.3333333333$

$R1 = 5.33\,k\Omega$

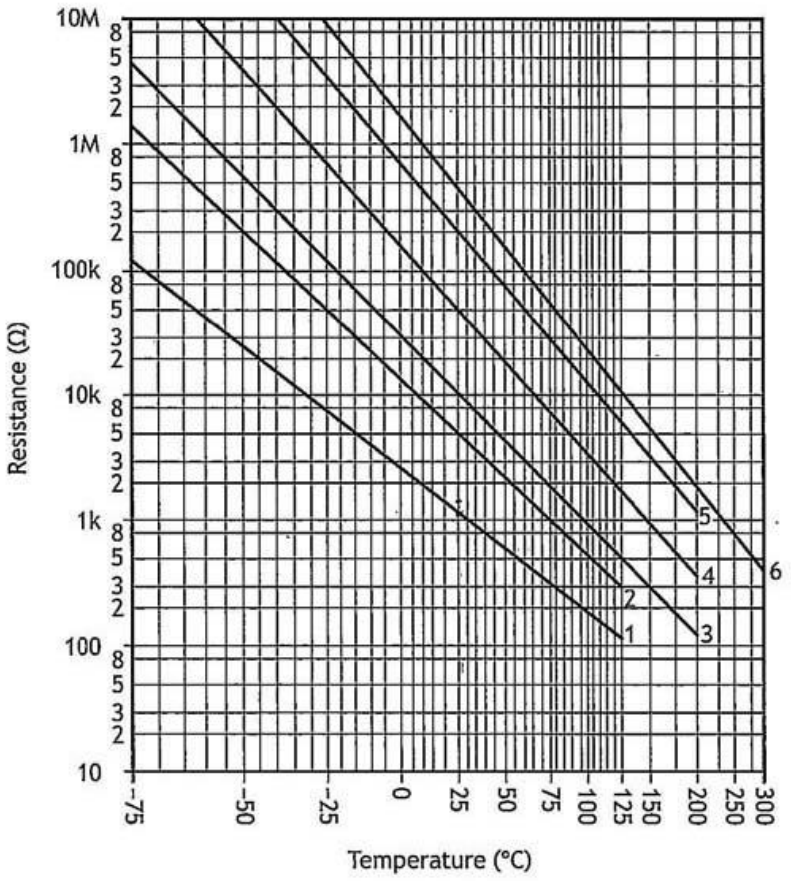
(c) Describe how the input sensing circuit could be modified so that the user can alter the temperature at which the fan motor switches on. 1

a Vairiable resistor can be added

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

1 kΩ



14. (continued)

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

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

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

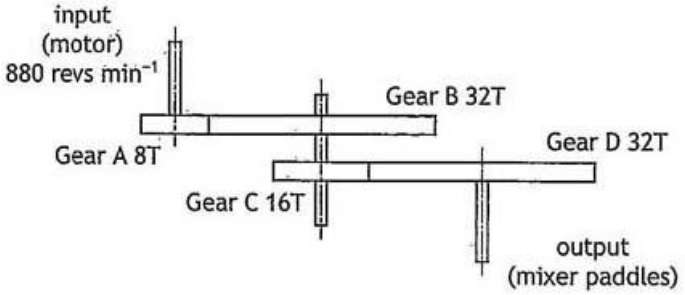
$$0.029 = \frac{25}{A}$$

$$A = \frac{25}{0.029}$$

$$A = 862.0689655$$

$$A = 862.07\ \text{mm}^2$$

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

In speed x In Size = out speed x outSize

$880 \times 8 = a \times 32$

$\frac{880 \times 8}{32} = a$

$a = \frac{7040}{32}$

$a = 220$

output speed = 220 revs min^{-1}

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

VR = $\frac{\text{Speed in}}{\text{Speed out}}$

$= \frac{880}{220}$

VR = 4

15. (continued)

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

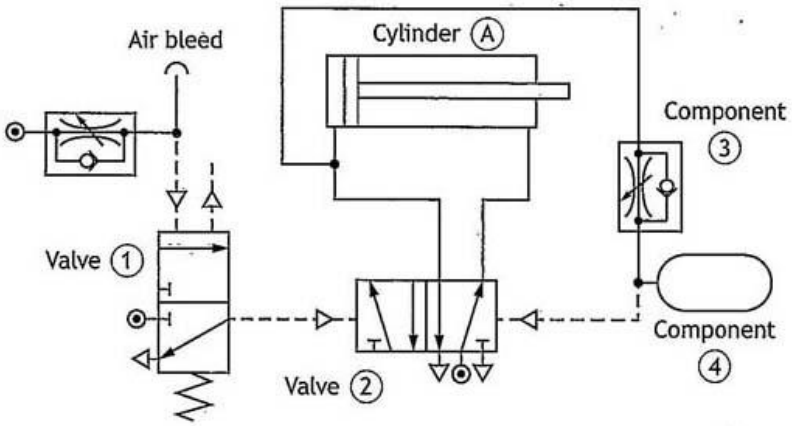
Describe one change that could be made to Gear B in order to increase the speed of the mixing paddles. 1

it could be made smaller

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.

which actuates the valve (2). This then makes cylinder (A) out stroke. Air also goes to component (3) and through component (4) causing a time delay before going back through valve (2) causing cylinder (A) to instroke.

15. (continued)

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

It can be manually operated

(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**

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

$$P = \frac{73}{810}$$

$P = 0.090123456 79$

$P = 0.09$

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

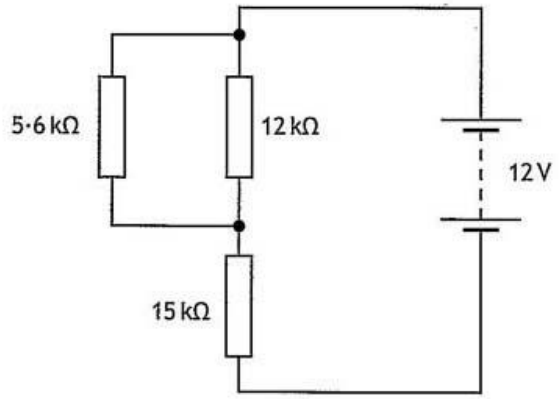
not fuel gasses are released into the air

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

charging them costs money.

16. (continued)

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



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

$$\frac{R_1 \times R_2}{R_1 + R_2}$$

$$= \frac{5.6 \times 12}{5.6 + 12}$$

$$= \frac{67.2}{17.6}$$

$$= 3.818181818 + 15$$

$$18.818181818$$

$$TR = 18.82 k\Omega$$

16. (continued)

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

V = ?
I = 0.6
R = 15

V = I x R = 0.6 x 15 = 9

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

V = 9
I = ?
R = 5.6

I = V/R = 9/5.6
= 1.607142857
= 1.61 A

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.

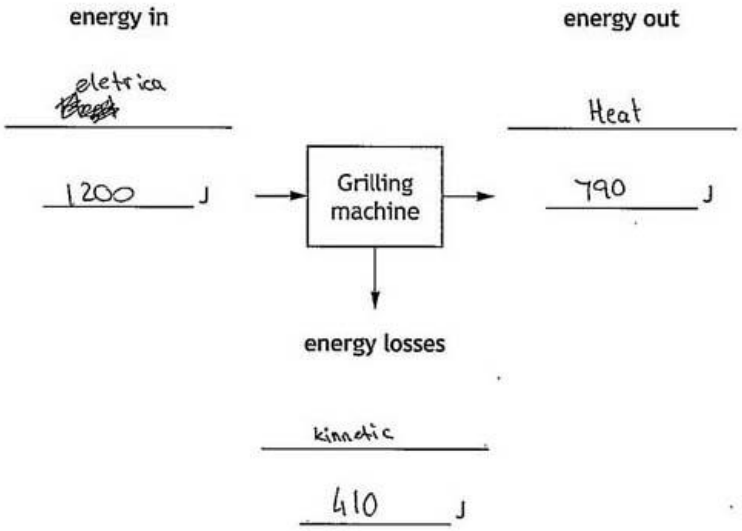
(d) Explain the possible impact of an **emerging technology** that you are familiar with. 2

Artificail farming, more crops can be grown.

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



Space for rough working

17. (continued)

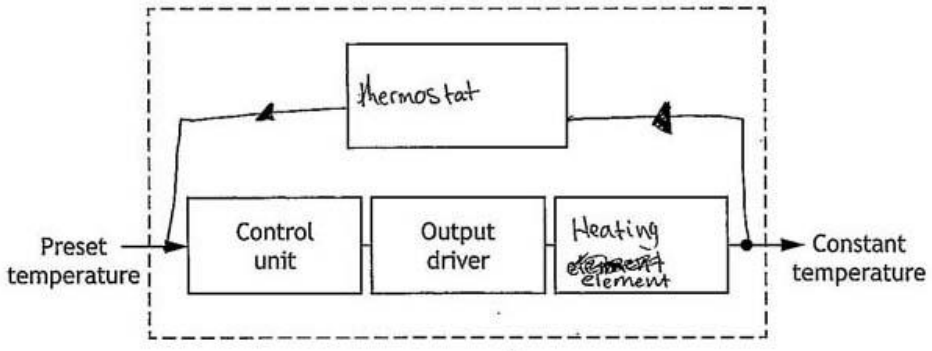
(b) Calculate the efficiency of the grilling machine. 2

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

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

open loop

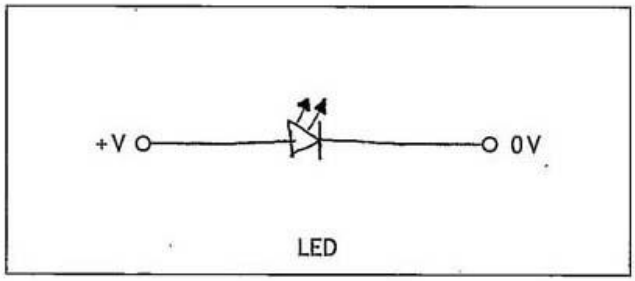
(ii) Complete the sub-system diagram below for the grilling machine. 3



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

less voltage / add resistor.

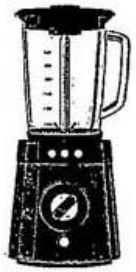
[END OF QUESTION PAPER]

Candidate 6 evidence

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

Mechanical

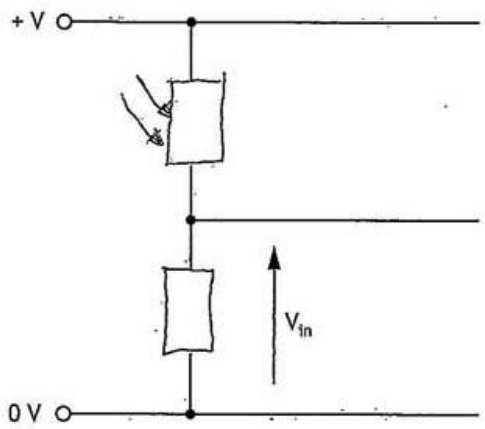
(b) State the type of engineer that would simulate the speed control circuit in the kitchen blender. 1

electronic

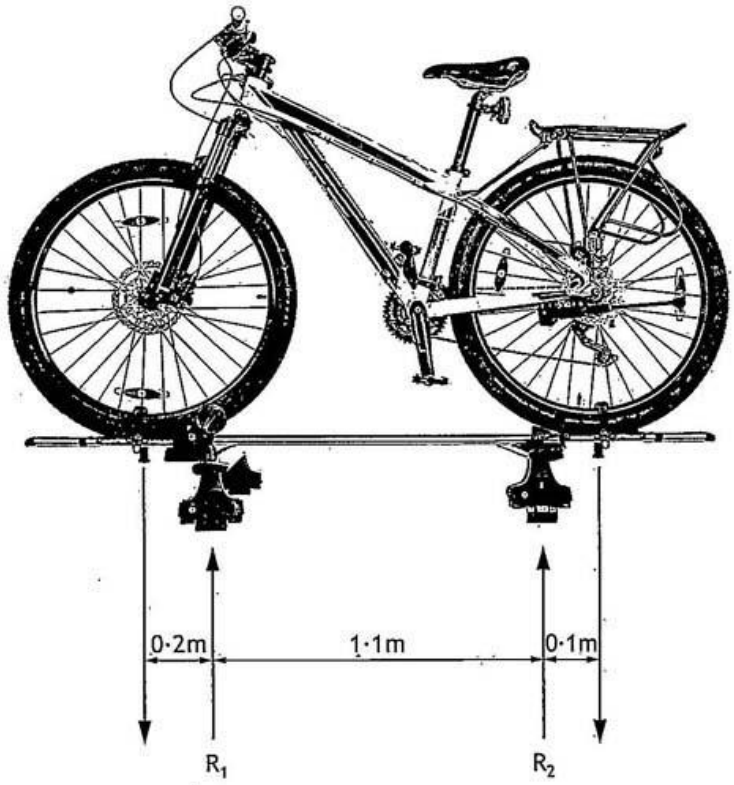
2. An electronic circuit is being designed to meet the following specification:

- 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



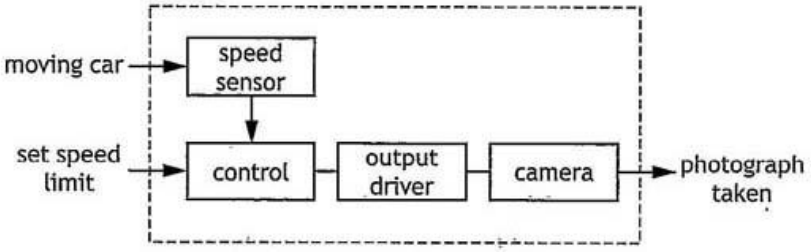
3. A bike and carrier are shown below. Each bike wheel applies a force of 15 N onto the carrier.



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

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

Open loop

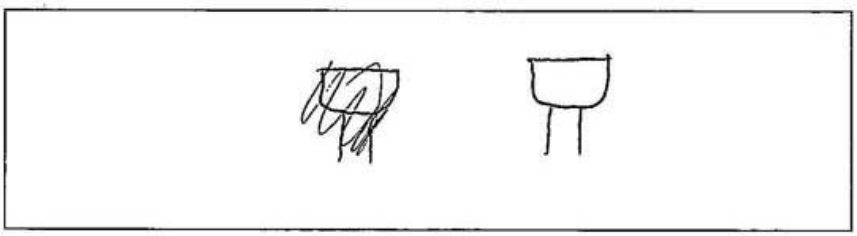
(b) Describe the operation of the motorway speed camera. 3

The speed limit is set.

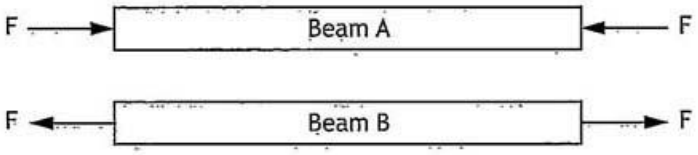
When the car moves past the Speed Sensor the Speed will be then sent to the control unit. If it is above the set speed limit then the control unit will then turn the output driver on which will then power the camera and take the photograph

5. A buzzer is a commonly used electronic component.

Draw the symbol for a buzzer. 1



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

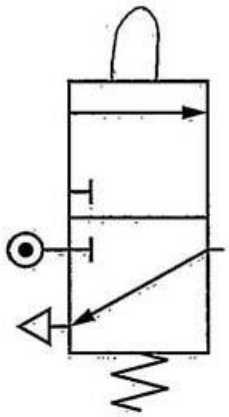


State the nature of the force acting on: **2**

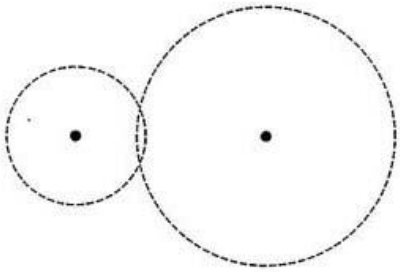
Beam A Compression

Beam B Tension

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



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



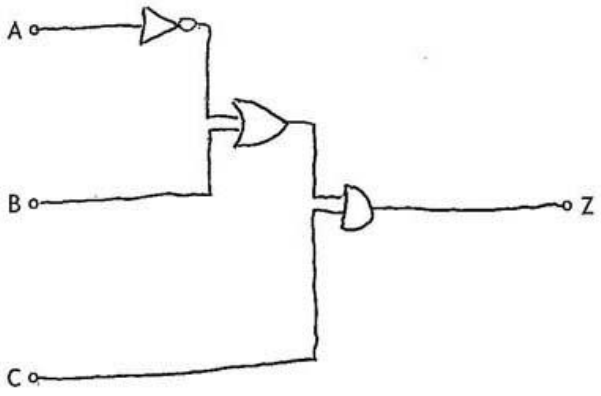
Describe two errors that were made when drawing this simple gear train. 2

Error 1 The gears have been drawn inside each other

Error 2 They have used dotted lines

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

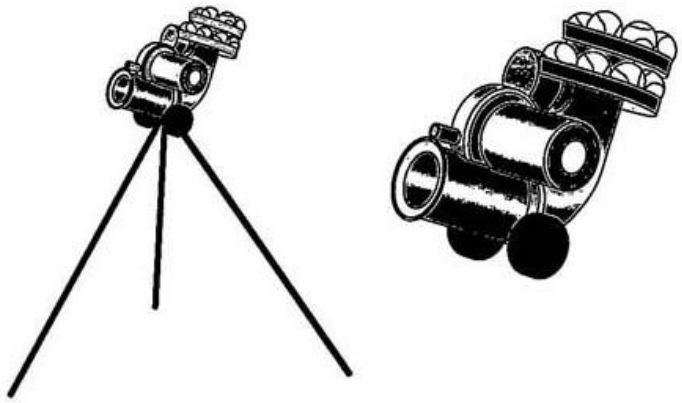
$$Z = (\overline{A} + B) \bullet C$$



SECTION 2 — 90 marks

Attempt ALL questions

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.

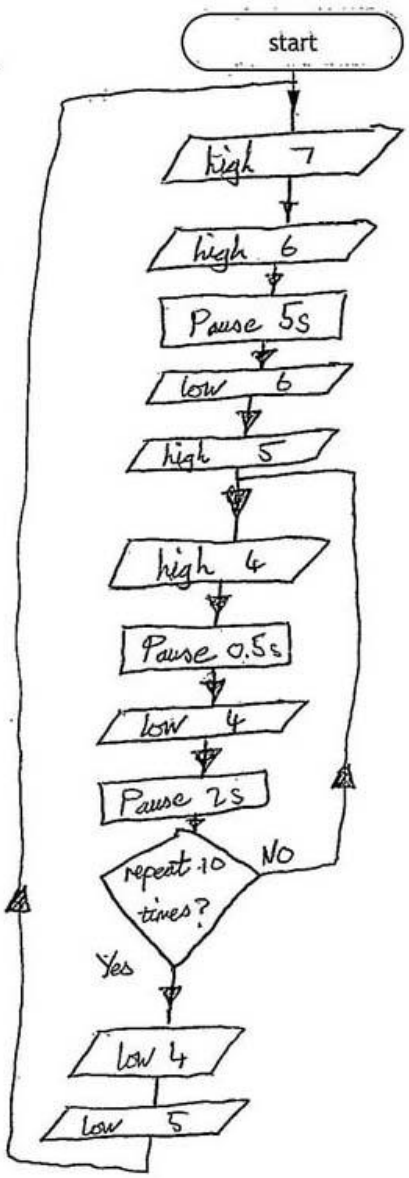
Input connections	Pin	Output connections
	7	ball firing motor
	6	red light
	5	green light
	4	ball release
start button	0	

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.

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**



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**

$\epsilon = \frac{\Delta L}{L}$

$\Delta L = \epsilon L$

$= 0.0016 \times 1200$

$= 1.92 \text{ mm}$

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

rotary

(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

$E_p = mgh$

$= 69 \times 9.8 \times 6.8$

$= 4598.16\ J$

11. (b) (continued)

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

$E_k = \frac{1}{2} m v^2$

$v^2 = \frac{E_k}{\frac{1}{2} m}$

$= \frac{970}{\frac{1}{2} \times 69}$

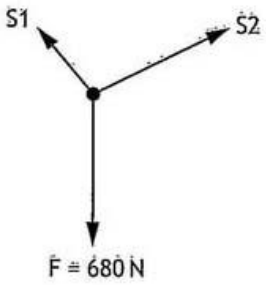
$= 28.115$

$= 28^2$

$v = \sqrt{28}$

$= 5.29 \text{ ms}^{-1}$

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

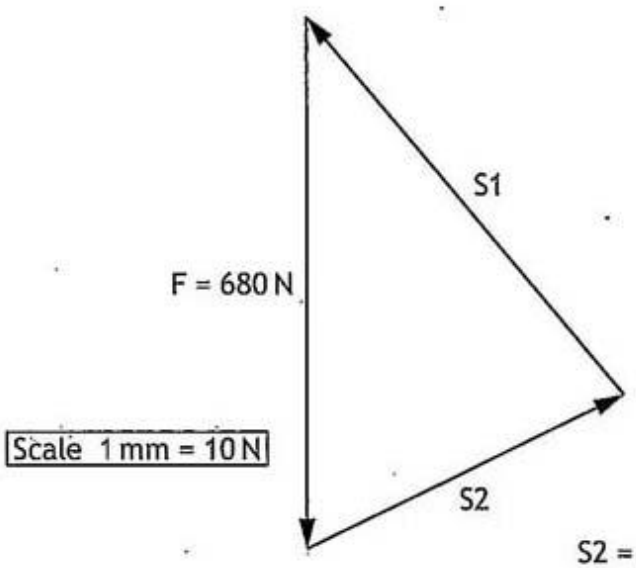


(i) State, with reference to the Data Booklet, the condition of equilibrium which does **not** need to be considered when studying forces acting at a single point. 1

kg height

11. (c) (continued)

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



S2 = 450 N

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

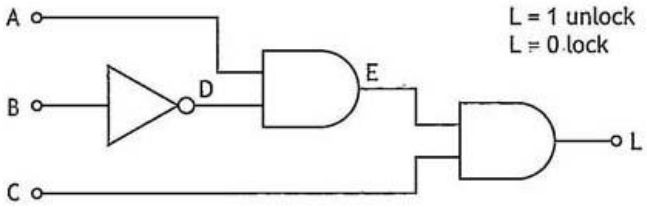
Select the most suitable material (A-D) from the table above to be used for the support wires and justify your choice. **2**

Choice of material Material C

Reason for choice It has a high durability and can handle both support wires forces

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 = $(A.\overline{B}):C$

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

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

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

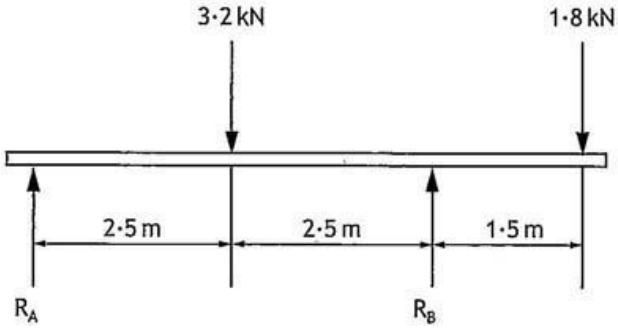
It is smaller and has less components

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

less components needed so less components being made in factory so less emissions are being sent into the air

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**

Σ clockwise moments = Σ anti-clockwise moments

$(1.8 \times 1.5) = (3.2 \times 2.5)$

$2.7 = 8$

13. (a) (continued)

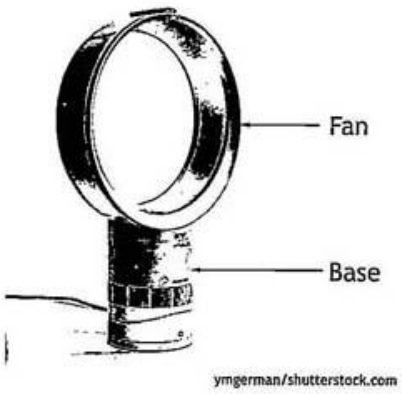
(ii) Calculate the size of reaction force R_B. 2

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

1 Make Sure the ropes can handle enough force

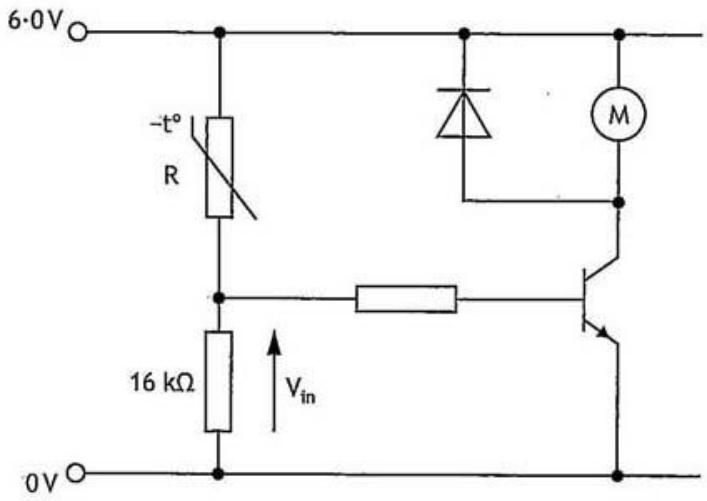
2 Make Sure the boats can handle enough weight from the people

14. A desktop fan is shown.



ymgerman/shutterstock.com

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



14. (continued)

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

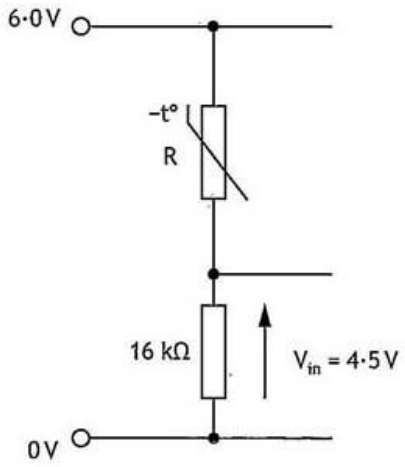
Include reference to the resistance of the thermistor and the voltage V_{in}.

As the temperature increases...

resistance drops over the resistor and so does the voltage in. The transistor will then act as a switch and power the motor. The diode protects the motor from too much current.

14. (continued)

The input sensing circuit of the fan is shown below.



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

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

$$\frac{6}{4.5} = \frac{R_1}{16}$$

$$1.3 = \frac{R_1}{16}$$

$$R_1 = 1.3 \times 16$$

$$= 20.8\ \Omega$$

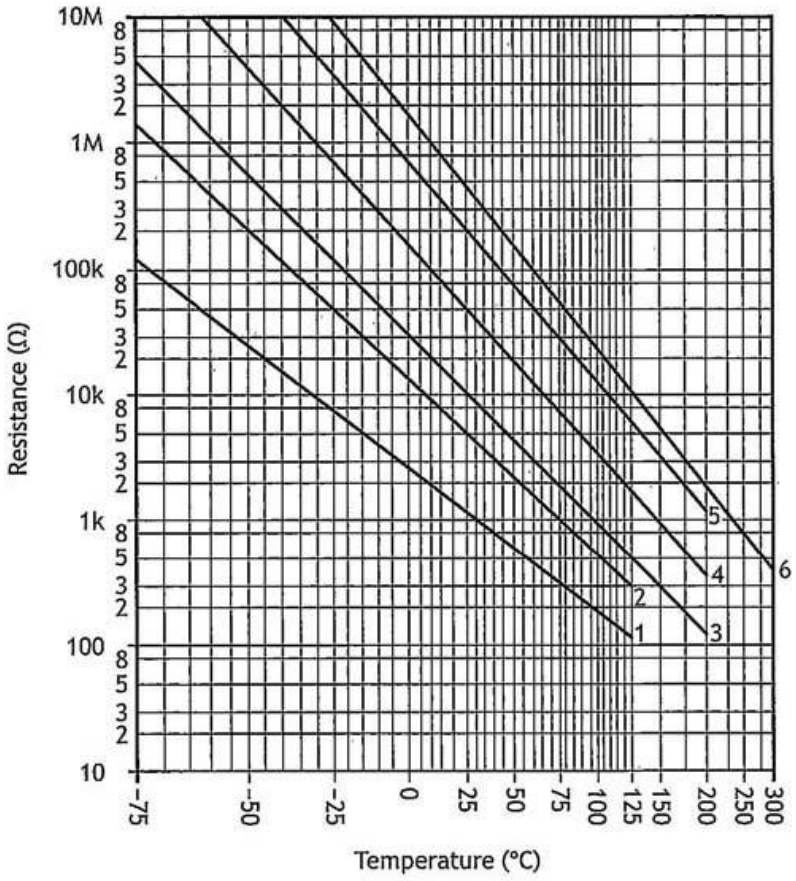
(c) Describe how the input sensing circuit could be modified so that the user can alter the temperature at which the fan motor switches on. 1

By adjusting the temperature of the thermistor

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**

100k



14. (continued)

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

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

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

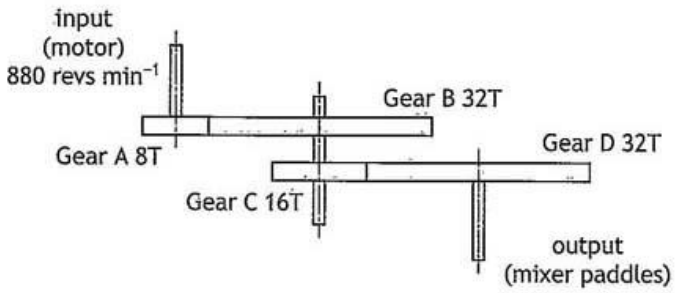
$$A = \frac{F}{\sigma}$$

$$= \frac{25}{0.029}$$

$$= 862.068$$

$$= 862 m^2$$

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

input Speed × input Size = output Speed × output Size

$880 \times 8 = \text{output Speed} \times 32$

$7040 = \text{output Speed} \times 32$

$\text{output Speed} = \frac{7040}{32}$

$= 220 \text{ revs min}^{-1}$

input Speed × input Size = output speed × output Size

$220 \times 16 = \text{output Speed} \times 32$

$3520 = \text{output Speed} \times 32$

$\text{output speed} = \frac{3520}{32} = 110 \text{ revs min}^{-1}$

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

$VR = \frac{\text{Speed of input}}{\text{Speed of output}}$

$= \frac{880}{110}$

$= 8$

$= 8:1$

15. (continued)

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

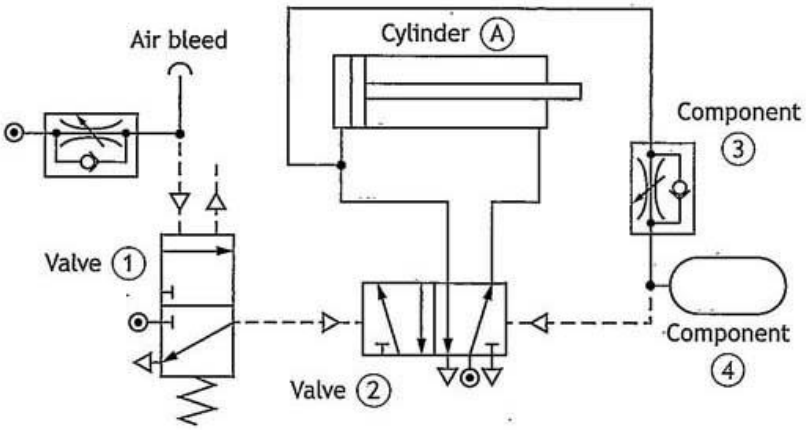
Describe one change that could be made to Gear B in order to increase the speed of the mixing paddles. 1

Add more ~~teeth~~ teeth or increase input Speed

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.

Air is then sent to valve 2 and when actuated sends air to Cylinder A. Air is then sent around the cylinder and sent to Component 3 and 4 to create a time delay before the cylinder retracts.

15. (continued)

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

- Does not require a person to operate the system
- Can be more accurate than a person

(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

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

$$= \frac{73}{810}$$

$$= 0.090 \text{ Nm}^{-2}$$

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

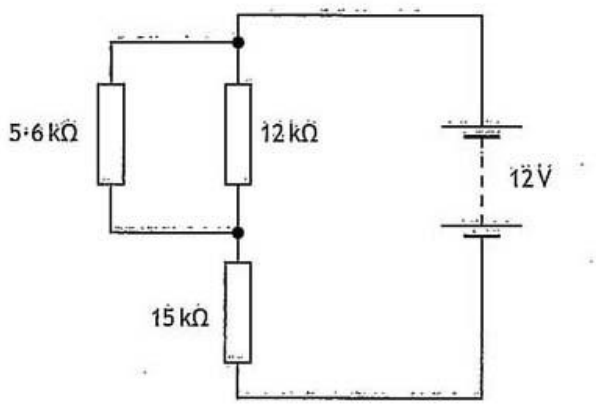
• No gases are being emitted into the air

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

• More electricity is required so more power stations may be needed which emit gases

16. (continued)

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



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

$$R_t = \frac{R_1 R_2}{(R_1 + R_2)}$$

$$= \frac{5.6 \times 12}{(5.6 + 12)}$$

$$= 3.81\ \Omega$$

$$R_t = R_1 + R_2$$

$$= 3.8 + 15$$

$$= 18.8\ \Omega$$

16. (continued)

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

$V = IR$
$= 0.6 \times 15$
$= 9$

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

$V = IR$
$I = \frac{V}{R}$
$= \frac{12}{5.6}$
$= 2.16\ A$

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.

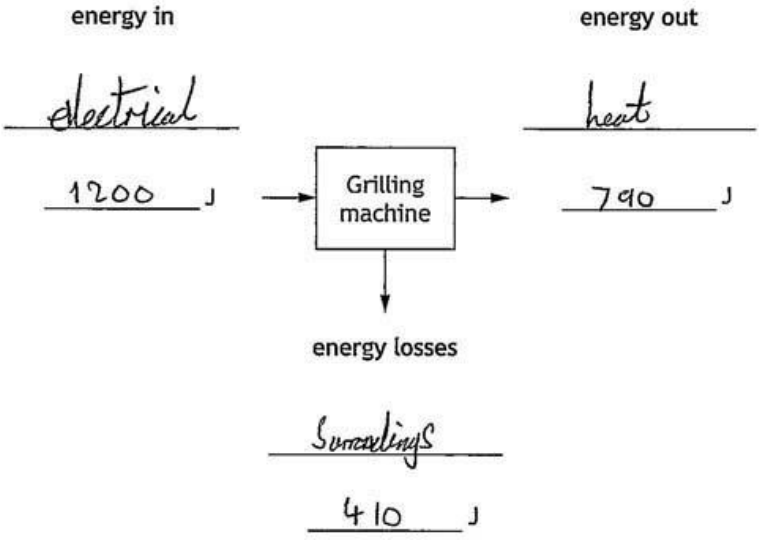
(d) Explain the possible impact of an **emerging technology** that you are familiar with. 2

- Increase production in a workplace
- You can work anywhere

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



Space for rough working

17. (continued)

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

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

$= \frac{790}{1200} \times 100$

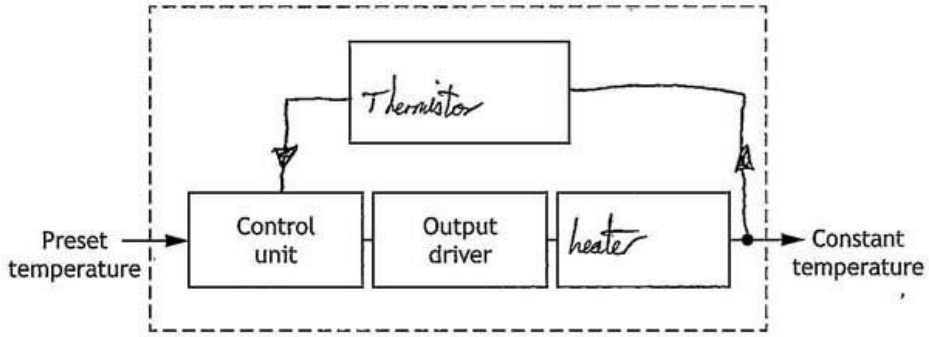
$= 65.83\%$

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

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

Closed loop

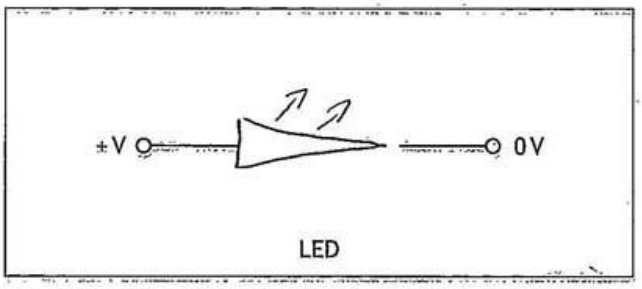
(ii) Complete the sub-system diagram below for the grilling machine. 3



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

Add Something to prevent to much Current

[END OF QUESTION PAPER]