Surname		Other Names	
Centre Number			Candidate Number				
Candidate Signature									

Leave blank

General Certificate of Secondary Education
June 2005

ASSESSMENT and QUALIFICATIONS ALLIANCE

DESIGN AND TECHNOLOGY
SYSTEMS AND CONTROL TECHNOLOGY
Higher Tier

3546/H

H

Friday 24 June 2005 1.30 pm to 3.30 pm

In addition to this paper you will require:
a pen, pencil, ruler, eraser and pencil sharpener.

Time allowed: 2 hours

Instructions

- Write your name and other details in the spaces provided above.
- Answer **either Section A** – Mechanisms Focus Technology;
  or **Section B** – Pneumatics Focus Technology.
  not both.
- Write your answers in this question paper/answer book.

Information

- The maximum mark for this paper is 125.
- A list of formulae is given on page 2 which you may need to use when answering certain questions.
- Mark allocations are shown in brackets.
- Wherever calculations are needed you should show your working.
- All dimensions are given in millimetres unless otherwise stated.
- You are reminded of the need for good English and clear presentation.

For Examiner's Use	
SECTION A MECHANISMS FOCUS	
Number	Mark
A1	
A2	
A3	
A4	
A5	
A6	
A7	
A8	
A9	
TOTAL	
SECTION B PNEUMATICS FOCUS	
Number	Mark
B1	
B2	
B3	
B4	
B5	
B6	
B7	
B8	
B9	
TOTAL	
Examiner's initials	

The following information may be of use to you when answering questions on this paper.

Pneumatics

$$\text{Force} = \text{Pressure} \times \text{Area}$$

Ratio of Simple Gears

$$\text{Gear Ratio} = \frac{\text{Number of teeth on driven gear}}{\text{Number of teeth on driver gear}}$$

Velocity Ratio

$$\text{Velocity Ratio} = \frac{\text{Diameter of driven pulley}}{\text{Diameter of driver pulley}}$$

$$\text{Output speed} = \frac{\text{Input speed}}{\text{Gear/Velocity ratio}}$$

Forces

$$\text{Moments} = \text{Force} \times \text{Distance}$$

Sum of clockwise moments = sum of anti-clockwise moments

Series Resistance

$$R_T = R_1 + R_2 + R_3$$

Parallel Resistance

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} \quad \text{OR} \quad R_T = \frac{R_1 \times R_2}{R_1 + R_2}$$

Potential Difference

$$V = I \times R$$

Transistors

$$\text{Current Gain} = \frac{\text{Collector Current}}{\text{Base Current}}$$

Amplifier Gain

$$\text{Av} = \frac{\text{Change in output voltage}}{\text{Change in input voltage}}$$

Area of circle = πr^2

$\pi = 3.142$

Resistor Colour Code

Colour	Number	Number of Zeros
Black	0	
Brown	1	0
Red	2	00
Orange	3	000
Yellow	4	0,000
Green	5	00,000
Blue	6	000,000
Violet	7	0,000,000
Grey	8	00,000,000
White	9	000,000,000

E12 Resistor preferred values

10, 12, 15, 18, 22, 27, 33, 39, 47, 56, 68, 82 and decades thereafter.

NO QUESTIONS APPEAR ON THIS PAGE

TURN OVER FOR QUESTION A1 – MECHANISMS FOCUS

TURN TO PAGE 24 FOR QUESTION B1 – PNEUMATICS FOCUS

LEAVE MARGIN BLANK

SECTION A – MECHANISMS FOCUS

Answer **all** questions in this section.

Do **not** answer these questions if you have answered the questions in **Section B – Pneumatics Focus** (pp. 24–42).

A1 The block diagram, **Figure 1** shows how a fire prevention water sprinkler system works.

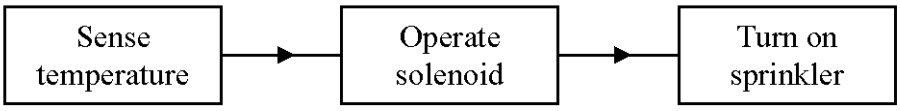


Figure 1

The sensing part of the circuit created to operate the sprinkler is shown in **Figure 2** below.

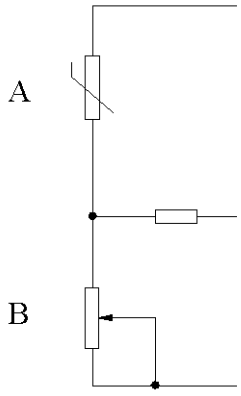


Figure 2

(a) (i) Which component acts as a sensor in this circuit?

.....

(1 mark)

(ii) What does the component sense?

.....

(1 mark)

(b) Which component is used to adjust the sensitivity of the circuit?

.....

(1 mark)

(c) The circuit could also be modified to sense ice. Complete **Figure 3** below to show how you would re-arrange the components from **Figure 2** to detect ice. The heater must turn on when ice is detected.

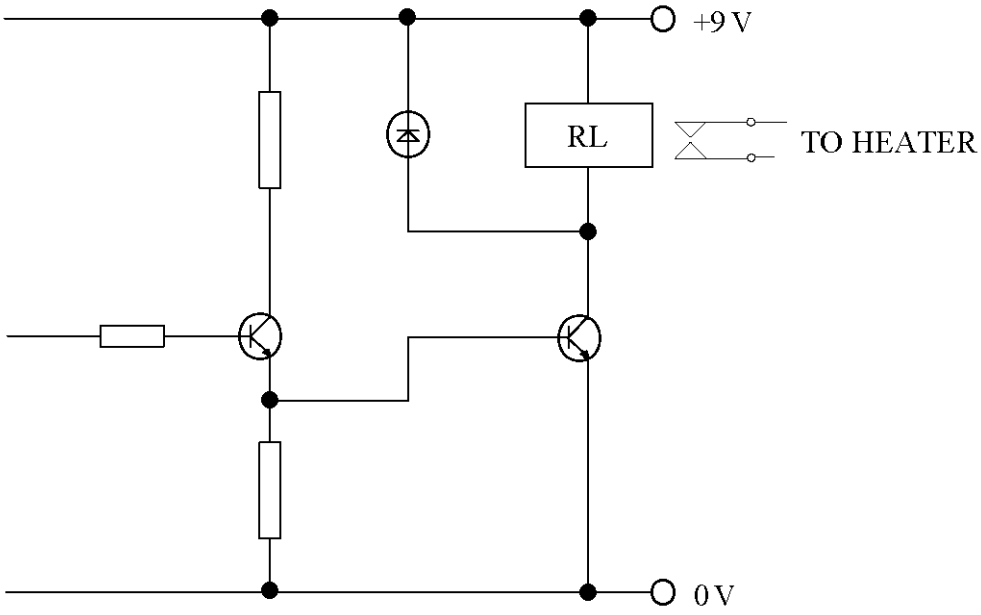


Figure 3

(8 marks)

11

TURN OVER FOR THE NEXT QUESTION

A2 (a) Many circuits use a safety procedure requiring **two** switches to be pressed before a mechanism operates.

In the space below draw a circuit requiring **two** push-to-make switches to be pressed before the motor will work. A range of components that can be used are shown in **Figure 4**.

This question is worth 10 marks.

Marks will be awarded as follows:

Quality of drawing;	*(2 marks)*
Correct arrangement of switches;	*(2 marks)*
Correct circuit symbols;	*(4 marks)*
Correct output.	*(2 marks)*

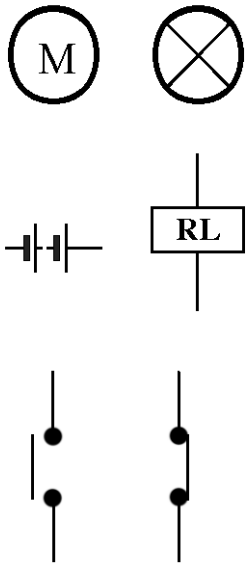


Figure 4

(b) Study the symbols shown in **Figure 5** then fill in the missing words in the sentences below.

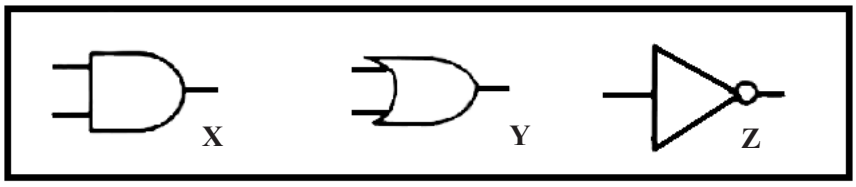


Figure 5

(i) The symbols in **Figure 5** are all examples of ..... gates.

(1 mark)

(ii) The gate labelled **X** is an ..... gate and the gate labelled **Y** is an ..... gate.

(2 marks)

(iii) Complete the truth table, **Figure 6** for gate **X**.

Input 1	Input 2	Output
0	0	
0	1	
1	0	
1	1	

Figure 6

(4 marks)

17

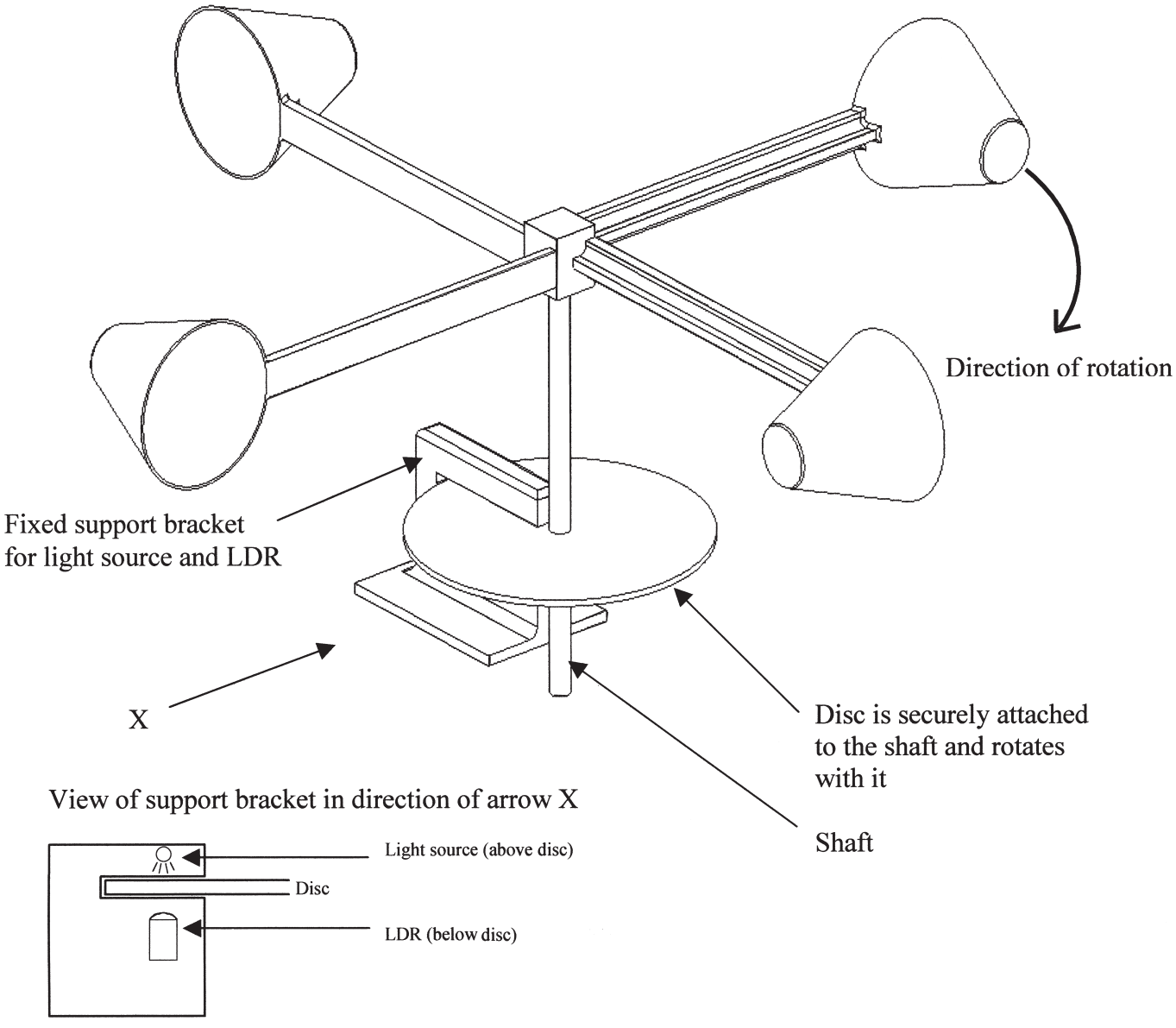
TURN OVER FOR THE NEXT QUESTION

A3 A primary school needs a wind speed indicator (anemometer).

The anemometer uses four wind blown rotating cups to turn the shaft.

A light source and LDR (Light Dependent Resistor) are used to sense movement of the shaft.

(a) Show on **Figure 7** how the disc could be modified to allow the LDR to be exposed to the light twice for each rotation of the shaft.



(4 marks)

Figure 7

(b) The signal from the LDR (Light Dependent Resistor) is amplified using an Operational Amplifier. The circuit used is shown in **Figure 8**.

Using the Op Amp pin information in **Table 1** complete the labelling of the Op Amp in the circuit diagram entering the appropriate pin numbers in the shaded circles.

1 & 5	offset null
2	inverting
3	non-inverting
4	0 V
6	output
7	+Vcc
8	NC

Table 1

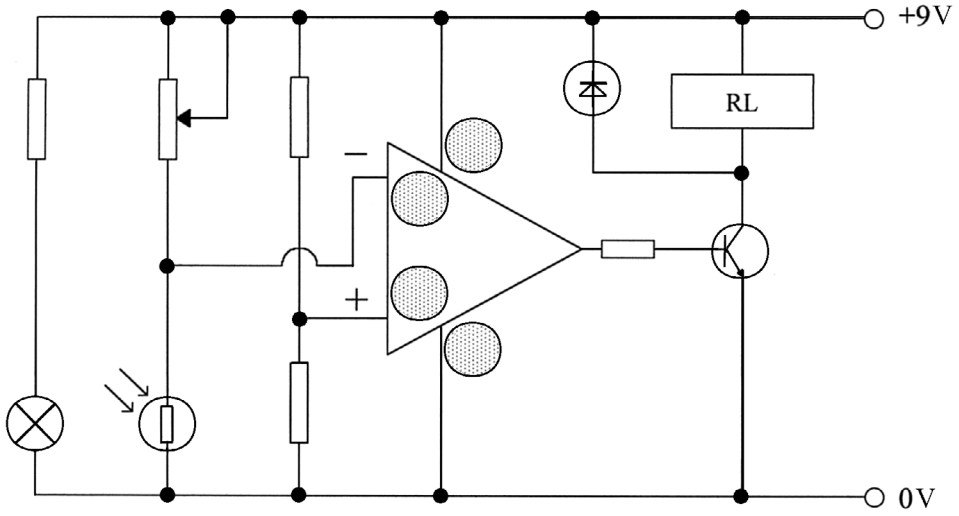


Figure 8

(4 marks)

(c) **Figure 9** shows one of the wind collectors and locating arm.

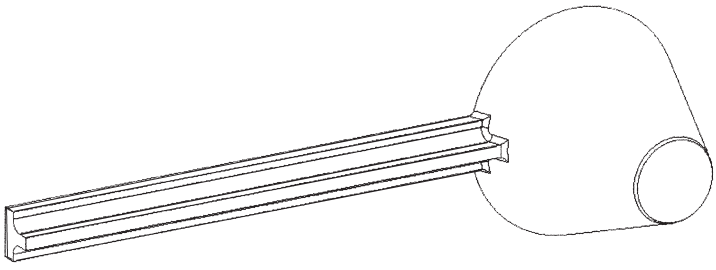


Figure 9

Name **one** suitable industrial moulding process for making this component.

.....

(1 mark)

QUESTION A3 CONTINUES ON THE NEXT PAGE

(d) Many schools do not have the ability to mould a wind collector of this type.

In the space below sketch an alternative wind collector that could easily be made in school. Label the materials that would be used.

This question is worth 5 marks.

Marks will be awarded as follows:

Appropriate method;	*(1 mark)*
Appropriate materials;	*(2 marks)*
Quality of drawing.	*(2 marks)*

14

NO QUESTIONS APPEAR ON THIS PAGE

TURN OVER FOR THE NEXT QUESTION

A4 *Secure-it* makes rising bollards for people to protect their drive-ways.

The bollard is a post that rises out of the ground to prevent a car being removed from the driveway.

Figure 10

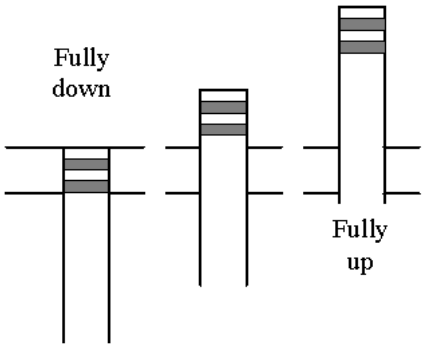


Figure 11

(a) *Secure-it* has asked you to design a working model that could be used in an exhibition. The model will be table mounted and the bollard and the table surface are shown in **Figure 12**.

Complete **Figure 12** to show a suitable mechanism to give a *continuous* slow up and down movement.

This question is worth 10 marks.

Marks will be awarded as follows:

Suitability of mechanism;	*(4 marks)*
Notes on construction/materials/components/operation;	*(4 marks)*
Quality of drawing.	*(2 marks)*

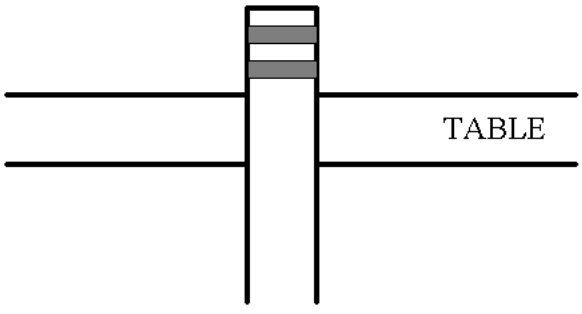


Figure 12

(b) Improve your system to include a *pause at the top and bottom* of the bollard's travel.

Add notes to your diagram explaining how the pauses are produced.

This question is worth 9 marks.

Marks will be awarded as follows:

Facility to pause at top/bottom;	*(4 marks)*
Notes explaining how the system works;	*(3 marks)*
Quality of drawing.	*(2 marks)*

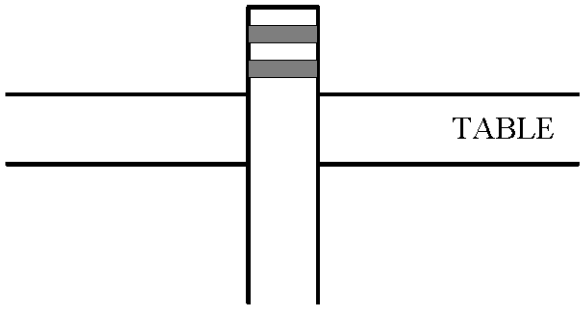


Figure 13

A5 **Figure 14** shows part of a test rig that is used to test the action of a retractable pen.

(a) Complete the drawing to show:

- a suitable cam
- an appropriate lever follower

to ensure that the button is pressed **three** times for each full rotation of the cam.

This question is worth 7 marks.

Marks are awarded as follows:

Lever modified to incorporate the follower;	*(2 marks)*
Appropriate cam design for 3 presses;	*(3 marks)*
Quality of drawing.	*(2 marks)*

The circular arrow shows the direction of rotation of the cam

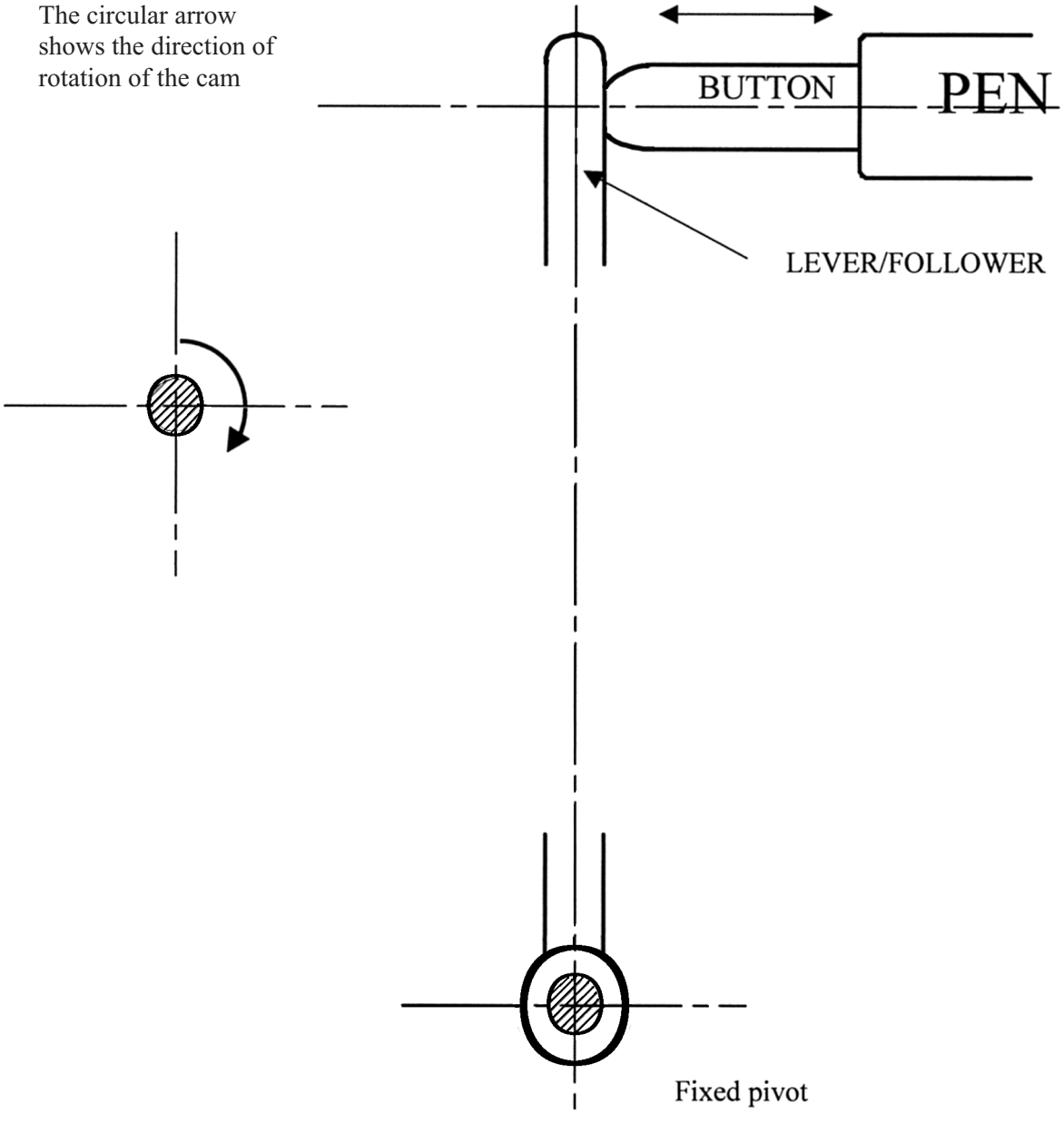


Figure 14

(b) **Figure 15** shows a piece of plastic material that is used as a flexible hinge on a pencil case.

- It is to bend through 90 degrees when in use.
- The material springs back to the flat state after bending.

Design a testing machine where the motion from a motor can be used to test repeated bending through 90 degrees.

The piece of hinge material is held in a slot in a testing bench as shown in **Figure 16** and you should complete your design around this. Use any mechanism which is appropriate.

This question is worth 6 marks.

Marks will be awarded for:

Quality of idea; *(4 marks)*
Quality of drawing. *(2 marks)*

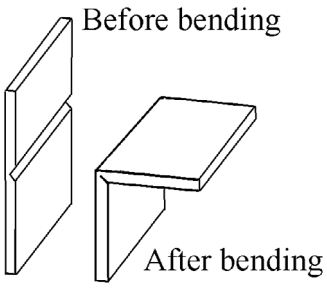


Figure 15

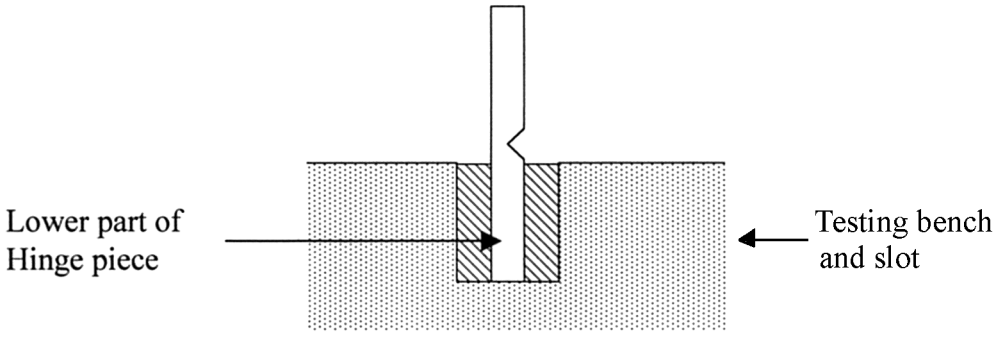


Figure 16

A6 A test rig is used to check the opening and closing of car tailgates.

Part of the system in **Figure 17** has to press the tailgate button.

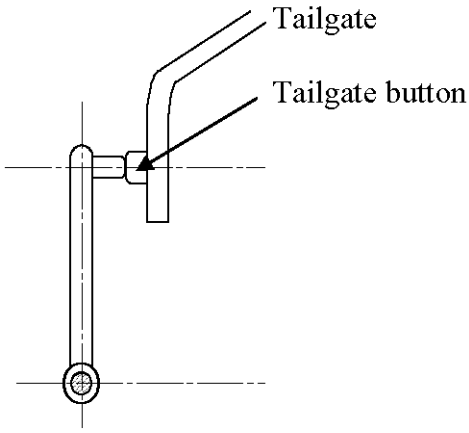


Figure 17

A 10 kN pushing force at **A**, as shown in **Figure 18**, is needed to activate the tailgate button.

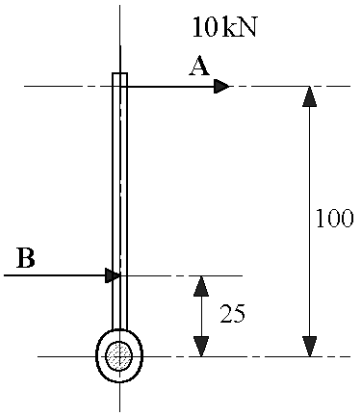


Figure 18

(a) What force will be needed at **B** to produce this force?

.....

.....

.....

.....

(3 marks)

(b) Another part of the test rig lifts the tailgate using a hoist mechanism.

The motor powering the hoist is connected to the compound gear mechanism shown in **Figure 19**.

- The driver gear has 20 teeth and rotates at 240 rpm.
- The intermediate gears have 40 teeth and 20 teeth.

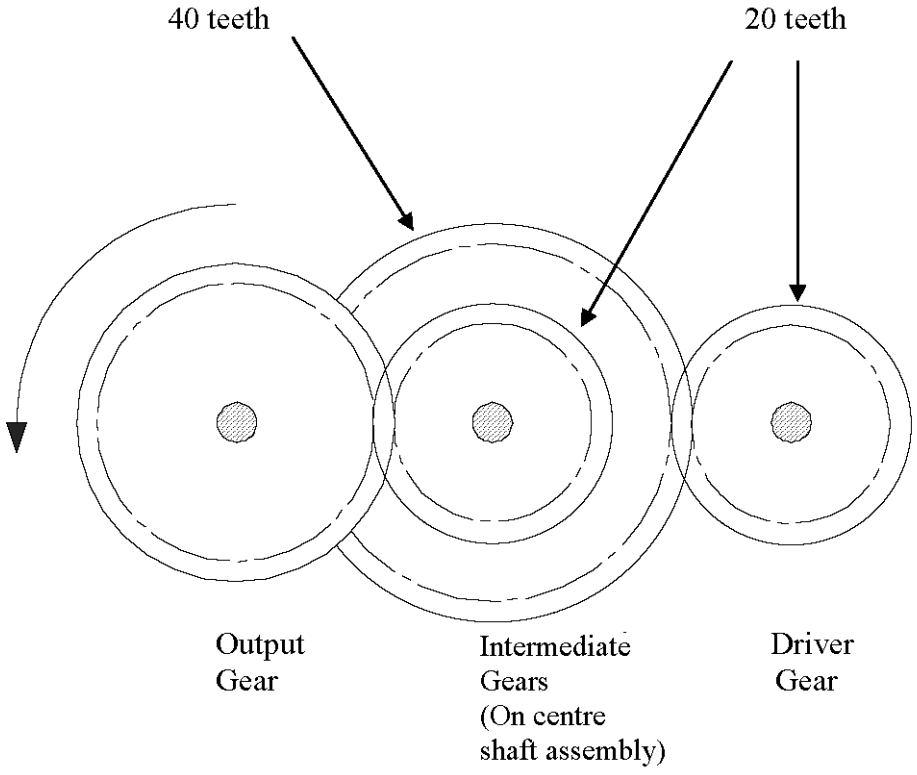


Figure 19

How many teeth will be required on the output gear to give a rotational speed of 80 rpm?

.....

.....

.....

.....

(5 marks)

QUESTION A6 CONTINUES ON THE NEXT PAGE

(c) The tailgate test rig is designed to run continuously.

In operation the mechanism has a sensor to detect when the tailgate has reached the maximum height.

(i) Name **one** type of switch that could be used as a positional sensor.

.....

(1 mark)

(ii) Modify **Figure 20** to show how you could use a positional sensor to detect the maximum opening of the tailgate.

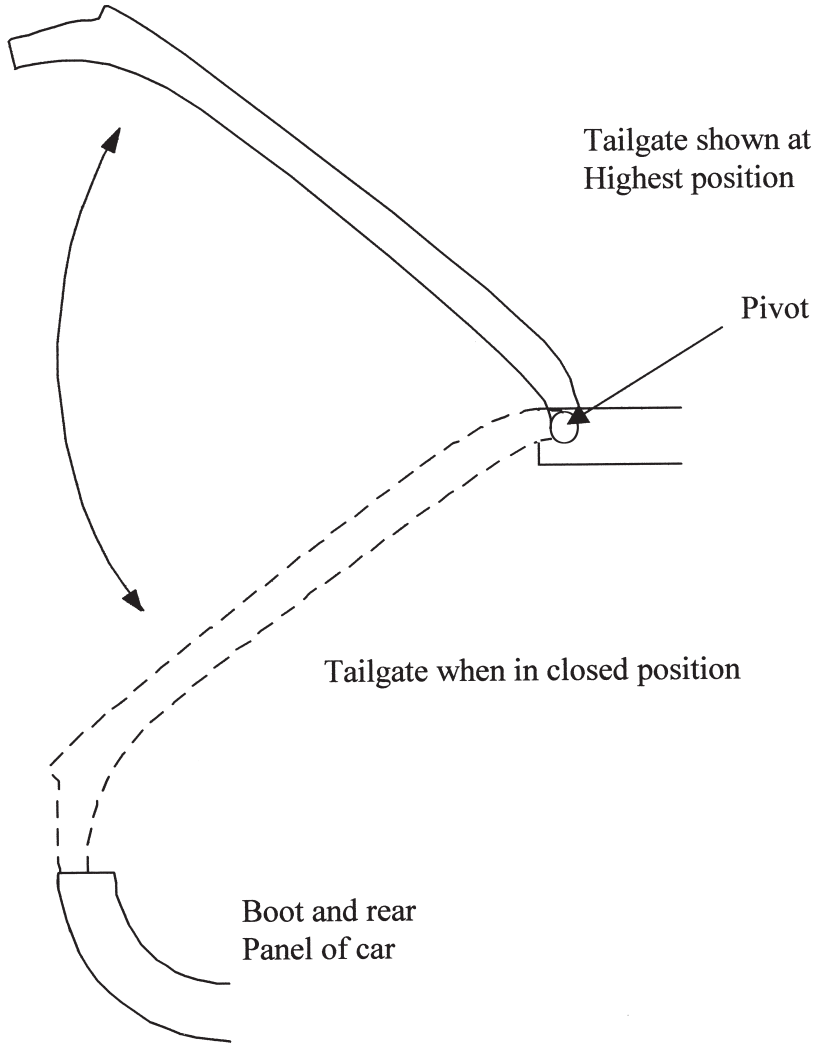


Figure 20

(3 marks)

A7 (a) Safety is of importance in the workshop.

Table 2 below contains some common situations you may experience.

For each situation specify the hazard and give a method of reducing it in the appropriate boxes.

Situation	Hazard	Method of reducing hazard
Exposed gearing on mechanical components		
Fumes from etching tanks		
Drilling holes using a pillar drill		
Soldering components to a PCB		

Table 2

(8 marks)

(b) Complete the production plan in **Table 3** for the process of etching a PCB.

Process	Materials and components	Tools
	Etch resist coated copper clad board	Etching tank, chemicals, tongs
Drilling PCB		
Insert components and solder to copper tracks	PCB, resistors, LEDs, 555 chip, capacitor	
Cut off surplus wire	NONE	
Check continuity	Completely soldered circuit	

Table 3

(6 marks)

Turn over ►

A8 (a) **Figure 21** shows a pedestrian crossing.

Input A and Input B are the push buttons placed at each side of the road.

1 = on 0 = off

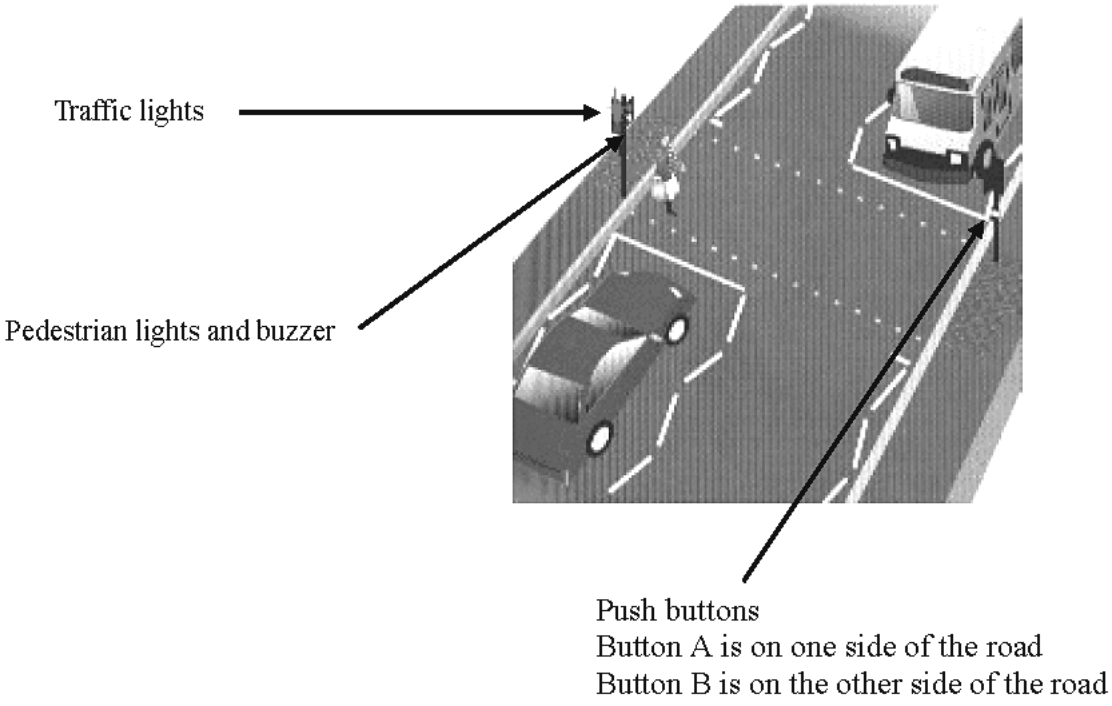


Figure 21

The output devices in the system are listed below:

C = green traffic light
D = amber traffic light
E = red traffic light
F = red pedestrian light
G = green pedestrian light
H = pedestrian buzzer
J = audible *do not cross*

The sequence below begins when button A or B is pressed.

Button A or B pressed:

- Traffic light changes from green to amber
- Wait 5 seconds
- Traffic light changes from amber to red
- Red pedestrian light changes to green pedestrian light and the pedestrian buzzer sounds
- Wait 15 seconds
- Pedestrian buzzer stops and the green pedestrian light begins to flash
- Red traffic light changes to flashing amber traffic light
- Wait 5 seconds
- Pedestrian light changes from green to red
- Traffic light changes from amber to green

End of sequence.

Using the commands below complete the control program for the traffic light sequence described on page 20.

The bold section has been given to you as a starting place.

Turnoff *X*	turns off the output labelled *X*
Turnon *X*	turns on the output labelled *X*
Wait *Y*	waits for the number of seconds specified
Flash *Z*	flashes the output labelled *Z*
End	ends the program.

X, *Y* and *Z* are given as examples – you should use the outputs C to J in your answer.

If input A = 1 or input B = 1
Turnoff C, Turnon D
Wait 5

.....

.....

.....

.....

.....

.....

.....

.....

.....

(9 marks)

(b) The program can be improved by using an audible output saying *do not cross*.

- The audible output sounds at the same time as the pedestrian lights flash.
- This audible output is Output J.

In the space below rewrite the relevant lines of the control program to include the commands to turn the audible output on and off.

.....

.....

.....

.....

.....

(4 marks)

13

A9 A robotic arm is a systems and control device that is often used on a production line in conjunction with CAM equipment.

(a) Give **two** examples where a robotic arm could be used in a production process to ensure that the health and safety of workers is not put at risk.

For each of your examples give a reason for using the robotic arm in terms of the health and safety of the workers.

(i) Example 1 .....

(1 mark)

Reason for using the robotic arm

.....

.....

(2 marks)

(ii) Example 2 .....

(1 mark)

Reason for using the robotic arm

.....

.....

(2 marks)

(b) A robotic arm is a control system that has moving parts. Describe a safety system that could be used to protect the operators.

.....

.....

(2 marks)

(c) Describe a way in which the use of robotic production lines has benefited customers.

.....

.....

(2 marks)

(d) Describe a method of using CAM to produce a PCB (printed circuit board).

.....

.....

.....

(2 marks)

END OF SECTION A

NO QUESTIONS APPEAR ON THIS PAGE

TURN OVER FOR SECTION B – PNEUMATICS FOCUS

SECTION B – PNEUMATICS FOCUS

Answer **all** questions in this section.

Do **not** answer these questions if you have answered the questions in **Section A – Mechanisms Focus** (pp. 4–22).

B1 The block diagram, **Figure 1** shows how a fire prevention water sprinkler system works.

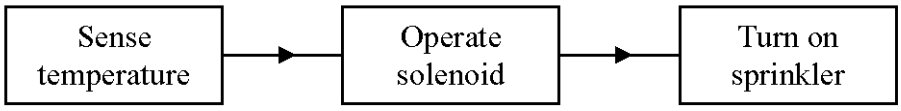


Figure 1

The sensing part of the circuit created to operate the sprinkler is shown in **Figure 2**.

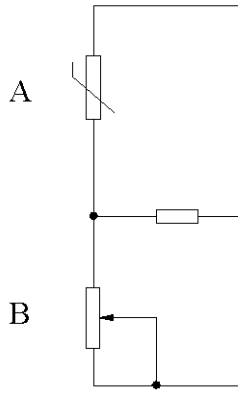


Figure 2

(a) (i) Which component acts as a sensor in this circuit?

.....

(1 mark)

(ii) What does the component sense?

.....

(1 mark)

(b) Which component is used to adjust the sensitivity of the circuit?

.....

(1 mark)

(c) The circuit could also be modified to sense ice.

Complete **Figure 3** to show how you would re-arrange the components from **Figure 2** to detect ice.

The heater must turn on when ice is detected.

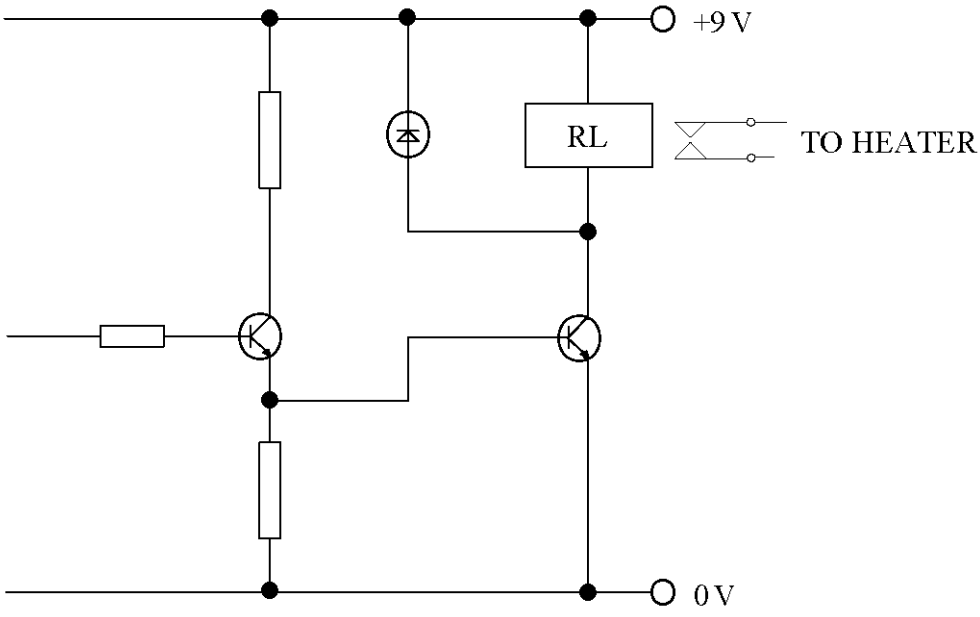


Figure 3

(8 marks)

11

TURN OVER FOR THE NEXT QUESTION

B2 (a) Many circuits use a safety procedure requiring **two** switches to be pressed before a mechanism operates.

In the space below draw a circuit requiring **two** push-to-make switches to be pressed before the motor will work. A range of components that can be used are shown in **Figure 4**.

This question is worth 10 marks.

Marks will be awarded as follows:

Quality of drawing;	*(2 marks)*
Correct arrangement of switches;	*(2 marks)*
Correct circuit symbols;	*(4 marks)*
Correct output.	*(2 marks)*

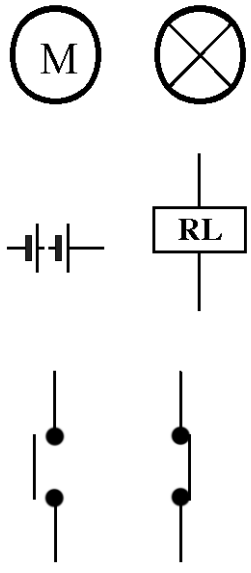


Figure 4

(b) Study the symbols shown in **Figure 5** then fill in the missing words in the sentences below.

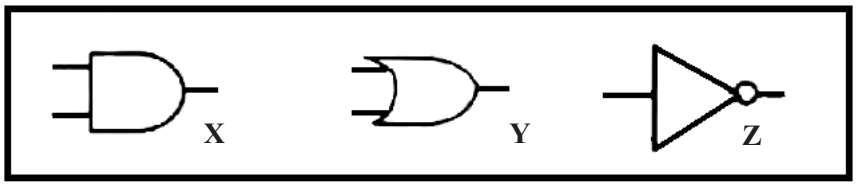


Figure 5

(i) The symbols in **Figure 5** are all examples of ..... gates.

(1 mark)

(ii) The gate labelled **X** is an ..... gate and the gate labelled **Y** is an ..... gate.

(2 marks)

(iii) Complete the truth table in **Figure 6** for gate **X**.

Input 1	Input 2	Output
0	0	
0	1	
1	0	
1	1	

Figure 6

(4 marks)

17

TURN OVER FOR THE NEXT QUESTION

B3 A primary school needs a wind speed indicator (anemometer).

The anemometer uses four wind blown rotating cups to turn the shaft.

A light source and LDR (Light Dependent Resistor) are used to sense movement of the shaft.

(a) Show on **Figure 7** how the disc could be modified to allow the LDR to be exposed to the light twice for each rotation of the shaft.

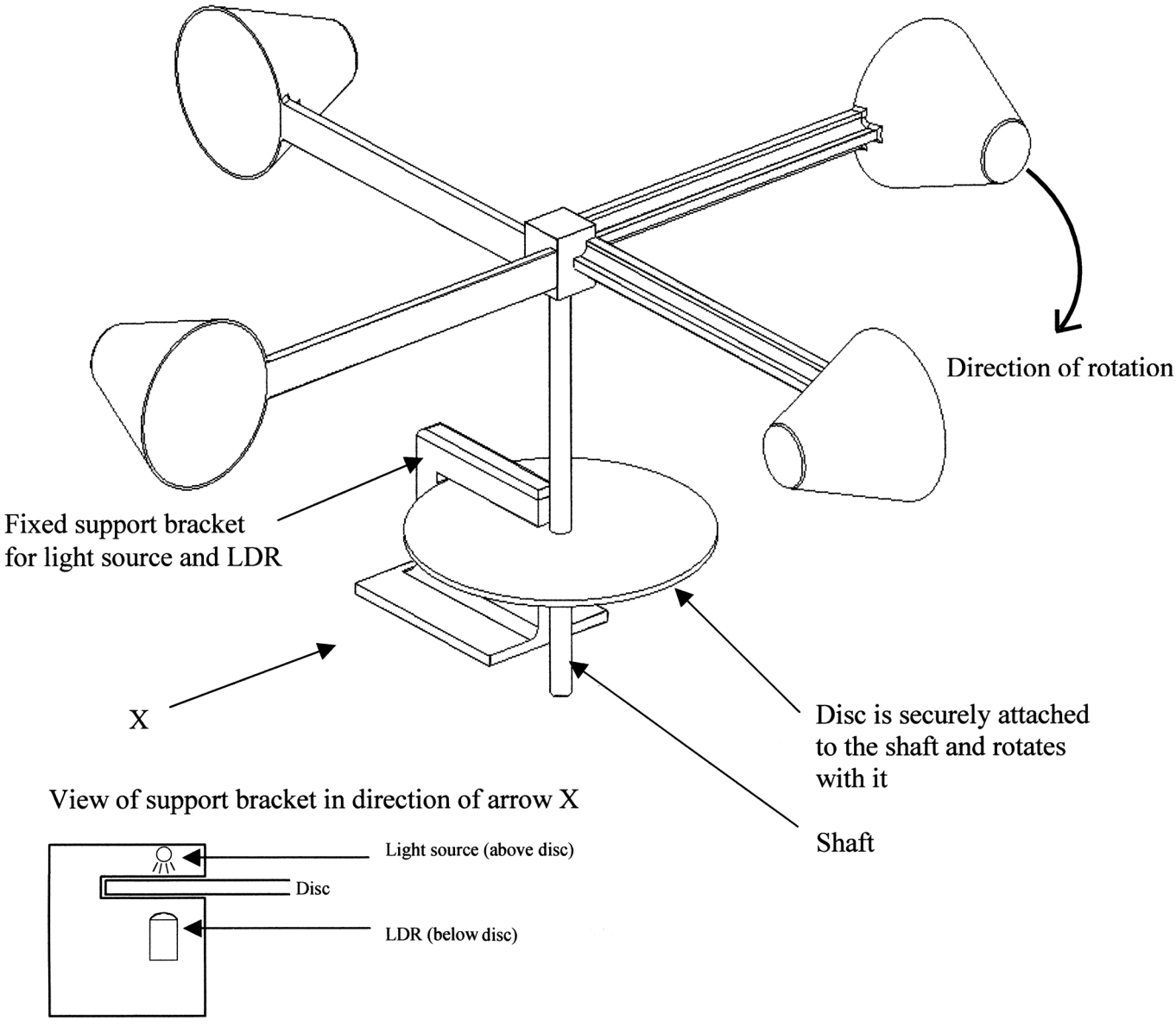


Figure 7

(4 marks)

(b) The signal from the LDR (Light Dependent Resistor) is amplified using an Operational Amplifier. The circuit used is shown in **Figure 8**.

Using the Op Amp pin information in **Table 1** complete the labelling of the Op Amp in the circuit diagram entering the appropriate pin numbers in the shaded circles.

1 & 5	offset null
2	inverting
3	non-inverting
4	0 V
6	output
7	+Vcc
8	NC

Table 1

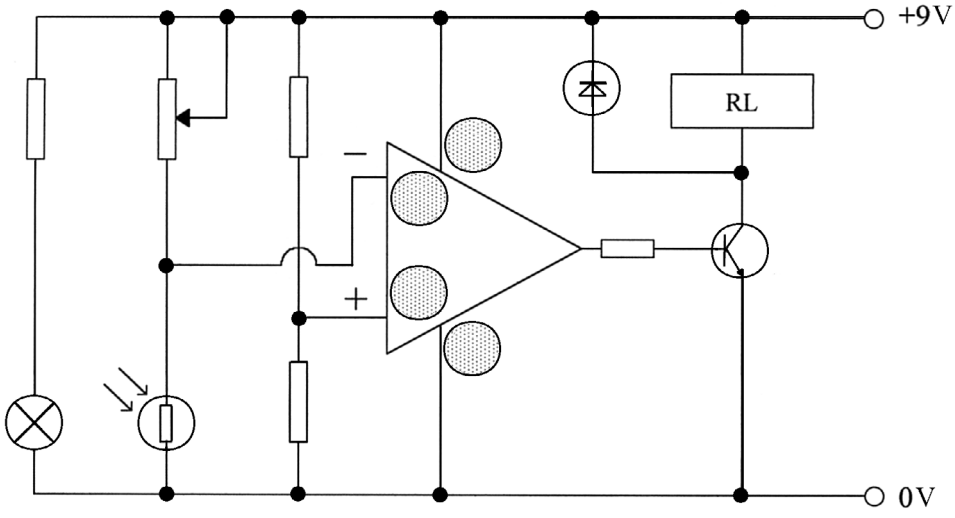


Figure 8

(4 marks)

(c) **Figure 9** shows one of the wind collectors and locating arm.

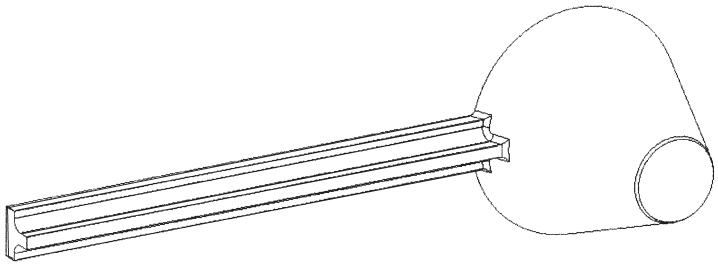


Figure 9

Name **one** suitable industrial moulding process for making this component.

.....

(1 mark)

QUESTION B3 CONTINUES ON THE NEXT PAGE

(d) Many schools do not have the ability to mould a wind collector of this type.

In the space below sketch an alternative wind collector that could easily be made in school. Label the materials that would be used.

This question is worth 5 marks.

Marks will be awarded for:

Appropriate method;	*(1 mark)*
Appropriate materials;	*(2 marks)*
Quality of drawing.	*(2 marks)*

14

NO QUESTIONS APPEAR ON THIS PAGE

TURN OVER FOR THE NEXT QUESTION

B4 *Secure-it* makes rising bollards for people to protect their drive-ways.

The bollard is a post that rises out of the ground to prevent a car being removed from the driveway.

Figure 10

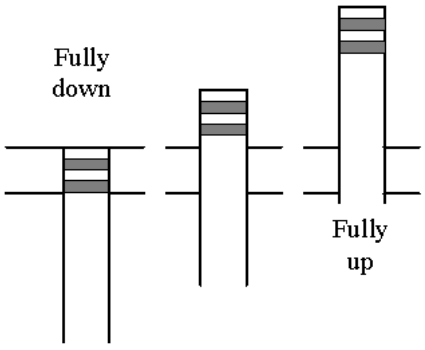


Figure 11

(a) *Secure-it* has asked you to design a working model that could be used in an exhibition. The model will be table mounted and the bollard and the table surface are shown in **Figure 12**.

Complete **Figure 12** to show a suitable pneumatic system to give a *continuous* slow up and down movement.

This question is worth 10 marks.

Marks will be awarded as follows:

Suitability of pneumatic system;	*(4 marks)*
Notes on construction/materials/components/operation;	*(4 marks)*
Quality of drawing.	*(2 marks)*

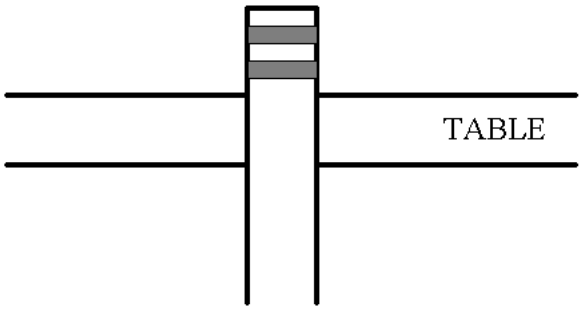


Figure 12

(b) Improve your system to include a *pause at the top and bottom* of the bollard's travel.

Add notes to your diagram explaining how the pauses are produced.

This question is worth 9 marks.

Marks will be awarded as follows:

Facility to pause at top/bottom;	*(4 marks)*
Notes explaining how the system works;	*(3 marks)*
Quality of drawing.	*(2 marks)*

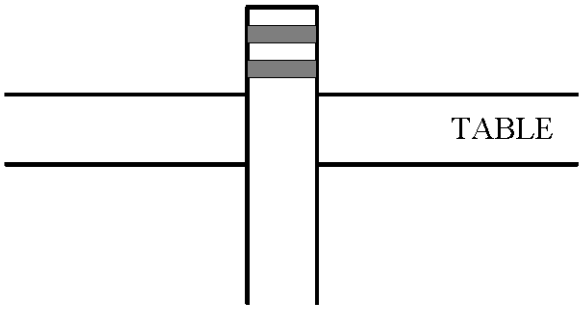


Figure 13

B5 **Figure 14** shows a pneumatic system constructed from a kit.

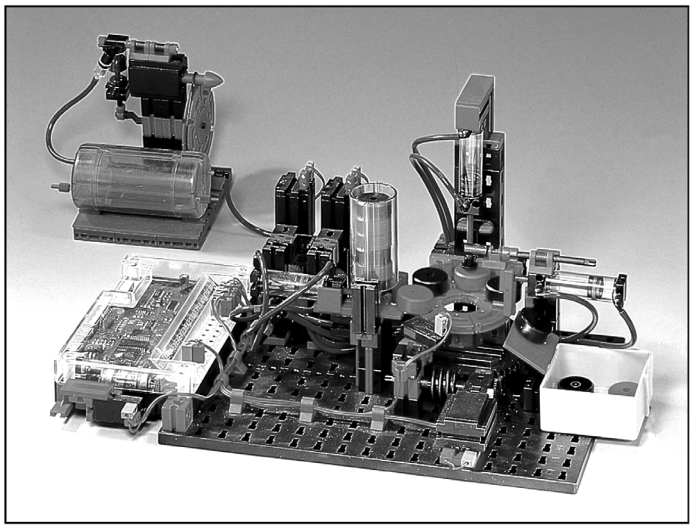


Figure 14

(a) The component shown in **Figure 15** is the double acting cylinder used to push an activating bar.

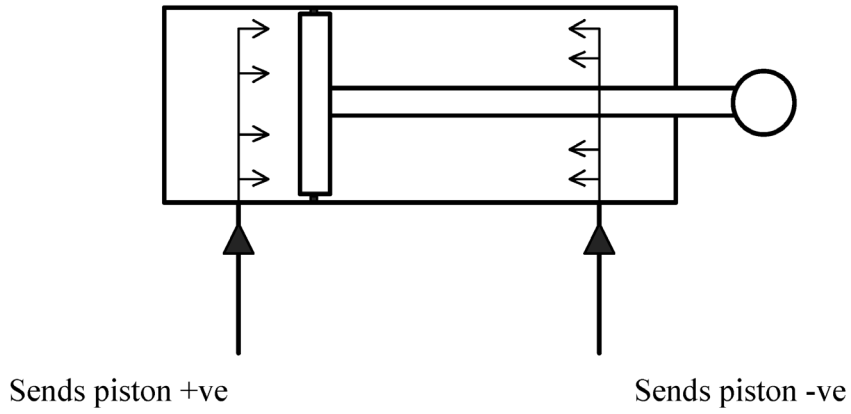


Figure 15

The internal diameter of the cylinder is 30 mm.

Calculate the surface area of the piston.

Formula for area of piston .....

(1 mark)

Calculation .....

.....

.....

(2 marks)

Answer and units .....

(2 marks)

(b) What pressure will the air entering the cylinder need to be at in order to produce a force at the piston of 10 kN?

Formula .....

(1 mark)

Calculation .....

.....

.....

(2 marks)

Answer and units .....

(2 marks)

(c) The forces produced by a Double Acting Cylinder are different as it goes positive and negative. Explain why this is true.

.....

.....

.....

.....

(3 marks)

13

TURN OVER FOR THE NEXT QUESTION

B6 Many pneumatic circuits are designed to be reciprocating as long as the air supply remains uninterrupted. An incomplete version of one such circuit is shown in **Figure 16**.

It is shown as the piston is moving in the *positive direction*.

(a) Complete the circuit in **Figure 16** by adding a flow control valve that will control the piston speed as it moves in the *negative direction*.

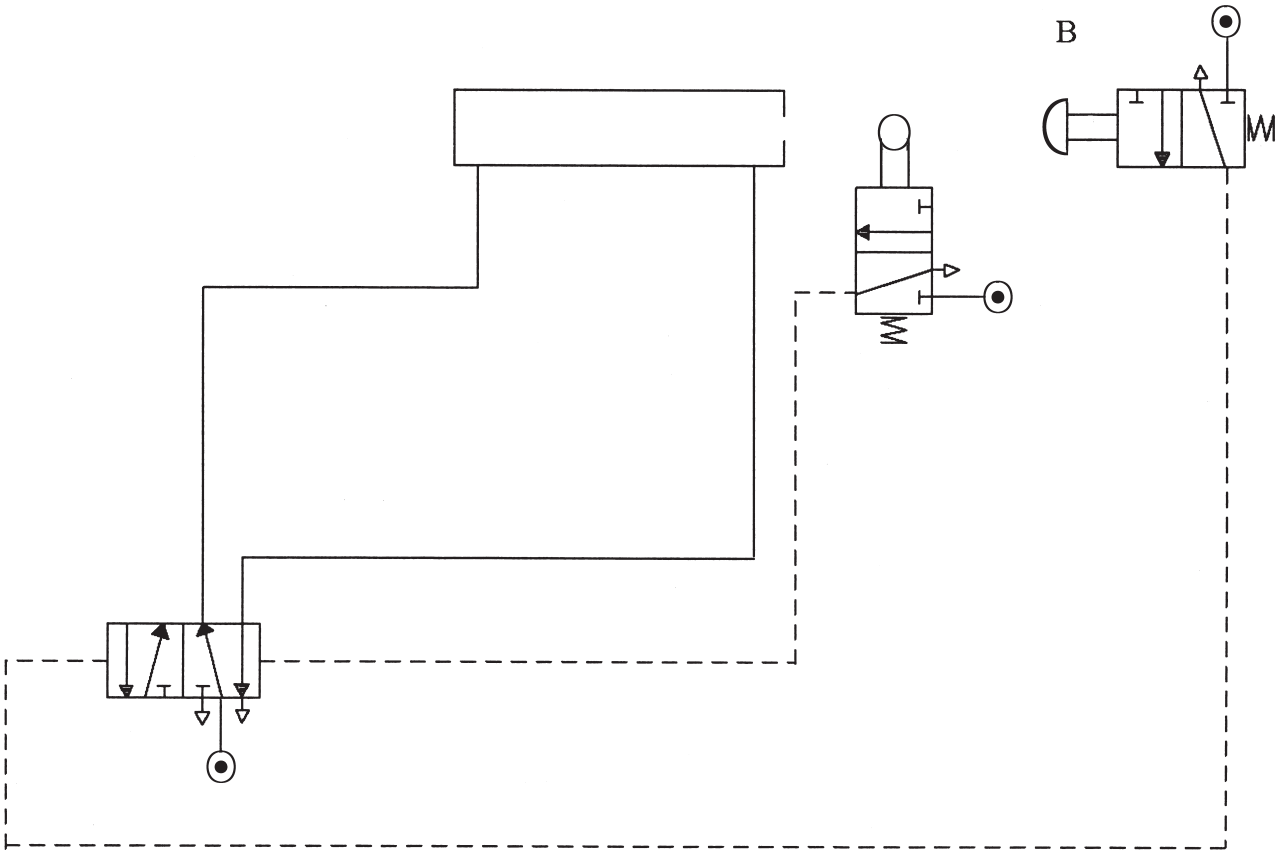


Figure 16

(4 marks)

(b) Complete the drawing of the double acting cylinder in **Figure 16** by drawing the piston and showing its direction of movement with an arrow after button B has been pressed and a short period of time has elapsed. *(2 marks)*

(c) (i) In the space below redraw the double pressure operated 5 port valve and show the correct pilot air numbers. *(4 marks)*

(ii) Show the correct valve window in place when valve B has been activated on the same diagram as your answer to part (i). *(2 marks)*

12

B7 (a) Safety is of importance in the workshop.

Table 2 contains some common situations you may experience. For each situation specify the hazard and give **one** method of reducing it in the appropriate boxes.

Situation	Hazard	Method of reducing hazard
Exposed gearing on mechanical components		
Fumes from etching tanks		
Drilling holes using a pillar drill		
Soldering components to a PCB		

Table 2

(8 marks)

(b) Complete the production plan in **Table 3** for the process of etching a PCB.

Process	Materials and components	Tools
	Etch resist coated copper clad board	Etching tank, chemicals, tongs
Drilling PCB		
Insert components and solder to copper tracks	PCB, resistors, LEDs, 555 chip, capacitor	
Cut off surplus wire	NONE	
Check continuity	Completely soldered circuit	

Table 3

(6 marks)

NO QUESTIONS APPEAR ON THIS PAGE

TURN OVER FOR THE NEXT QUESTION

B8 (a) **Figure 17** shows a pedestrian crossing.

Input A and Input B are the push buttons placed at each side of the road.

1 = on 0 = off

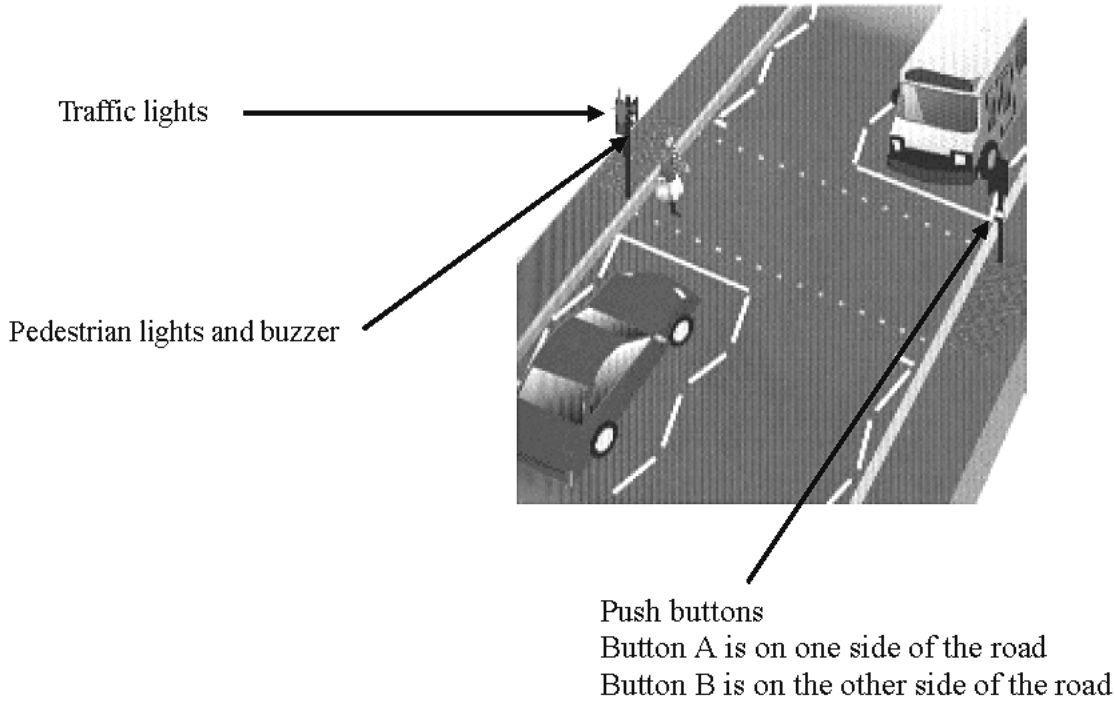


Figure 17

The output devices in the system are listed below:

C = green traffic light
D = amber traffic light
E = red traffic light
F = red pedestrian light
G = green pedestrian light
H = pedestrian buzzer
J = audible *do not cross*

The sequence below begins when button A or B is pressed.

Button A or B pressed:

- Traffic light changes from green to amber
- Wait 5 seconds
- Traffic light changes from amber to red
- Red pedestrian light changes to green pedestrian light and the pedestrian buzzer sounds
- Wait 15 seconds
- Pedestrian buzzer stops and the green pedestrian light begins to flash
- Red traffic light changes to flashing amber traffic light
- Wait 5 seconds
- Pedestrian light changes from green to red
- Traffic light changes from amber to green

End of sequence.

Using the commands below complete the control program for the traffic light sequence described on page 40.

The bold section has been given to you as a starting place.

Turnoff *X*	turns off the output labelled *X*
Turnon *X*	turns on the output labelled *X*
Wait *Y*	waits for the number of seconds specified
Flash *Z*	flashes the output labelled *Z*
End	ends the program.

X, *Y* and *Z* are given as examples – you should use the outputs C to J in your answer.

If input A = 1 or input B = 1
Turnoff C, Turnon D
Wait 5

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(9 marks)

(b) The program can be improved by using an audible output saying *do not cross*.

- The audible output sounds at the same time as the pedestrian lights flash.
- This audible output is Output J.

In the space below rewrite the relevant lines of the control program to include the commands to turn the audible output on and off.

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(4 marks)

13

Turn over ►

B9 A robotic arm is a systems and control device that is often used on a production line in conjunction with CAM equipment.

(a) Give **two** examples where a robotic arm could be used in a production process to ensure that the health and safety of workers is not put at risk.

For each of your examples give a reason for using the robotic arm in terms of the health and safety of the workers.

(i) Example 1 .....

(1 mark)

Reason for using the robotic arm

.....

.....

(2 marks)

(ii) Example 2 .....

(1 mark)

Reason for using the robotic arm

.....

.....

(2 marks)

(b) A robotic arm is a control system that has moving parts. Describe a safety system that could be used to protect the operators.

.....

.....

(2 marks)

(c) Describe a way in which the use of robotic production lines has benefited customers.

.....

.....

(2 marks)

(d) Describe a method of using CAM to produce a PCB (printed circuit board)

.....

.....

.....

(2 marks)

END OF QUESTIONS

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