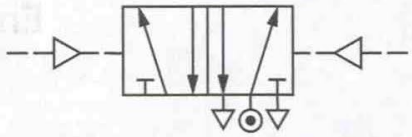
Candidate 1 evidence

SECTION 1 — 20 marks
Attempt ALL questions

1. The symbol for a 5/2 valve is shown.



Complete the table below by naming the air type symbols shown on the valve. **3**

Air type symbol	Name of air type
	Connector
	Exhaust
	Pilot air

2. A drone is shown.

The drone has a mass of 1.2 kg and travels at 15 ms^{-1}.

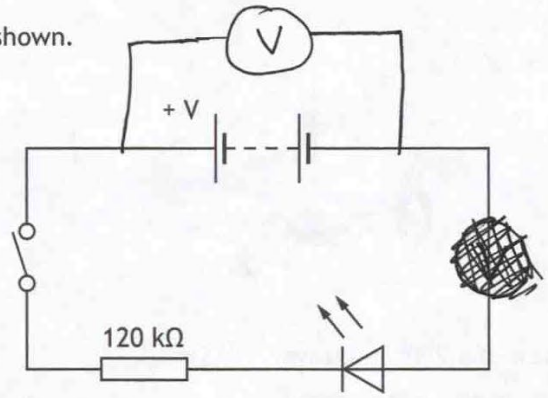
Calculate the kinetic energy of the drone. **2**

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

$E_k = \frac{1}{2} \times 1.2 \times 15^2$

$E_k = \underline{135N}$

3. A circuit diagram is shown.



(a) State the name given to the arrangement of the components connected in the circuit. 1

Series

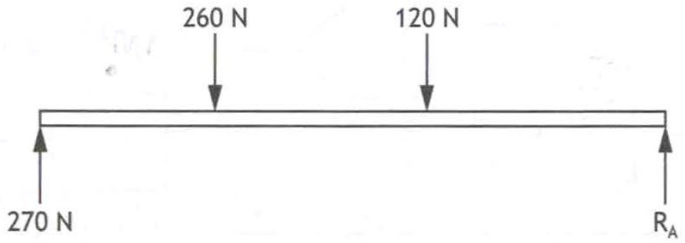
(b) Draw, on the circuit diagram shown above, the symbol for a voltmeter connected to measure the supply voltage. 2

During testing the LED did not light when the switch was pressed.

(c) Describe why the LED did not light. 1

Because there is not enough voltage to supply the LED with power.

4. An incomplete free body diagram of a beam in equilibrium is shown.



(a) Calculate the reaction force R_A. 2

(260 x 270)(RA x 120)

70200 = 120

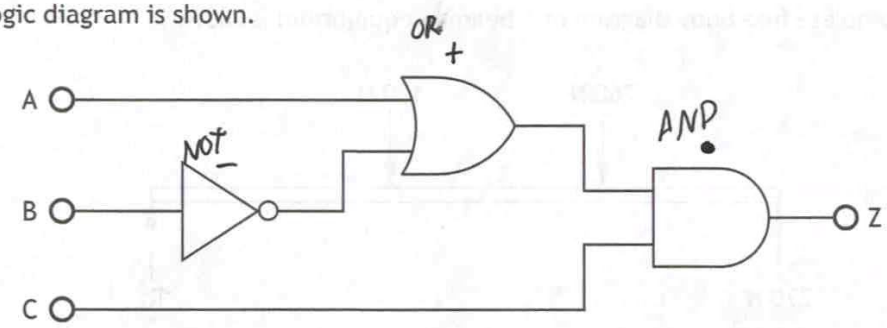
120
70200

=> 585 N

(b) State one other piece of information that should be included on the free body diagram. 1

Lengths / Measurements.

5. A logic diagram is shown.



Complete the Boolean equation for output Z in terms of inputs A, B and C. **3**

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

6. A piece of metal is tested by applying a large force along its length.

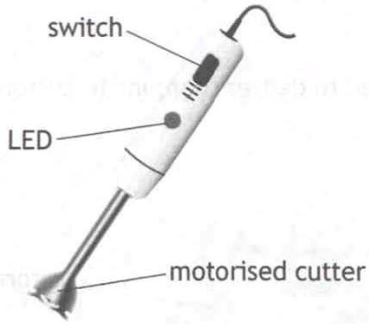
(a) State what happens to the **length** of the metal when it is in **tension.** **1**

It stretches.

(b) State what happens to the **length** of the metal when it is in **compression.** **1**

It gets flatned

7. A hand blender is shown.



An incorrect system diagram for the hand blender is shown below.

(a) Describe two errors that were made when completing the system diagram. 2

Error 1 There is no output for the cutting part of the motor moving.

Error 2 There is no input for the LED turning on

The hand blender operates without the use of feedback.

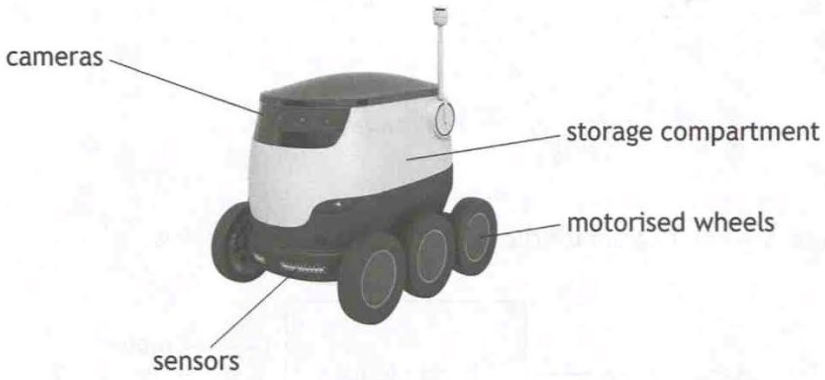
(b) State the type of control used in the hand blender. 1

Fixed Loop Control

SECTION 2 — 90 marks

Attempt ALL questions

8. A battery powered robot used to deliver shopping to customers is shown.



Different engineering branches were involved in the **development** of the robot.

(a) (i) Describe a task an **electronic** engineer would have completed in the development of the robot. 1

The circuit design of the robot.

(ii) Describe a task an **electrical** engineer would have completed in the development of the robot. 1

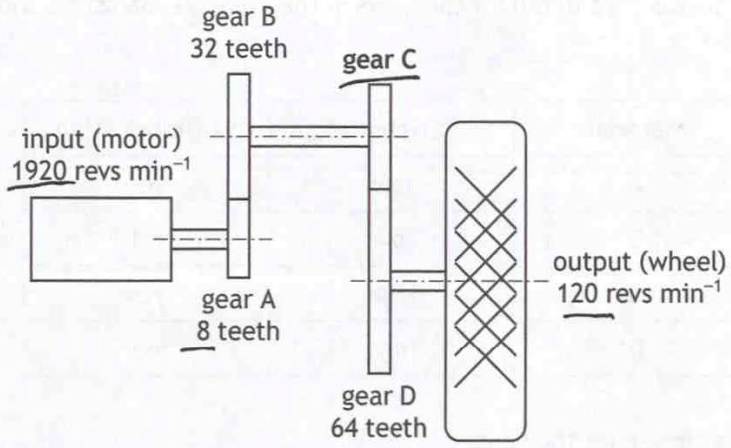
The wiring of the circuit and the mechanics of the robot.

(b) Explain a **social** impact of using the robot to deliver shopping. 2

That it gets to its destination quicker and wont get stuck in traffic like other delivery drivers.

8. (continued)

The drive mechanism used in the movement of the delivery robot is shown.



(c) State the name of this drive mechanism. **1**

Compound Gear Train

(d) Calculate the number of teeth on **gear C**. **4**

Input Speed x Input Size = output speed x output size

= 1920 x 8 = gear C x 120

= [illegible]

= [illegible]

= [illegible]

1920 x 8 = [illegible] 16 x 120

15360 = 1920

= $\frac{15360}{1920}$

=> 8 teeth

VR = $\frac{SOI}{SOO}$

= $\frac{1920}{120}$

= 16

8. (continued)

A range of materials considered for the gears in the drive mechanism is shown in the table below.

Material	Strength	Self-lubricating
A	low	yes
B	low	no
C	high	yes
D	high	no

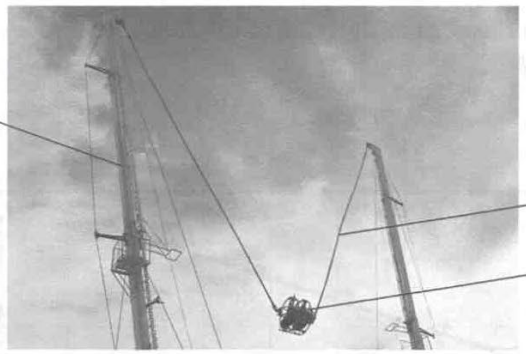
Material C was chosen for the gears.

(e) Describe an advantage of using a material for the robot gears that is:

(i) high strength means that it wont breake and you wont have to waste money buying new parts. 1

(ii) self-lubricating. means that you wont have to lubricate it everytime it begins to sound different or become dry. 1

9. A slingshot ride in a fairground is shown.



(a) Describe two tasks a **structural** engineer would have undertaken during the **development** of the slingshot ride. **2**

1. If the two beams can withstand the weight and stretch of the bungee cords.
2. If the bugee cord would hold the seating and people inside without snapping.

At the start of the slingshot ride a bungee cord is stretched by 6.2 m before it is released.

(b) Calculate the original length of the bungee cord when a strain of 0.17 is experienced. **3**

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

$$6.2 = \frac{\Delta L}{0.17}$$

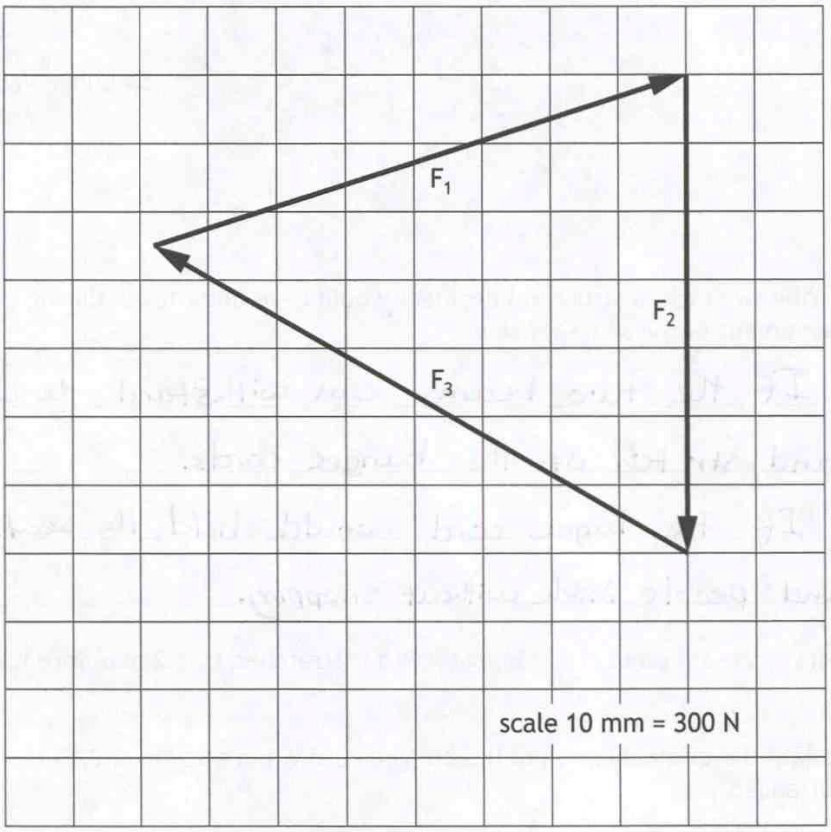
$$= \frac{6.2}{0.17}$$

$$= 36.4705$$

$$\Rightarrow 36.5\text{m}$$

9. (continued)

The forces acting on the cage at the start of the slingshot ride are shown on the scale diagram below.



(c) Complete, with reference to the scale diagram, the table shown below for the forces acting on the cage. 2

Force	F_1	F_2	F_3
Magnitude	2460 N	2400 N	3000 N

9. (continued)

During the ride the cage and riders have a potential energy of 110 kJ at a height of 43 m.

(d) Calculate the total mass of the cage and riders. 3

$E_p = mgh$

$E_p = m \times 110000 \times 43$

$= 4730000$

$= 473\,kg$

$m =$

$g = 110000$

$h = 43m$

At its highest point, the slingshot ride has an output energy of 140 kJ.

(e) Calculate the input energy if the slingshot ride is 0.32 (32%) efficient. 3

$\eta = \frac{\text{Energy out}}{\text{Energy In}} = \frac{\text{Power out}}{\text{Power In}}$

$= 140\,kJ \times 0.32$

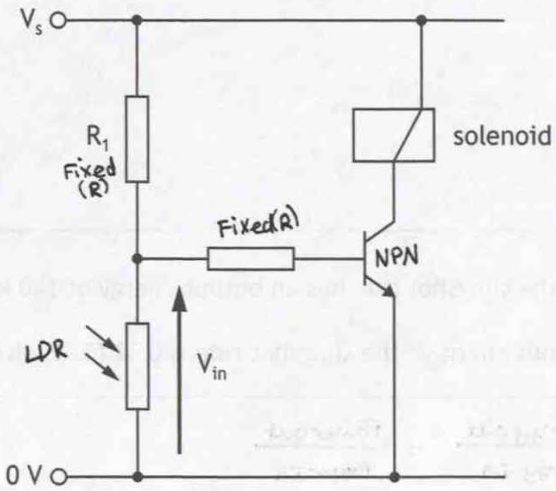
$= 44800J$

$=$ [illegible]

10. A machine for making pancakes is shown.

The machine is activated when a user places their hand in front of a sensor.

Part of the circuit used to activate the machine is shown below.



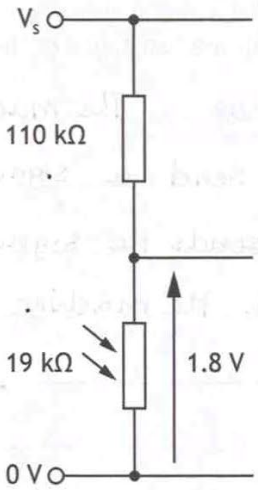
10. (continued)

(a) Describe the operation of the circuit shown on the opposite page. Make reference to the light level, the resistance of the LDR, and the voltage V_{in}. **5**

When the user covers the LDR . . . The machine switches on causing Vin to send a signal to the transistor, the transistor sends the signal to the solenoid telling it switch the machine on because of the users input.

10. (continued)

The sensing circuit is shown below.



(b) Calculate the supply voltage (V_s). 4

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

$$\frac{1.8V}{V_2} = \frac{110}{19}$$

$$\frac{1.8 \times 110}{19}$$

$$= 10.421$$

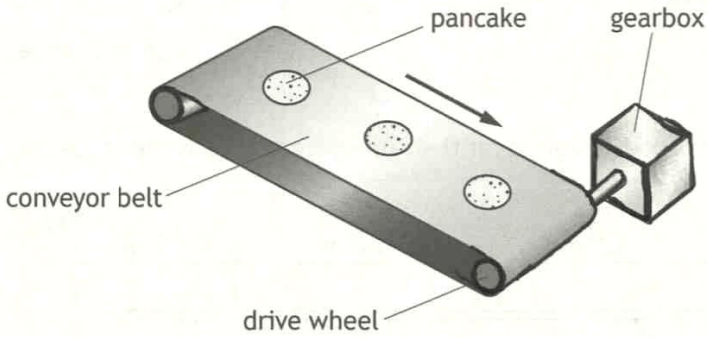
$$= 10.5V$$

(c) Describe one alteration to the sensing circuit that would allow different operating light levels to be set. 1

by hovering your hand over multiple times to set the light level desired.

10. (continued)

A motorised conveyor belt used to move the pancakes through the machine is shown.



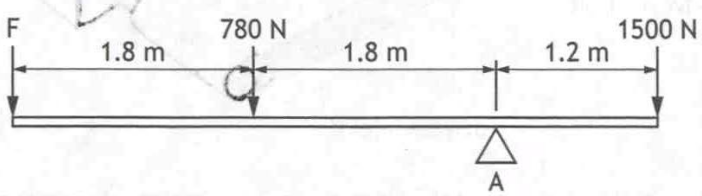
(d) Describe two tasks a **mechanical** engineer would complete during the **development** of the motorised conveyor belt. **2**

1. That the gears in the gear box turn and there are no problems with it.

2. Ensuring that conveyor belt runs smoothley and there is nothing in the way to stop it.

11. A television camera and crane are shown.

A simplified free body diagram for the camera and crane is shown below.



(a) State the name given to a group of forces that act on an object but do not meet at a single point, such as is shown on the free body diagram. **1**

(b) Calculate the force F by taking moments about point A. **3**

$\Sigma CWM = \Sigma ACWM$

[redacted] = [redacted]

[redacted] = [redacted]

$(780 \times 1.8) = ([redacted] 1500 \times 4.8)$

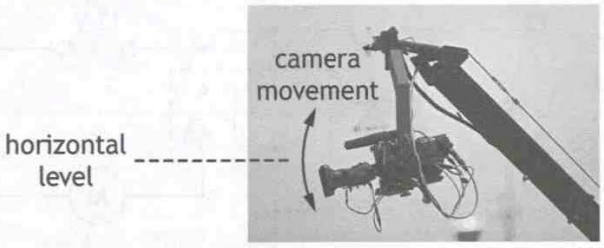
$7200 = 1404$

$= \frac{7200}{1404}$

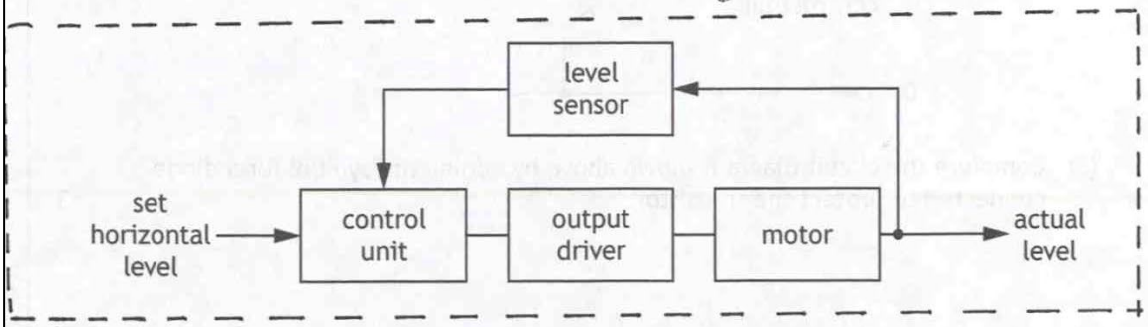
$=> 5.1282 \quad => \underline{5.1\ N}$

11. **(continued)**

A motorised levelling system ensures the camera is horizontal.



An incomplete sub-system diagram for the levelling system is shown below.



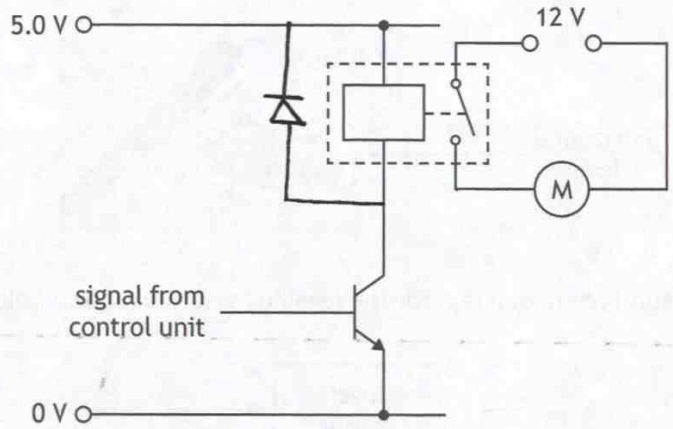
(c) Complete the sub-system diagram by adding the system boundary. 1

(d) Describe, with reference to the sub-system diagram, the operation of the levelling system. 4

The horizontal level is set . . . the control unit then sends the level set to the output driver which turns on the motor to change the level this then sets the level desired through the level sensor it then returns to the beginning and tells the control unit to set the actual level set.

11. (continued)

The circuit diagram for the output driver and motor is shown.



(e) Complete the circuit diagram shown above by adding the symbol for a diode connected to protect the transistor. **3**

12. An electric toothbrush is shown.

The electric toothbrush is operated by a microcontroller.

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

Input connection	Pin	Output connection
	5	LED
	4	motor
battery level sensor (charged = 1)	2	
start switch	1	

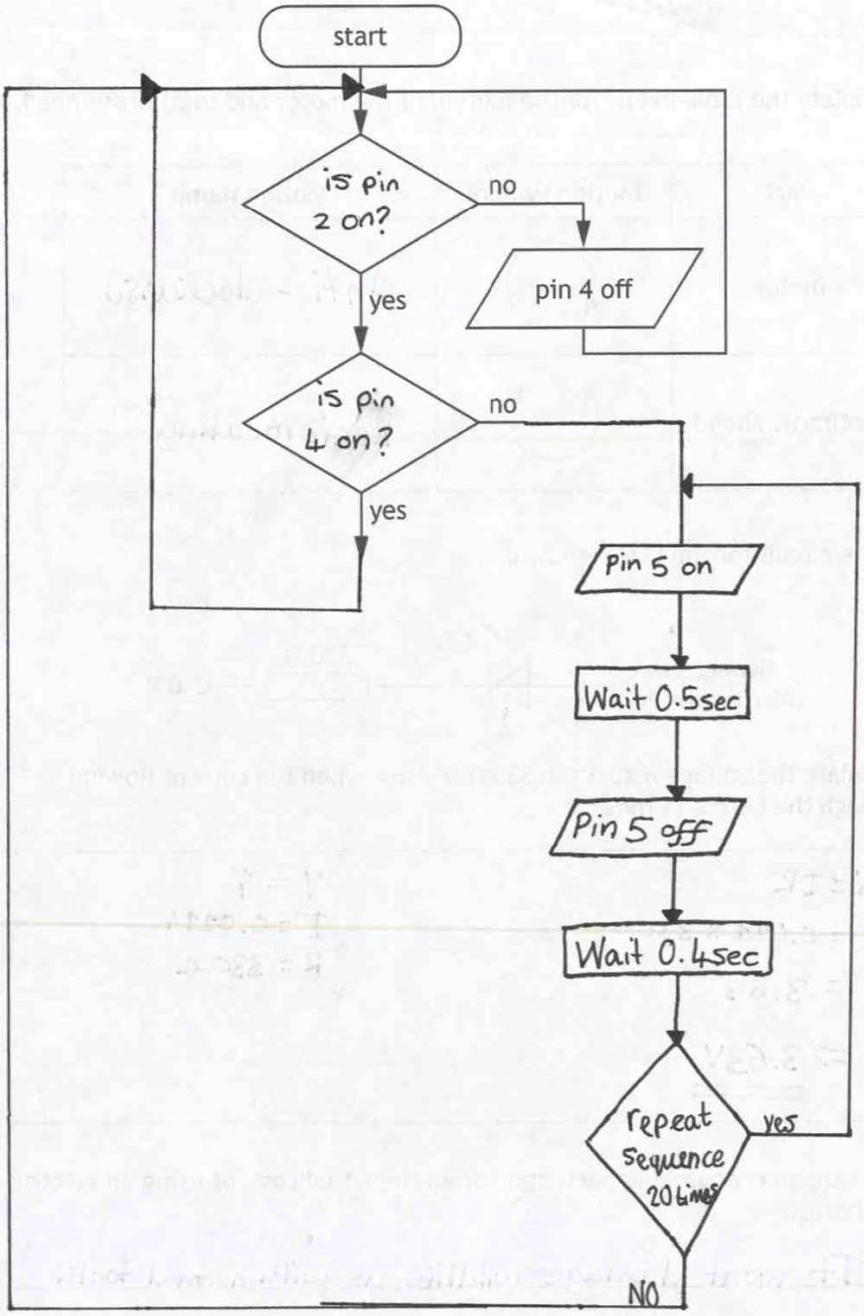
The electric toothbrush operates using the following sequence:

- When the start switch is pressed, the battery level sensor is checked. If it is not pressed, the motor will be off.
- If the battery level is charged, the motor will turn on and the sequence will return to the start.
- If the battery level is not charged, the LED will turn on for 0.5 seconds and off for 0.4 seconds. This will repeat twenty times.
- The sequence will then return to the start.

12. (continued)

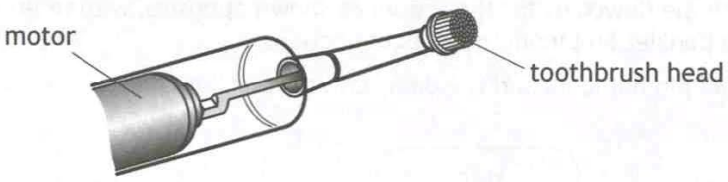
(a) Complete the flowchart for the sequence shown opposite, with reference to the data booklet and input/output connections.

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



12. **(continued)**

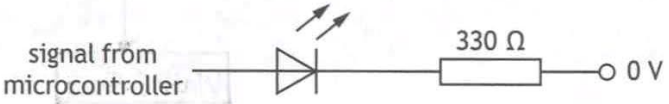
The motor and toothbrush head are shown below.



(b) Complete the table below for the motion of the motor and toothbrush head. 2

Part	Motion symbol	Motion name
motor		Anti - clockwise
toothbrush head		Reciprocating

Part of the circuit for the LED is shown.



(c) Calculate the voltage across the 330 Ω resistor when the current flowing through the LED is 11 mA. 2

$V = IR$

$V = 0.011 \times 330$

$= 3.63$

$\Rightarrow 3.63V$

$V = ?$

$I = 0.011A$

$R = 330\Omega$

(d) Describe an **economic** impact, apart from the initial cost, of **using** an electric toothbrush. 1

It wont damage wildlife as with normal tooth brushes when they go bad you throw them out put with an electric one you can change the head of the brush.

13. An air source heat pump used to replace a gas boiler for heating a home is shown.

The air source heat pump takes heat from the outside air, which is then used to warm the home. Installing the air source heat pump will have an impact on climate change.

(a) Explain what this impact will be. 2

Instead of using boilers that heat water with gases and chemicals that produce fossil fuels, these will leave no trace behind but still produce enough warm air to heat your home.

The air source heat pump sits on four supports.

(b) Calculate the cross-sectional area of one support if a stress of 14 N mm^{-2} acts on it when a force of 220 N is applied. 3

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

$\sigma = 14 mm$
$F = 220 N$
$A = ?$

$14 = \frac{220}{A}$

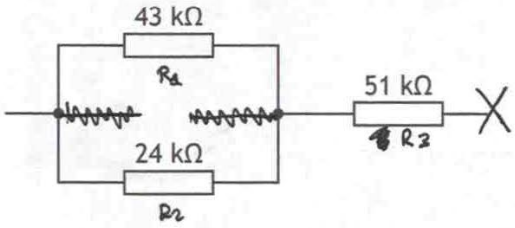
$= \frac{220}{14}$

$\Rightarrow 15.714$

$\Rightarrow 15.7 Nm^{-2}$

13. (continued)

Part of a circuit used in the air source heat pump is shown.



(c) Calculate the total resistance of the circuit shown above. 3

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

$R_t = \frac{43 \times 24}{43 + 24}$

$R_t = 15.4\ \Omega$

(d) (i) Calculate the current flowing through the 51 kΩ resistor when 48 V was measured across it. 3

$V = IR$

$I = VR$

$I = 48 \times 51000$

$= 2{,}448000\ A$

$I = ?$
$V = 48V$
$R = 51000$

(ii) Indicate, with a cross (X) on the circuit shown above, where an ammeter would be connected to measure the current flowing through the 51 kΩ resistor. 1

13. (continued)

The air source heat pump is operated by a microcontroller.

(e) Describe two advantages of **using** a microcontroller compared to a hard-wired electronic circuit in the operation of the air source heat pump. 2

1. To find any fauths and problems with the [redacted] circuit and its easy to change something if there is.

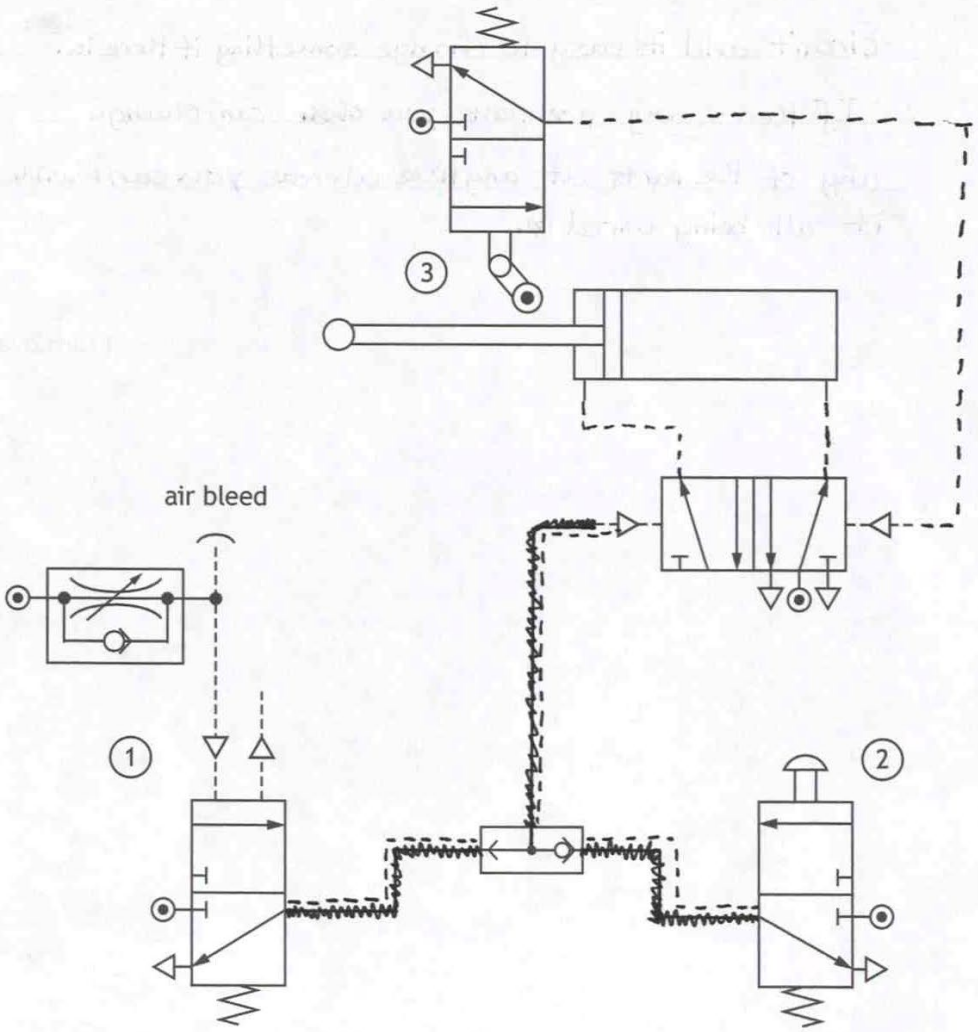
2. If theres any problems you [redacted] can change any of the parts at anytime whereas you cant with it all being wired up.

14. Pneumatics is used in part of a food production factory.

An incomplete pneumatic circuit is shown below.

(a) (i) Complete the piping of the pneumatic circuit to instroke the piston in the cylinder when valve (1) **or** when valve (2) is actuated.

The piston will outstroke when valve (3) is actuated. **5**



(ii) State the name of the actuator that is operated by the signal from the air bleed. **1**

Double Acting Cylinder

14. (continued)

The piston in the cylinder has a cross sectional area of 420 mm^2 and instrokes with a force of 65 N.

(b) Calculate the air pressure supplied to instroke the piston. 2

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

$P = \frac{65}{420}$

$P = 0.15476$

$= 0.2 Nm^{-2}$

$P = ?$

$F = 65N$

$A = 420mm$

During production a piston moves food a distance of 0.18 m with a force of 34 N.

(c) Calculate the work done by the piston. 2

$Ew = Fd$

$Ew = 34N \times 0.18m$

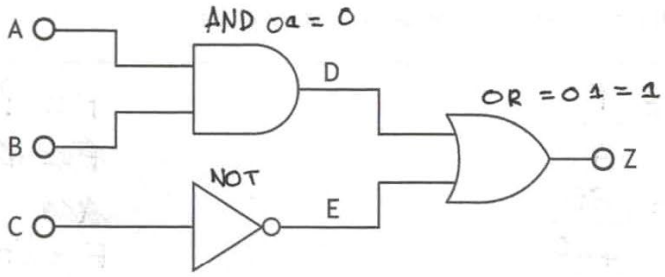
$Ew = 6.12J$

$F = 34N$

$D = 0.18m$

14. (continued)

A different part of the food production process is controlled electronically. A logic diagram used in part of the control is shown.



(d) Complete the truth table, shown below, for this logic diagram.

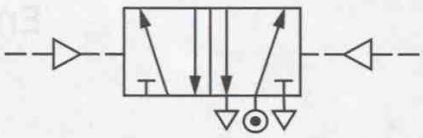
A	B	C	D	E	Z
0	0	0	1	0	
0	0	1	0	0	
0	1	0	1	0	
0	1	1	0	0	
1	0	0	1	0	
1	0	1	0	0	
1	1	0	1	1	
1	1	1	0	1	

[END OF QUESTION PAPER]

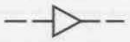
Candidate 2 evidence

SECTION 1 — 20 marks
Attempt ALL questions

1. The symbol for a 5/2 valve is shown.



Complete the table below by naming the air type symbols shown on the valve. 3

Air type symbol	Name of air type
	Main air
	Compressed air
	Pilot air

2. A drone is shown.

The drone has a mass of 1.2 kg and travels at 15 ms^{-1}.

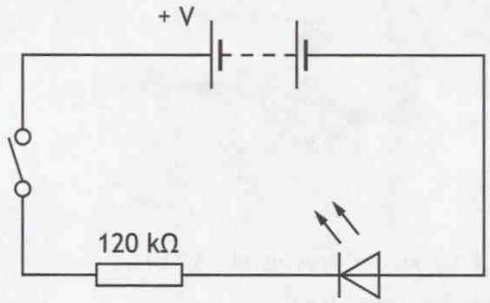
Calculate the kinetic energy of the drone. **2**

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

$= \frac{1}{2} \times 1.2 \times 15$

$= 9)$

3. A circuit diagram is shown.



(a) State the name given to the arrangement of the components connected in the circuit. 1

parallel

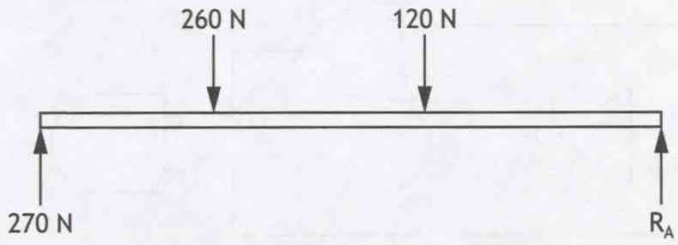
(b) Draw, on the circuit diagram shown above, the symbol for a voltmeter connected to measure the supply voltage. 2

During testing the LED did not light when the switch was pressed.

(c) Describe why the LED did not light. 1

The resistor was meant to be before the LED

4. An incomplete free body diagram of a beam in equilibrium is shown.



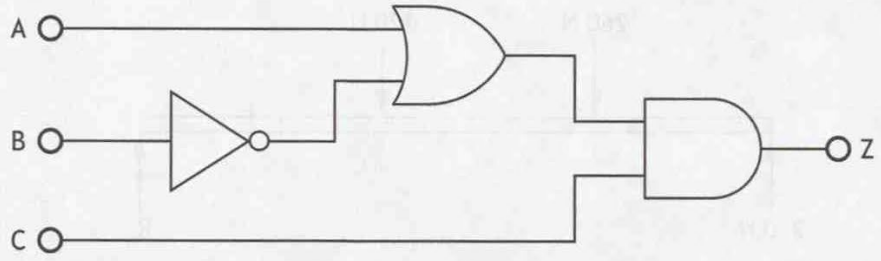
(a) Calculate the reaction force R_A. **2**

(760 x 170) / (270 x RA)
31200 = 270 RA
115.555... = RA
RA = 120 N

(b) State one other piece of information that should be included on the free body diagram. **1**

force xxx

5. A logic diagram is shown.



Complete the Boolean equation for output Z in terms of inputs A, B and C. **3**

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

6. A piece of metal is tested by applying a large force along its length.

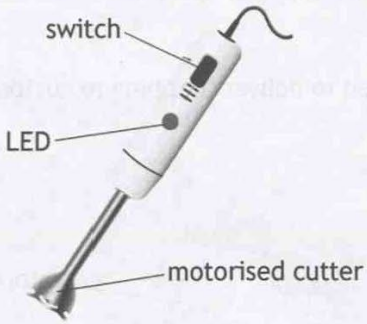
(a) State what happens to the **length** of the metal when it is in **tension**. **1**

It stretches (gets longer)

(b) State what happens to the **length** of the metal when it is in **compression**. **1**

It shortens (gets smaller)

7. A hand blender is shown.



An incorrect system diagram for the hand blender is shown below.

(a) Describe two errors that were made when completing the system diagram. **2**

Error 1 User input arrow should be other way round so arrow on the box

Error 2 User input should be switch

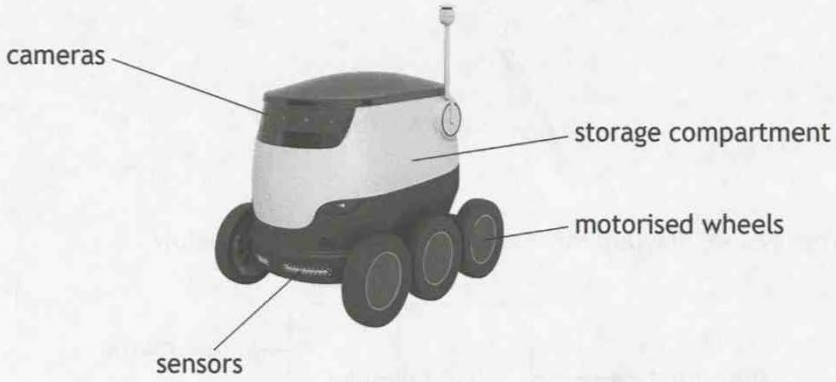
The hand blender operates without the use of feedback.

(b) State the type of control used in the hand blender. **1**

open loop control

SECTION 2 — 90 marks
Attempt ALL questions

8. A battery powered robot used to deliver shopping to customers is shown.



Different engineering branches were involved in the **development** of the robot.

(a) (i) Describe a task an **electronic** engineer would have completed in the development of the robot. **1**

Would of developed the sensors

(ii) Describe a task an **electrical** engineer would have completed in the development of the robot. **1**

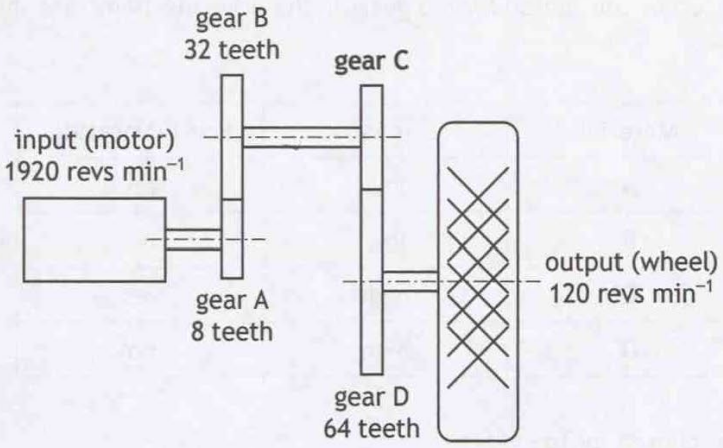
Would of developed the motorised wheels

(b) Explain a **social** impact of using the robot to deliver shopping. **2**

~~This~~ it won't make a noise so ~~so~~ people won't be annoyed at it for making loud noises

8. (continued)

The drive mechanism used in the movement of the delivery robot is shown.



(c) State the name of this drive mechanism. 1

Compound gear train.

(d) Calculate the number of teeth on **gear C**. 4

~~Gear A = Gear C~~

Input speed × input size = output speed × output size

1920 × 8 = output speed × 32

$\frac{15360}{32}$ = output speed

~~Gear A = Gear C~~

170 ÷ 64 = 1.875

× 32 = 60

Gear C = ~~60 teeth~~

32 teeth ?

8. (continued)

A range of materials considered for the gears in the drive mechanism is shown in the table below.

Material	Strength	Self-lubricating
A	low	yes
B	low	no
C	high	yes
D	high	no

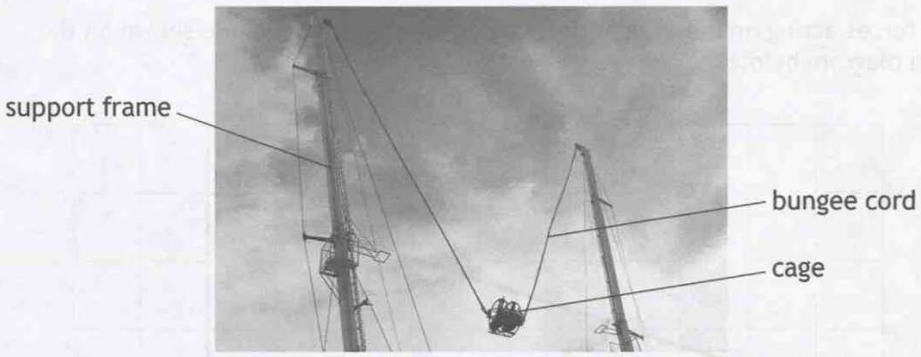
Material C was chosen for the gears.

(e) Describe an advantage of using a material for the robot gears that is:

(i) high strength This mean they will not break easily and last a long time. 1

(ii) self-lubricating. This mean that the lube on the gears will reduce any friction 1

9. A slingshot ride in a fairground is shown.



(a) Describe two tasks a **structural** engineer would have undertaken during the **development** of the slingshot ride. 2

1. To see if the structure of the support frame was strong and stable
2. To see if the cage was secure and strong.

At the start of the slingshot ride a bungee cord is stretched by 6.2 m before it is released.

(b) Calculate the original length of the bungee cord when a strain of 0.17 is experienced. 3

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

$0.17 = \frac{\Delta L}{6.2}$

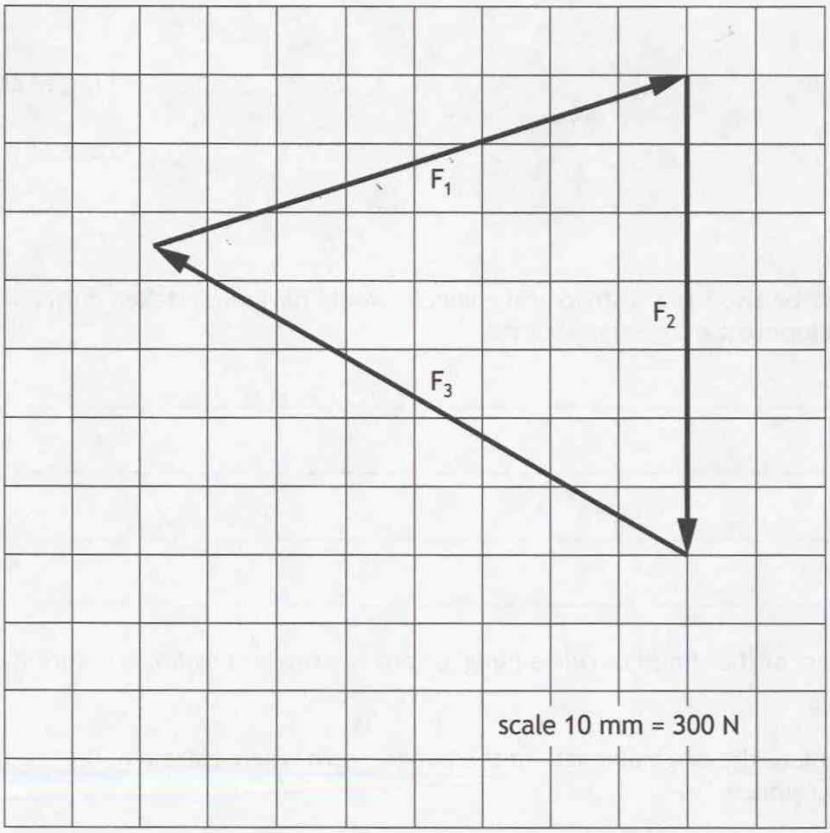
$0.17 \times 6.2 = \Delta L$

$\Delta L = 1.054$

$= 1.1\text{m}$

9. (continued)

The forces acting on the cage at the start of the slingshot ride are shown on the scale diagram below.



(c) Complete, with reference to the scale diagram, the table shown below for the forces acting on the cage. 2

Force	F_1	F_2	F_3
Magnitude	2460 N	2730N	2130 N

9. (continued)

During the ride the cage and riders have a potential energy of 110 kJ at a height of 43 m.

(d) Calculate the total mass of the cage and riders. **3**

$E_p = mgh$

$110 = m \times 9.8 \times 43$

$110 = 421.4m$

$\frac{110000}{421.4} = m$

$m = 261.0346...$

$= 260kg$

At its highest point, the slingshot ride has an output energy of 140 kJ.

(e) Calculate the input energy if the slingshot ride is 0.32 (32%) efficient. **3**

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

$0.32 = \frac{140}{E_{in}}$

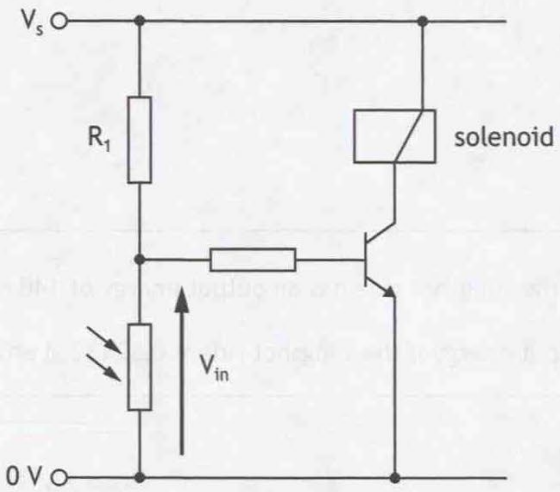
$E_{in} = 44.8)$

$140 \div 0.00228571428$

10. A machine for making pancakes is shown.

The machine is activated when a user places their hand in front of a sensor.

Part of the circuit used to activate the machine is shown below.



10. (continued)

(a) Describe the operation of the circuit shown on the opposite page. Make reference to the light level, the resistance of the LDR, and the voltage V_{in}. **5**

When the user covers the LDR . . .

the ~~Vin decreases~~ Vin increases

the new Vin is then fed through as

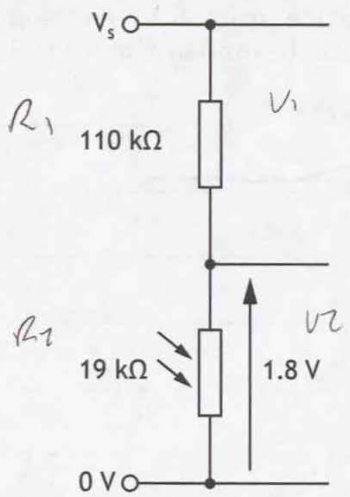
resistor to the transistor, if 0.7 and

above it will turn on

the solenoid

10. (continued)

The sensing circuit is shown below.



(b) Calculate the supply voltage (V_s). 4

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

$$\frac{V_1}{1.8} = \frac{110}{1.9}$$

$$1.9 \times V_1 = 1.8 \times 110$$

$$1.9V_1 = 198$$

$$V_1 = 104.2105\ldots$$

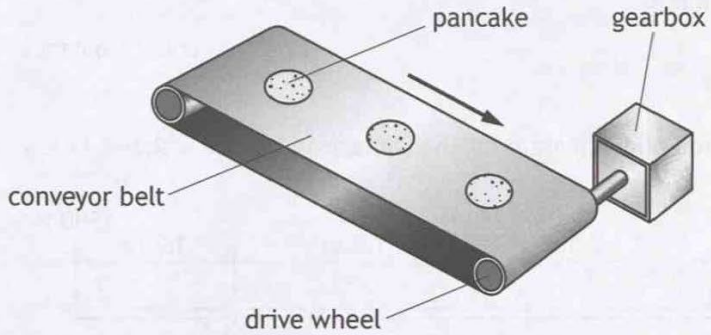
$$= 100\text{V}$$

(c) Describe one alteration to the sensing circuit that would allow different operating light levels to be set. 1

add a transistor

10. **(continued)**

A motorised conveyor belt used to move the pancakes through the machine is shown.



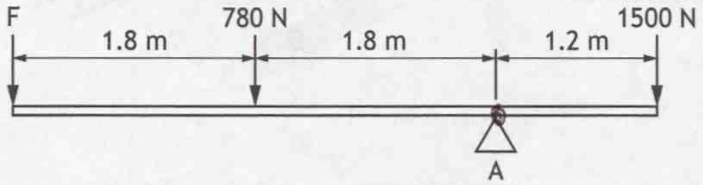
(d) Describe two tasks a **mechanical** engineer would complete during the **development** of the motorised conveyor belt. **2**

1. One task is develop the gearbox

2. The other task is develop the drive wheel

11. A television camera and crane are shown.

A simplified free body diagram for the camera and crane is shown below.



(a) State the name given to a group of forces that act on an object but do not meet at a single point, such as is shown on the free body diagram. **1**

compression

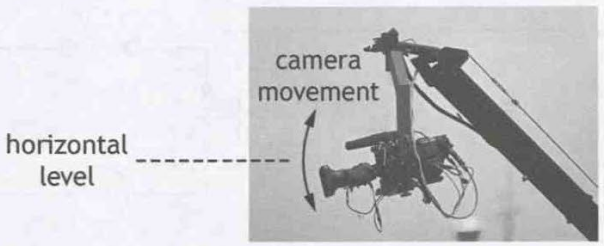
(b) Calculate the force F by taking moments about point A. **3**

$\Sigma CWM = \Sigma ACWM$

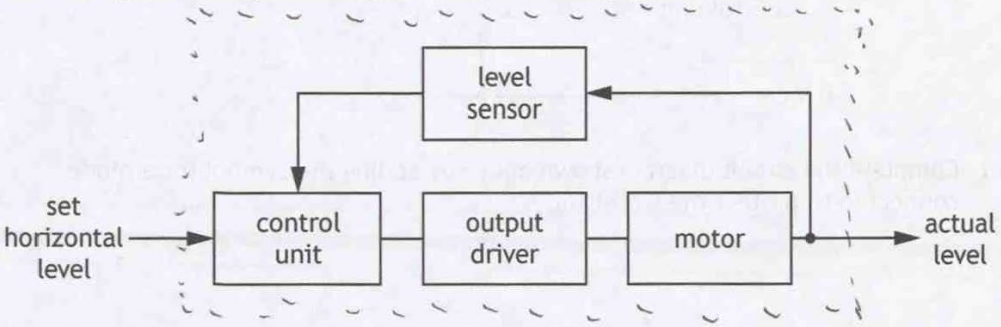
( )

11. (continued)

A motorised levelling system ensures the camera is horizontal.



An incomplete sub-system diagram for the levelling system is shown below.



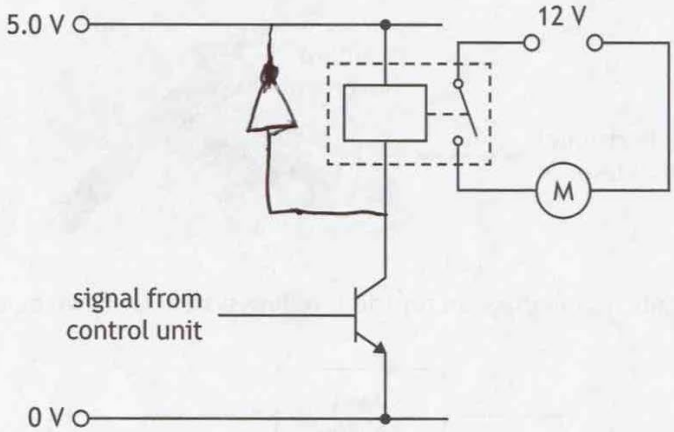
(c) Complete the sub-system diagram by adding the system boundary. **1**

(d) Describe, with reference to the sub-system diagram, the operation of the levelling system. **4**

The horizontal level is set . . . and is sent to control unit, Control unit then compares horizontal level with actual level, Then it sends the actual level back to level sensor which then sends it back to control unit - If it needs to turn so it will if not it won't

11. (continued)

The circuit diagram for the output driver and motor is shown.



(e) Complete the circuit diagram shown above by adding the symbol for a diode connected to protect the transistor. 3

12. An electric toothbrush is shown.

The electric toothbrush is operated by a microcontroller.

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

Input connection	Pin	Output connection
	5	LED
	4	motor
battery level sensor (charged = 1)	2	
start switch	1	

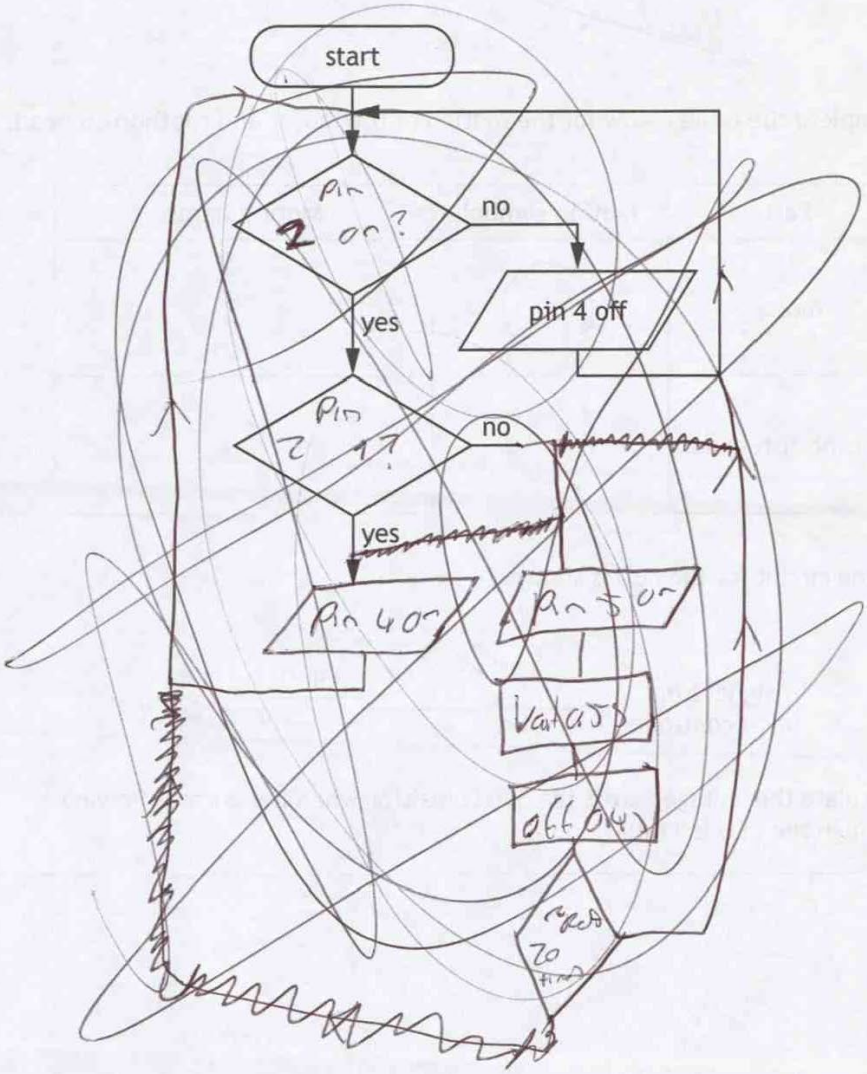
The electric toothbrush operates using the following sequence:

- When the start switch is pressed, the battery level sensor is checked. If it is not pressed, the motor will be off.
- If the battery level is charged, the motor will turn on and the sequence will return to the start.
- If the battery level is not charged, the LED will turn on for 0.5 seconds and off for 0.4 seconds. This will repeat twenty times.
- The sequence will then return to the start.

12. (continued)

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

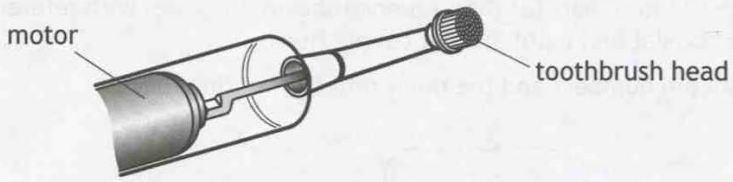
Include **all** pin numbers and the delay unit in your flowchart. **10**



Go to Pg 31 for question 12

12. (continued)

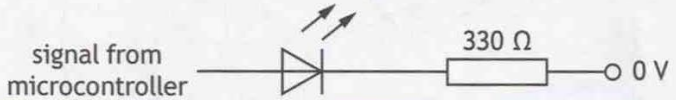
The motor and toothbrush head are shown below.



(b) Complete the table below for the motion of the motor and toothbrush head. 2

Part	Motion symbol	Motion name
motor		rotary
toothbrush head		oval ?

Part of the circuit for the LED is shown.



(c) Calculate the voltage across the 330 Ω resistor when the current flowing through the LED is 11 mA. 2

$V = IR$
$V = 330 \times 11$
$= 3630$ mV

(d) Describe an **economic** impact, apart from the initial cost, of **using** an electric toothbrush. 1

It will be more expensive to buy as it's electric.

13. An air source heat pump used to replace a gas boiler for heating a home is shown.

The air source heat pump takes heat from the outside air, which is then used to warm the home. Installing the air source heat pump will have an impact on climate change.

(a) Explain what this impact will be. **2**

A positive impact as it only using the natural air for heating and nothing else

The air source heat pump sits on four supports.

(b) Calculate the cross-sectional area of one support if a stress of 14 N mm^{-2} acts on it when a force of 220 N is applied. **3**

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

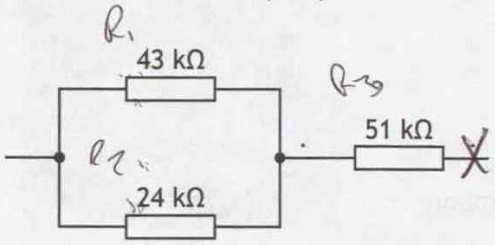
$14 = \frac{220}{A}$

$A = 3080 mm^2$

$= 3100 m^2$

13. (continued)

Part of a circuit used in the air source heat pump is shown.



(c) Calculate the total resistance of the circuit shown above. 3

$R_t = 43000 + 24000$
$= 67000$
$R_T = 51000 + 67000$
$= 118000\ \Omega$
$= 118\ k\Omega$

(d) (i) Calculate the current flowing through the 51 kΩ resistor when 48 V was measured across it. 3

$V = IR$
$48 = 51000I$
$0.941176... = I$
$I = 0.94\ A$

(ii) Indicate, with a cross (X) on the circuit shown above, where an ammeter would be connected to measure the current flowing through the 51 kΩ resistor. 1

13. (continued)

The air source heat pump is operated by a microcontroller.

(e) Describe two advantages of **using** a microcontroller compared to a hard-wired electronic circuit in the operation of the air source heat pump. **2**

1. It's alot cheaper to use the components are cheaper to make.

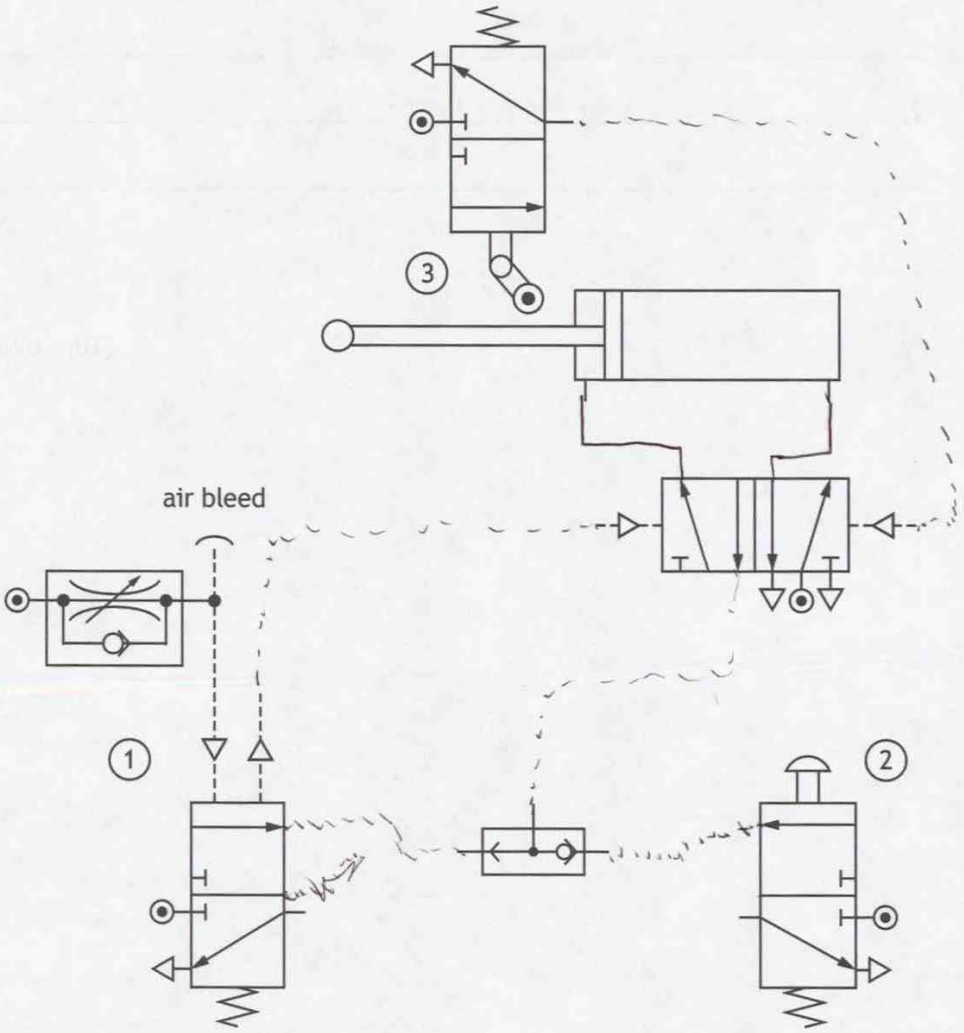
2. It takes less time to set up

14. Pneumatics is used in part of a food production factory.

An incomplete pneumatic circuit is shown below.

(a) (i) Complete the piping of the pneumatic circuit to instroke the piston in the cylinder when valve (1) **or** when valve (2) is actuated.

The piston will outstroke when valve (3) is actuated. **5**



(ii) State the name of the actuator that is operated by the signal from the air bleed. **1**

Gas directional actuator.

14. (continued)

The piston in the cylinder has a cross sectional area of 420 mm^2 and instrokes with a force of 65 N.

(b) Calculate the air pressure supplied to instroke the piston. 2

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

$= \frac{65}{420}$

$= 0.154761...$

$= 0.2 Nm^{-2}$

During production a piston moves food a distance of 0.18 m with a force of 34 N.

(c) Calculate the work done by the piston. 2

$E_W = Fd$

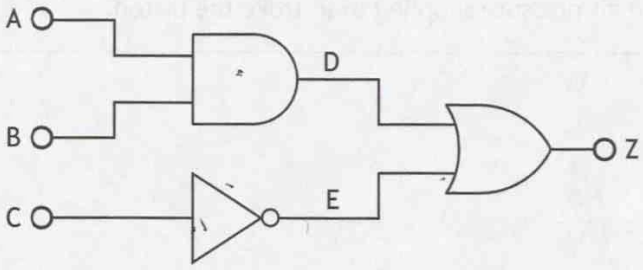
$= 0.18 \times 34$

$= 6.12$

$= 6.1 J$

14. (continued)

A different part of the food production process is controlled electronically. A logic diagram used in part of the control is shown.

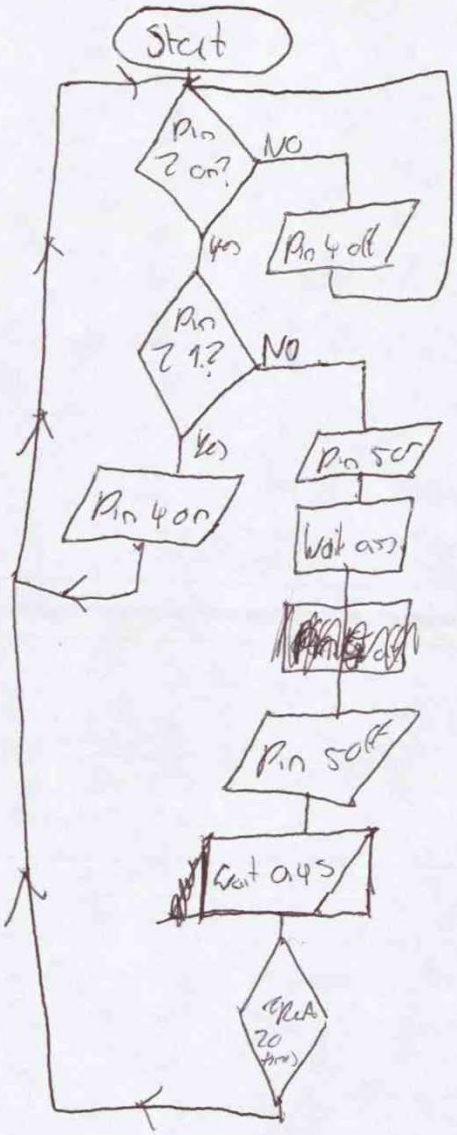


(d) Complete the truth table, shown below, for this logic diagram. 3

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

ADDITIONAL SPACE FOR ANSWERS

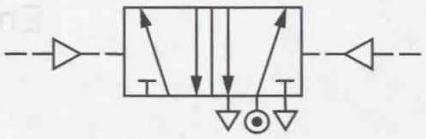
17.



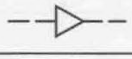
Candidate 3 evidence

SECTION 1 — 20 marks
Attempt ALL questions

1. The symbol for a 5/2 valve is shown.



Complete the table below by naming the air type symbols shown on the valve. **3**

Air type symbol	Name of air type
	Plunger
	Actuator
	Air Tube

2. A drone is shown.

The drone has a mass of 1.2 kg and travels at 15 ms^{-1}.

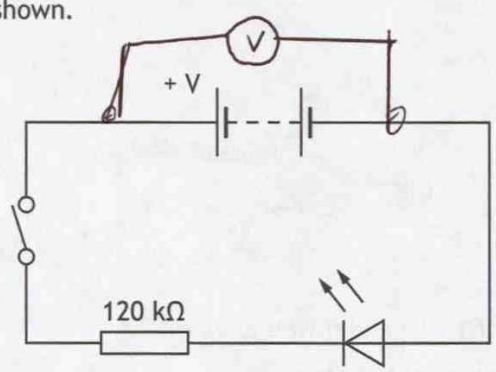
Calculate the kinetic energy of the drone. **2**

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

$\frac{1}{2} \times 1.2 \times 15^2$

$= 135 N$

3. A circuit diagram is shown.



(a) State the name given to the arrangement of the components connected in the circuit. 1

Series

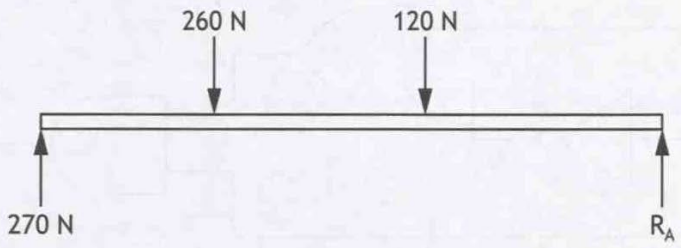
(b) Draw, on the circuit diagram shown above, the symbol for a voltmeter connected to measure the supply voltage. 2

During testing the LED did not light when the switch was pressed.

(c) Describe why the LED did not light. 1

Too much current going through the LED

4. An incomplete free body diagram of a beam in equilibrium is shown.



(a) Calculate the reaction force R_A. 2

N ↓ = ↑ N

260 + 120

= 380 N = 270 N

− 270

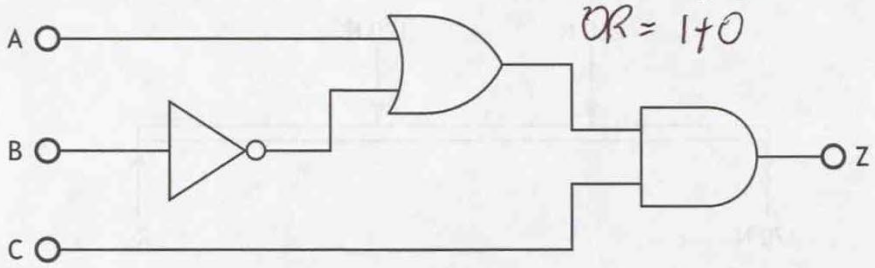
110 N F R_A

(b) State one other piece of information that should be included on the free body diagram. 1

The Length between the moments

And = 1.0
Not = i/o
OR = 1+0

5. A logic diagram is shown.



Complete the Boolean equation for output Z in terms of inputs A, B and C. **3**

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

6. A piece of metal is tested by applying a large force along its length.

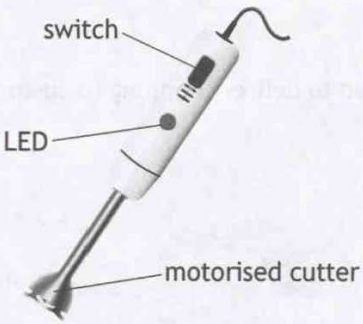
(a) State what happens to the **length** of the metal when it is in **tension**. **1**

It's being Pulled on

(b) State what happens to the **length** of the metal when it is in **compression**. **1**

It's being Pushed on

7. A hand blender is shown.



An incorrect system diagram for the hand blender is shown below.

(a) Describe two errors that were made when completing the system diagram. **2**

Error 1 User Input arrow is going the wrong way

Error 2 You wouldn't call it "hand blender" it's the control unit

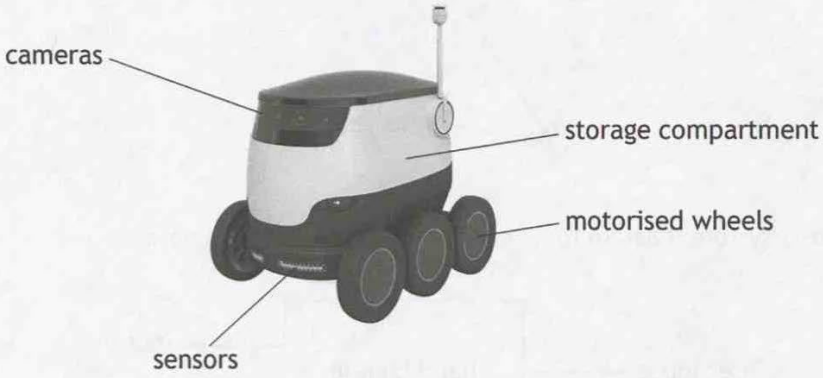
The hand blender operates without the use of feedback.

(b) State the type of control used in the hand blender. **1**

closed loop

SECTION 2 — 90 marks
Attempt ALL questions

8. A battery powered robot used to deliver shopping to customers is shown.



Different engineering branches were involved in the **development** of the robot.

(a) (i) Describe a task an **electronic** engineer would have completed in the development of the robot. 1

Making the motherboard and the sensors

(ii) Describe a task an **electrical** engineer would have completed in the development of the robot. 1

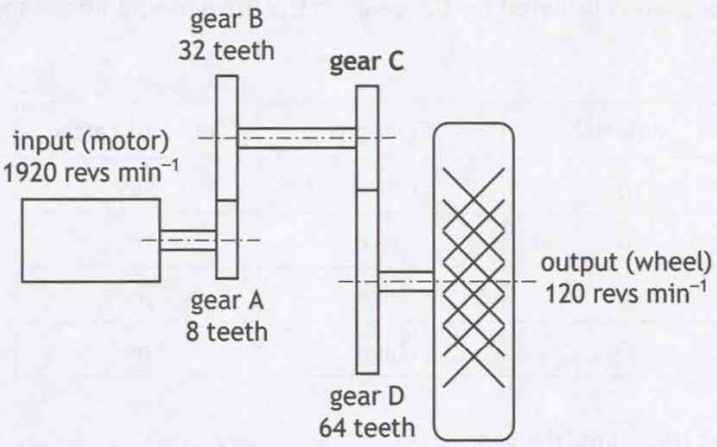
wiring up the robot

(b) Explain a **social** impact of using the robot to deliver shopping. 2

Less people outside on streets, making making less food traffic

8. (continued)

The drive mechanism used in the movement of the delivery robot is shown.



(c) State the name of this drive mechanism. 1

Gear train

(d) Calculate the number of teeth on **gear C**. 4

$\frac{\text{Teeth out}}{\text{Teeth in}} = \frac{\text{Vel in}}{\text{Vel out}}$

$\frac{32}{8} = \frac{1920}{?}$

$4 = \frac{1920}{?}$

$\frac{1920}{4} = 480 \text{ rel}$

$\frac{64}{?} = \frac{480}{120}$

$\frac{64}{?} = 4$

$\frac{64}{4} = 16 \text{ teeth}$

8. **(continued)**

A range of materials considered for the gears in the drive mechanism is shown in the table below.

Material	Strength	Self-lubricating
A	low	yes
B	low	no
C	high	yes
D	high	no

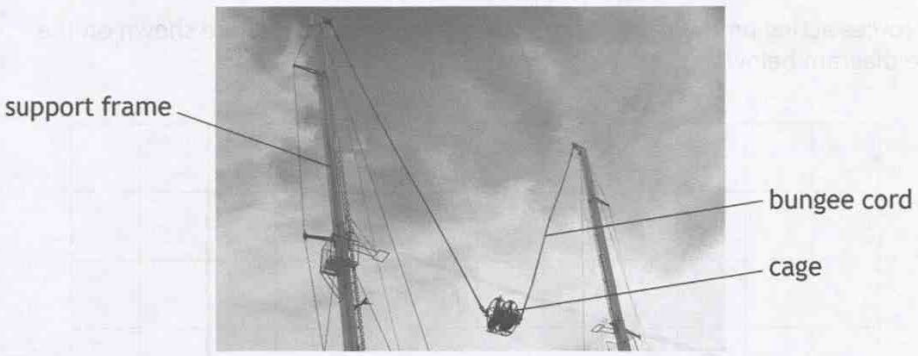
Material C was chosen for the gears.

(e) Describe an advantage of using a material for the robot gears that is:

(i) high strength The gears won't break every moving less repair often 1

(ii) self-lubricating. It won't generate as much heat every moving it won't need down or stop a fire 1

9. A slingshot ride in a fairground is shown.



(a) Describe two tasks a **structural** engineer would have undertaken during the **development** of the slingshot ride. **2**

1. How much the boom could hold

2. How much elastic is the bungee cord

At the start of the slingshot ride a bungee cord is stretched by 6.2 m before it is released.

(b) Calculate the original length of the bungee cord when a strain of 0.17 is experienced. **3**

Strain = $\frac{\Delta L \text{ change}}{L \text{ original}}$

$L =$

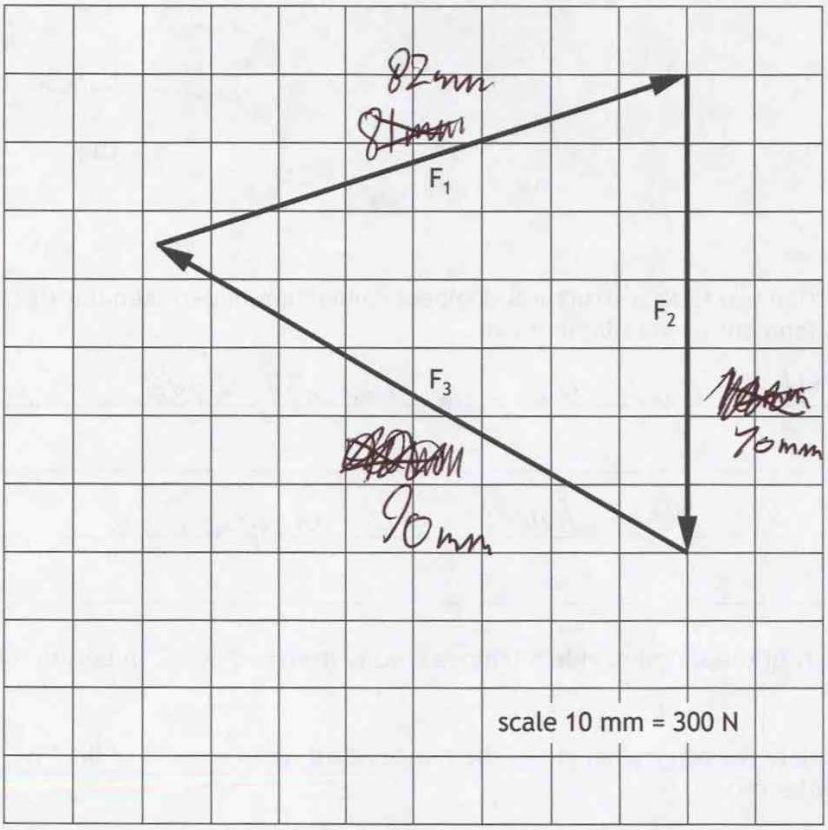
0.17×6.2

$= 1.054$

≈ 1.05

9. (continued)

The forces acting on the cage at the start of the slingshot ride are shown on the scale diagram below.



(c) Complete, with reference to the scale diagram, the table shown below for the forces acting on the cage. 2

Force	F_1	F_2	F_3
Magnitude	2460 N	2400 N	2700 N

9. **(continued)**

During the ride the cage and riders have a potential energy of 110 kJ at a height of 43 m.

(d) Calculate the total mass of the cage and riders. **3**

$E_p = mgh$

$m = \frac{E_p}{g \times h}$

$\frac{110000}{9.8 \times 43} = 261.0346464$

$= 261.03 kg$

At its highest point, the slingshot ride has an output energy of 140 kJ.

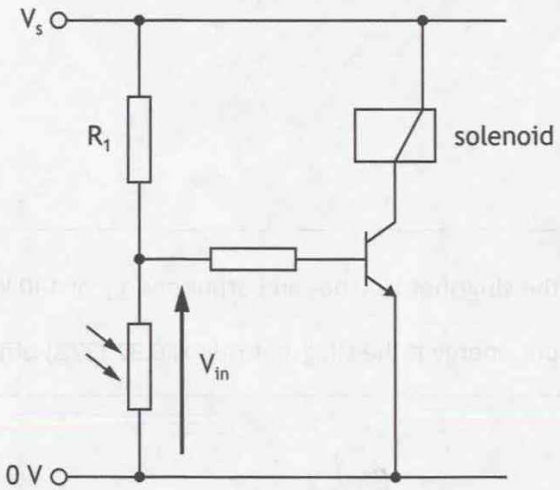
(e) Calculate the input energy if the slingshot ride is 0.32 (32%) efficient. **3**

Additional Answer

10. A machine for making pancakes is shown.

The machine is activated when a user places their hand in front of a sensor.

Part of the circuit used to activate the machine is shown below.



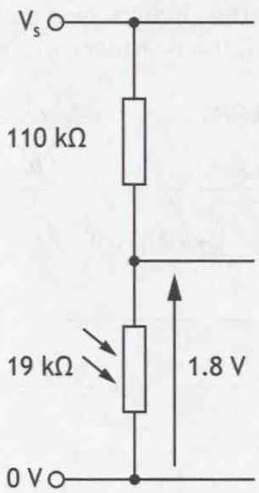
10. (continued)

(a) Describe the operation of the circuit shown on the opposite page. Make reference to the light level, the resistance of the LDR, and the voltage V_{in}. **5**

When the user covers the LDR . . . Resistance Increases on the other resistors Causing the Transistor to Turn off and the Solenoid to Turn off with it

10. (continued)

The sensing circuit is shown below.



(b) Calculate the supply voltage (V_s). 4

$V_{sup} = \frac{?}{1.8} = \frac{110K}{19K}$

$\frac{?}{1.8} = 5.789473684210526$

$\frac{5.78...}{1.8} = ? = 3.216374269005848$

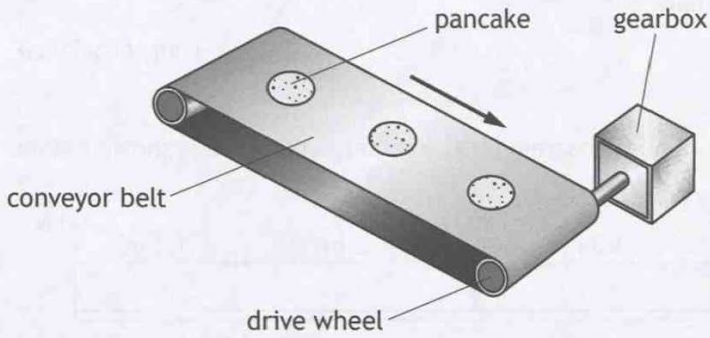
$= 3.22\,V$

(c) Describe one alteration to the sensing circuit that would allow different operating light levels to be set. 1

a LED or bulb

10. (continued)

A motorised conveyor belt used to move the pancakes through the machine is shown.



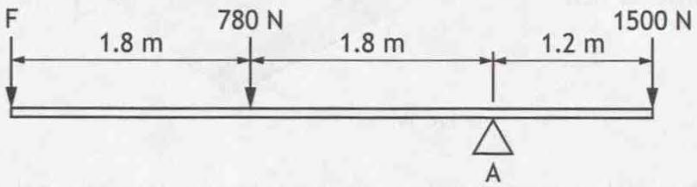
(d) Describe two tasks a **mechanical** engineer would complete during the **development** of the motorised conveyor belt. **2**

1. That the gearbox could create enough Torque to Spin the conveyor

2. That all the gears and wheels are lubricated well

11. A television camera and crane are shown.

A simplified free body diagram for the camera and crane is shown below.



(a) State the name given to a group of forces that act on an object but do not meet at a single point, such as is shown on the free body diagram. **1**

Moments

(b) Calculate the force F by taking moments about point A. **3**

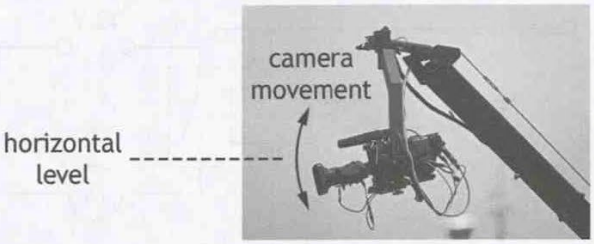
~~Total CW moments = 0~~
CW A CW = ↻ CW
780 × 1.8 + (? × (1.8 + 1.8))
= 1404 × 3.6
= 5054.4

1500 × 1.2 + 1.8 + 1.8
= 7200 J

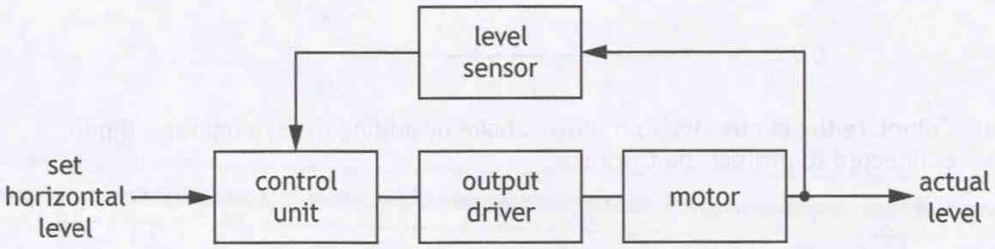
5054.4 = 7200 J
− 5054.4
= 2145.6 J = F

11. **(continued)**

A motorised levelling system ensures the camera is horizontal.



An incomplete sub-system diagram for the levelling system is shown below.



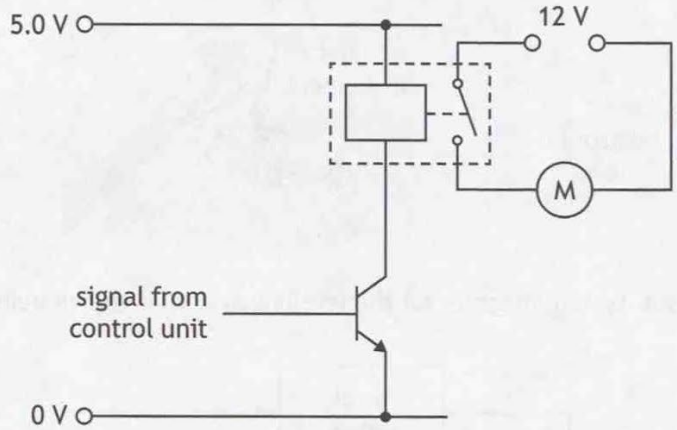
(c) Complete the sub-system diagram by adding the system boundary. 1

(d) Describe, with reference to the sub-system diagram, the operation of the levelling system. 4

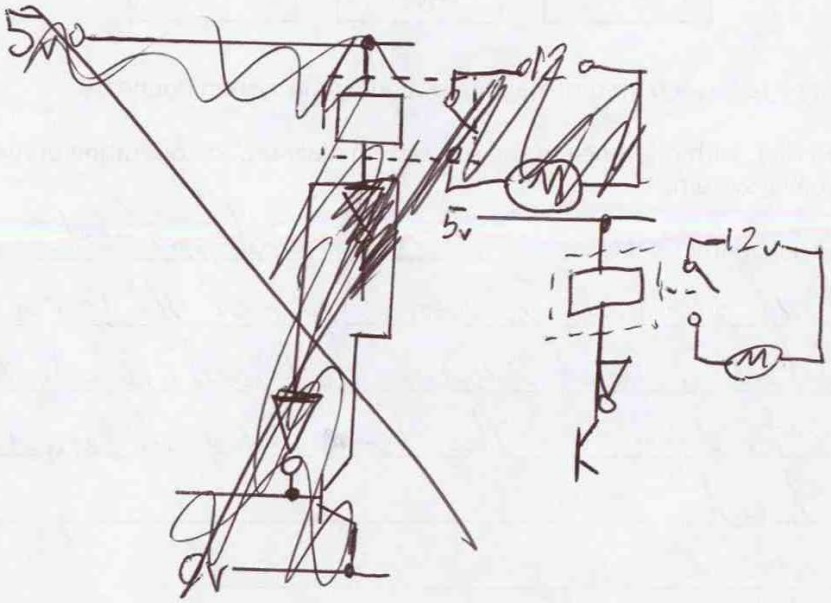
The horizontal level is set . . . on the control unit will tell the Driver to Push to motor to the Desired level while a level sensor will feed-back to the control unit if they have reached the desired level

11. (continued)

The circuit diagram for the output driver and motor is shown.



(e) Complete the circuit diagram shown above by adding the symbol for a diode connected to protect the transistor. 3



12. An electric toothbrush is shown.

The electric toothbrush is operated by a microcontroller.

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

Input connection	Pin	Output connection
	5	LED
	4	motor
battery level sensor (charged = 1)	2	
start switch	1	

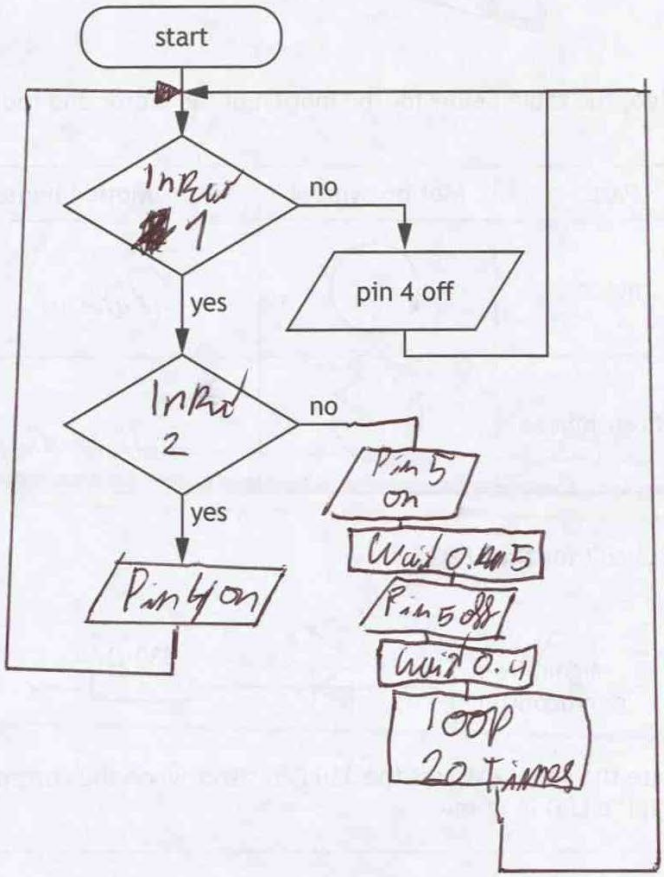
The electric toothbrush operates using the following sequence:

- When the start switch is pressed, the battery level sensor is checked. If it is not pressed, the motor will be off.
- If the battery level is charged, the motor will turn on and the sequence will return to the start.
- If the battery level is not charged, the LED will turn on for 0.5 seconds and off for 0.4 seconds. This will repeat twenty times.
- The sequence will then return to the start.

12. (continued)

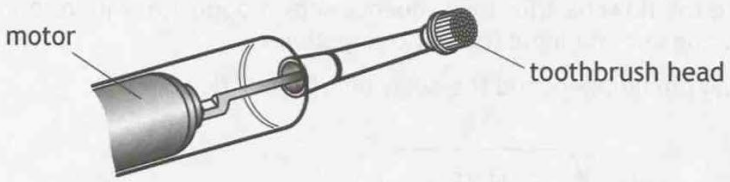
(a) Complete the flowchart for the sequence shown opposite, with reference to the data booklet and input/output connections.

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



12. **(continued)**

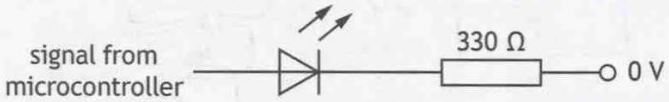
The motor and toothbrush head are shown below.



(b) Complete the table below for the motion of the motor and toothbrush head. 2

Part	Motion symbol	Motion name
motor		Rotational
toothbrush head		Reciprocating

Part of the circuit for the LED is shown.



(c) Calculate the voltage across the 330 Ω resistor when the current flowing through the LED is 11 mA. 2

$V = IR$

$11 \times 10^{-6} \times 330$

$= 3.63 \times 10^{-3}$ V

(d) Describe an **economic** impact, apart from the initial cost, of **using** an electric toothbrush. 1

Increase in Power bill

13. An air source heat pump used to replace a gas boiler for heating a home is shown.

The air source heat pump takes heat from the outside air, which is then used to warm the home. Installing the air source heat pump will have an impact on climate change.

(a) Explain what this impact will be. 2

Is
Less greenhouse gases as burning gas is burned

The air source heat pump sits on four supports.

(b) Calculate the cross-sectional area of one support if a stress of 14 N mm^{-2} acts on it when a force of 220 N is applied. 3

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

$14 = \frac{220}{a}$

$a = \frac{220}{14}$

15.7142857

$= 15.7 \text{ mm}^2$

13. (continued)

Part of a circuit used in the air source heat pump is shown.

(c) Calculate the total resistance of the circuit shown above. **3**

$\frac{1}{47} + \frac{1}{24} + 51 = 51.06\text{k}\Omega$

(d) (i) Calculate the current flowing through the 51 kΩ resistor when 48 V was measured across it. **3**

$V = IR$

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

$= 0.941176470588$

$= 0.94$

(ii) Indicate, with a cross (X) on the circuit shown above, where an ammeter would be connected to measure the current flowing through the 51 kΩ resistor. **1**

13. (continued)

The air source heat pump is operated by a microcontroller.

(e) Describe two advantages of **using** a microcontroller compared to a hard-wired electronic circuit in the operation of the air source heat pump. 2

1. Hard wired are harder to reverse

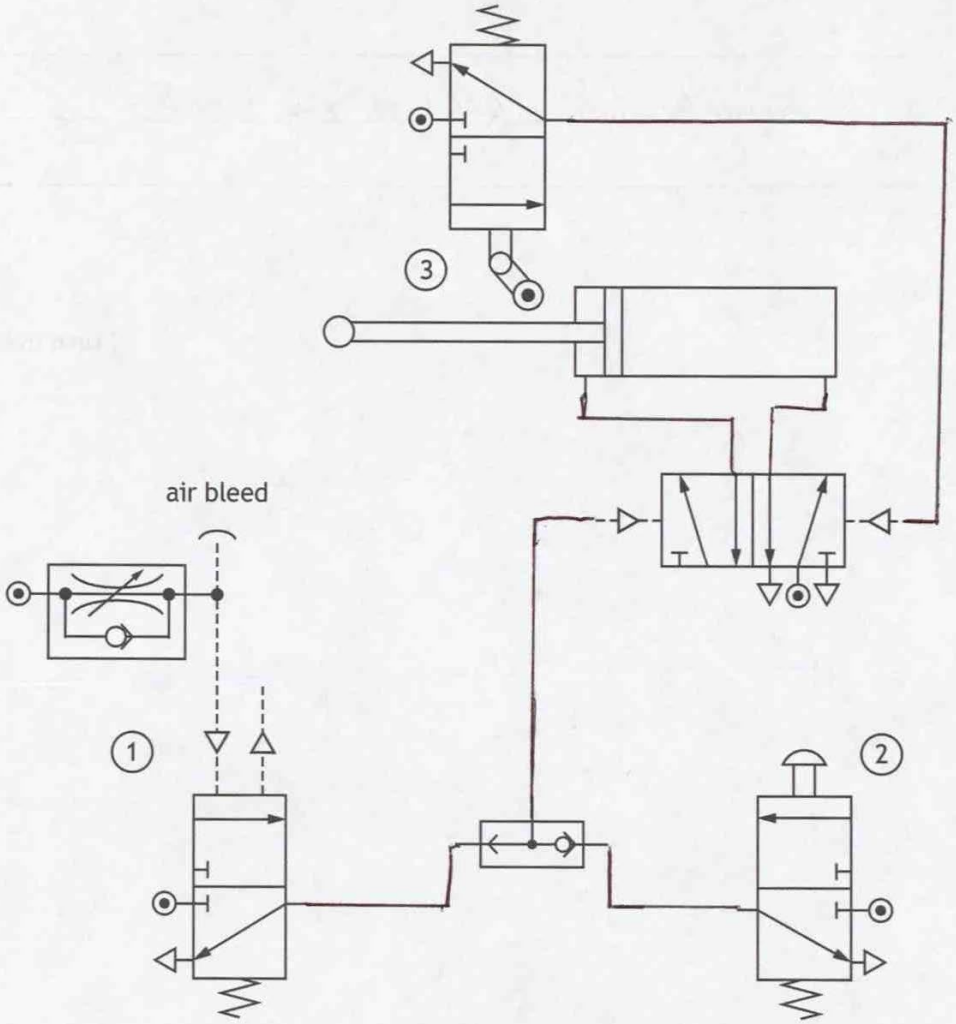
2. Micro controllers take up less room than circuits

14. Pneumatics is used in part of a food production factory.

An incomplete pneumatic circuit is shown below.

(a) (i) Complete the piping of the pneumatic circuit to instroke the piston in the cylinder when valve (1) **or** when valve (2) is actuated.

The piston will outstroke when valve (3) is actuated. **5**



(ii) State the name of the actuator that is operated by the signal from the air bleed. **1**

Solenoid

14. (continued)

The piston in the cylinder has a cross sectional area of 420 mm^2 and instrokes with a force of 65 N.

(b) Calculate the air pressure supplied to instroke the piston. 2

$P = \frac{F}{a}$ $\frac{65}{420}$

$= 0.15476190$

$= 0.15$

During production a piston moves food a distance of 0.18 m with a force of 34 N.

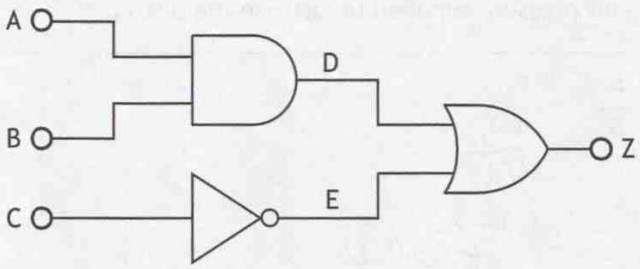
(c) Calculate the work done by the piston. 2

$E_w = Fd$

$34 \times 0.18 = 6.12$ J

14. (continued)

A different part of the food production process is controlled electronically. A logic diagram used in part of the control is shown.



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

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

ADDITIONAL SPACE FOR ANSWERS

9e. efficiency

$\eta = \frac{e_{out}}{e_{in}} = \frac{P_{out}}{P_{in}}$ $^1P = F \times V$

140 kJ

$^2EK = \frac{1}{2} \times mv^2$

$v^2 = \frac{EK \times 2}{m}$

$\frac{140}{e_{in}} = \frac{10.7267 \times 10^6}{P_{in}} = 32\%$ eff

$\frac{140 \text{ kJ} \times 2}{261.03}$

$= 1072.673639$

1072.67 m/s

$^1 140 \times 1072.67$

10.726700×10^6 watts

$140 = 32$

$= 4.375$

$437.5 = 100$

$\frac{140}{437.5} = \frac{10.7267 \times 10^6}{?}$

~~$0.32 = \frac{10.7267 \times 10^6}{?}$~~

~~$\frac{10.7267}{0.32} = ? = 33.52 \ldots 375 \times 10^7$ watts~~

$\frac{140}{0.32} = \frac{10.7267 \times 10^6}{437.5}$

$\frac{140}{437.5} = \frac{10.7267 \times 10^6}{1072.67 \times 10^6}$

$^2 * \times 10^3$