2007 Mechatronics

Higher

Finalised Marking Instructions

1 (a) Worksheet Q1

Robot	Joint 1	Joint 2	Joint 3
Polar	Rotary	Rotary	Linear
Cartesian	Linear	**Linear**	**Linear**
Cylindrical	Rotary	**Linear**	**Linear**

Table Q1

(4 answers = 0.5 mark per answer = 2 marks)

(b) Walkthrough = Using an interface like a teach pendant, the robot arm is driven through the various required positions as a sequence and these positions recorded by operator to memory. Then positions are recalled from memory and played back so that robot repeats the required movements.

"Lead by Nose" is similar except the robot is physically moved through the sequence by a person skilled in the task, eg a welding technician, and points are again recorded automatically for later replay. Or other suitable answer.
Note only the differences are required not the similarities and also the question only asks about programming so the later 'playback' is not essential in the answer. **2**

(c) Any two reasons from positioning precision, able to provide positioning at intermediate points in addition to full retraction/extension, able to produce large forces, able to lock joints at known positions, or other suitable answers.

(2 reasons = 0.5 mark per answer = 1 mark)

2 (a) (i) Any two from:- Microcontroller, PLC, PC

(2 reasons = 1 mark per answer = 2 marks)

(ii) For hardwired there is a need to rewire the system or reconfigure the connections to change the controlling action, or other suitable answers. **1**

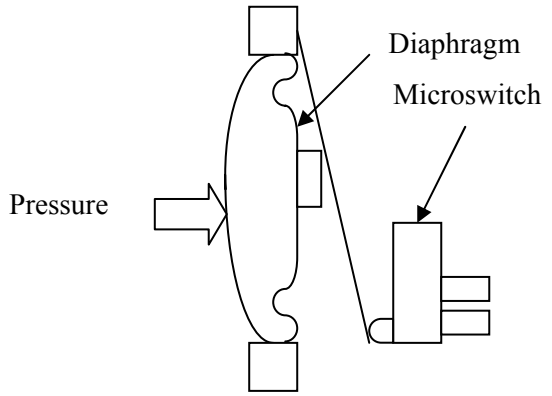
(b) Worksheet Q2

Decimal	Code type = **GRAY = 1 mark**
0	0000
1	0001
2	0011
3	0010
4	0110
5	0111
6	0101
7	0100
8	1100 = 0.5 mark
9	1101
10	1111
11	1110
12	1010
13	1011 = 0.5 mark
14	1001
15	1000

Table Q2 **2**

3 (a) Any suitable pressure sensor system. Example include: − piezo crystal, strain gauges, carbon device, diaphragm with microswitch. **1**

(b) Suitable sketch and description to match candidate's chosen system.
Example sketch for a Diaphragm with microswitch: As the pressure varies the diaphragm expands. At a certain point the displacement is sufficient to operate the microswitch.



Or other suitable answer which <u>describes the basic operation</u> of the selected pressure sensor correctly with the aid of a suitable diagram.

(Description + Diagram = 3 marks)

(c) As an alarm to indicate when the pressure has exceeded a set value. The sensor is simple, gives a digital output and its value can be set by the physical positioning of the switch relative to the diaphragm. Or any other suitable answer where the <u>stated</u> application matches the sensor system. Note: description is not required. **1**

4 (a) Any 2 PLC advantages over PC from: − include more robust, lower maintenance, cheaper for a given simple sequential control application, can use ladder diagramming for programming, physically smaller or other suitable advantages.

(2 advantages = 2 marks)

Worksheet Q4

Label	Element
A	**Address bus**
B	**CPU or Central Processing Unit or processor**
C	**Input interface unit**
D	**Memory**
E	**Output interface unit**
F	**Data bus**

(6 answers = 0.5 mark per answer = 3 marks)

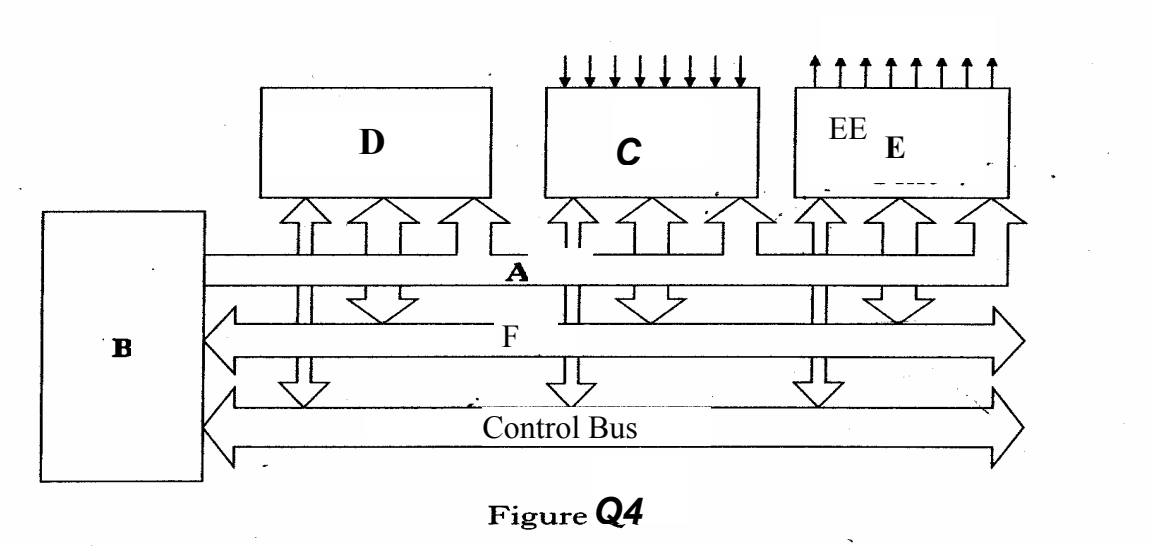


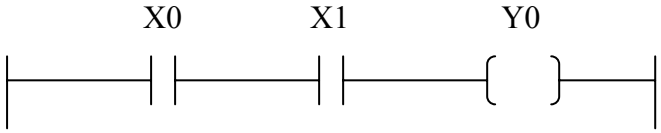
Figure *Q4*

5 (a)

X0	X1	Y0
0	0	0
0	1	0
1	0	0
1	1	1

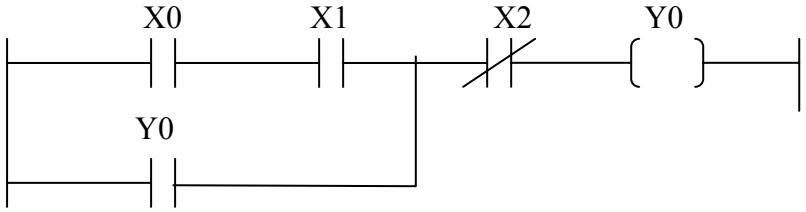
(4 answers (line entries) = 0.5 mark per answer = 1 mark)

(b)



(1 mark for inputs, X0 and X1 and output, Y0, 1 mark for AND function shown correctly = 2 marks)

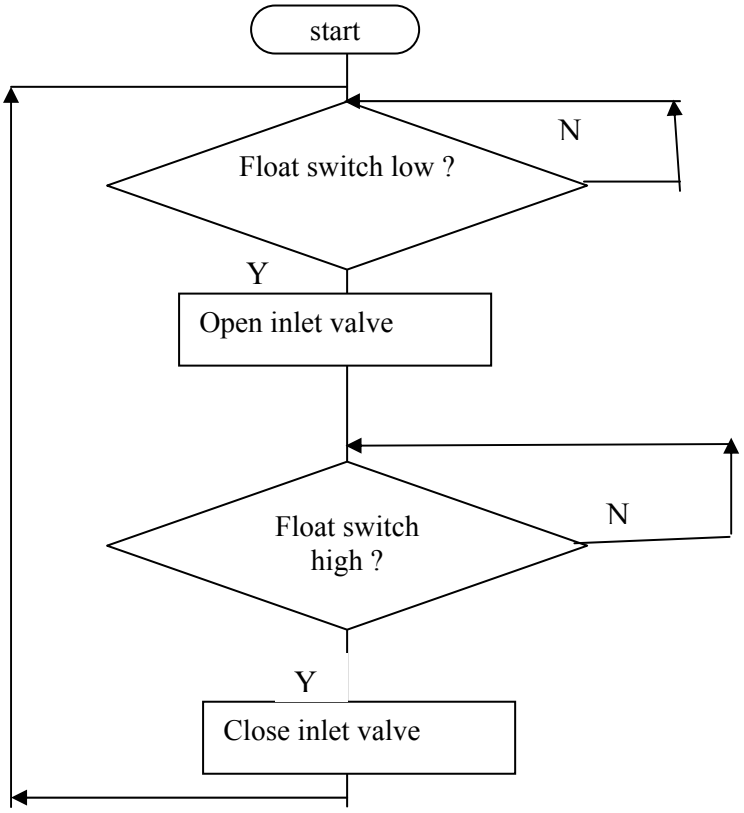
(c)



Basic latch circuit by MUST include X2.

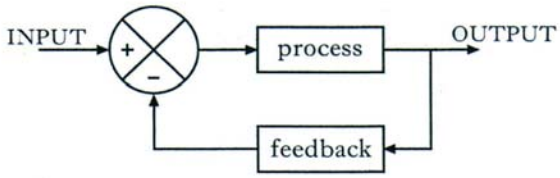
(1 mark for Y0 contact bridging X0 and X1, 1 mark for X2 NC contact = 2 marks)

6



Or equivalent flowchart
4 boxes = 2 marks
3 loops = 3 marks

7 (a) (i)



or suitable equivalent diagram. **1**

(ii) A cooking oven where the desired temperature is set and a sensor detects the oven temperature and the heat supply is regulated to control the oven at the required temperature.

OR

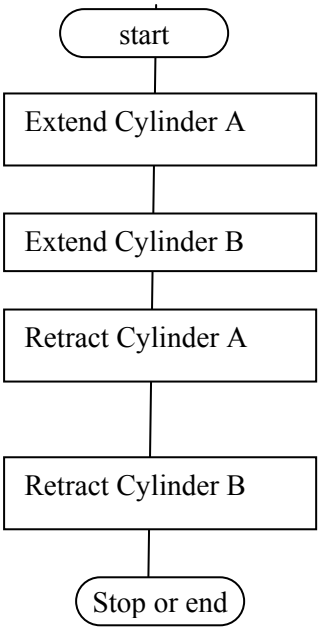
A cruise control system on a car where the speed is kept constant despite changing inclines and declines. A desired speed is set and the actual speed is sensed and fed back to the controller to inform the controlling process.

OR

Any other suitable system where the feedback about the sensed output closes the loop. **2**

(b) In an optical encoder light is used. A beam is interrupted by a slotted disc which provides pulses of light as the disc rotates. The pulses are counted and this can give positional and speed information of the rotary disc. It is called relative as the indicated position is relative to the previous. If power is lost then position is lost. Or other suitable description. **2**

8 (a)



Or equivalent flowchart – note the order of the last two retract boxes is NOT significant

Note: there is no mention of sensors to feedback cylinder position or timers. Any candidate correctly including sensors or timers should NOT be penalised but they are not required in this simplified sequence.

(4 boxes at 0.5 mark = 2 marks)

(b) Any suitable hazard related to the issue of conveyor 1 running continuously and the boxes arriving in a continuous stream. Example: − a box on conveyor 1 may arrive at cylinder A to find it still extended and collide with it.

OR

There may be insufficient time to deal with one box before the next arrives. **1**

(c) Sensors could be fitted to detect the position of cylinders and/or boxes.
Example: − sensors could be fitted to detect the position of cylinder A and only allow conveyor 1 to run if cylinder A is retracted. Or other suitable methods, including use of timers, for hazard avoidance. **2**

9 (a)

x axis = 1000mm y axis = 500mm
required accuracy = 0.1mm
therefore count = 10000 (1 mark)

$2^0 = 1$
$2^1 = 2$
$2^2 = 4$
$2^3 = 8$
$2^4 = 16$
$2^5 = 32$
$2^6 = 64$
$2^7 = 128$ (1 mark)
$2^8 = 256$
$2^9 = 512$
$2^{10} = 1024$
$2^{11} = 2048$
$2^{12} = 4096$
$2^{13} = 8192$
$2^{14} = 16384$

so 14 bits needed which is greater than 10000 (1 mark)

or

x axis = 1000mm y axis = 500mm
required accuracy = 0.1mm
therefore count = 10000 (1 mark)

$2^n = 10000$ therefore integer n > 13.2877 (1 mark) n = 14 bits (1 mark) **3**

(b) Relative encoder shows a position relative to another previous position – if power is lost then positional information lost.

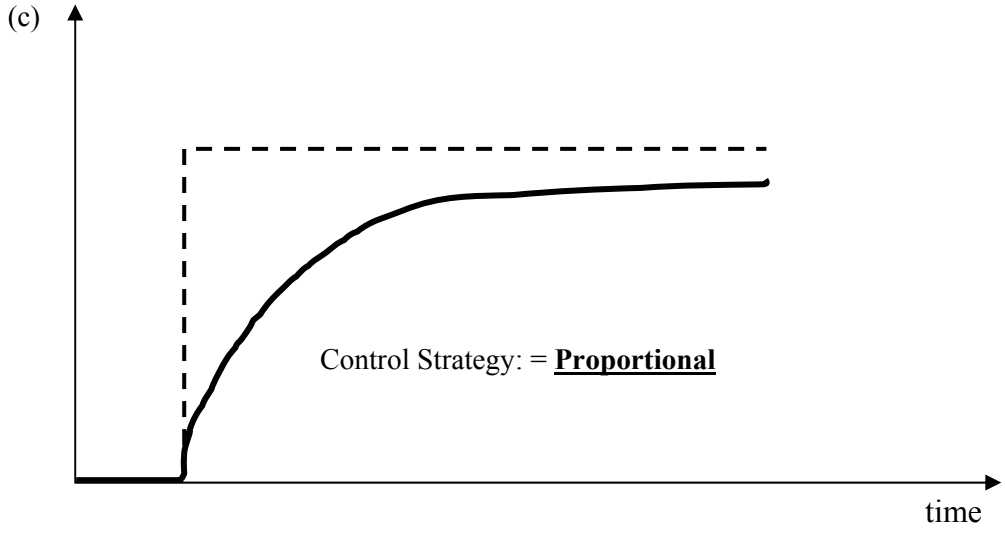
Absolute encoder shows position from a given, known position (fixed datum point) and if power is lost then position is still known after power restoration.

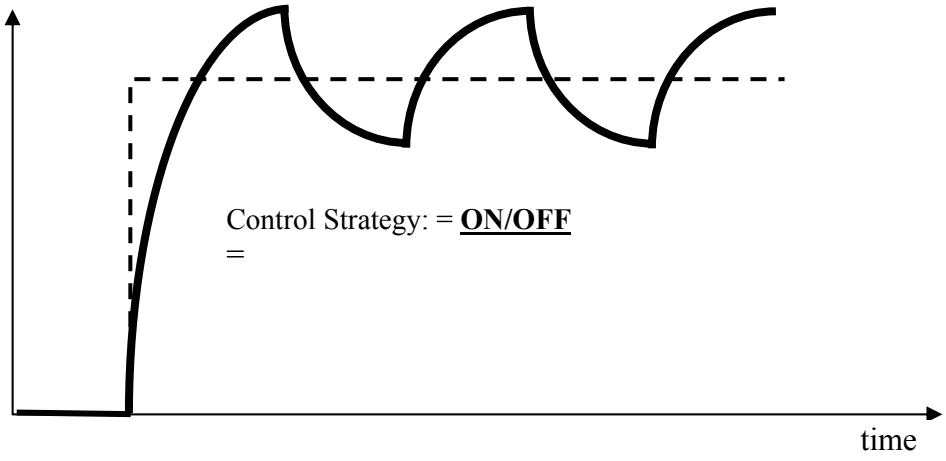
Or other suitable explanation of the difference. **2**

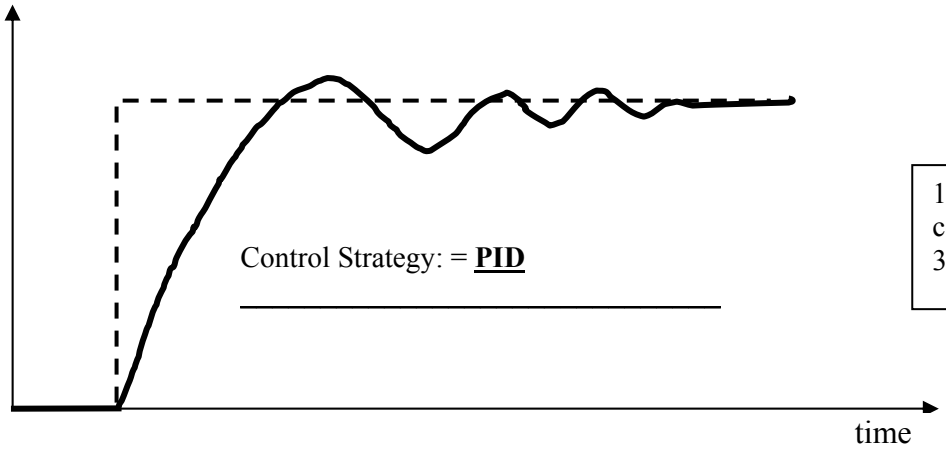
10 (a) Proportional action is where the control applied is <u>proportional to the error</u> signal (where the error is the difference between the set point and the actual). Or other suitable answer. **1**

(b) Offset is when the steady state output differs from the desired value by a fixed constant amount. Or other suitable answer. **1**

(c)







1 mark per correct label = 3 marks

11 (a) Two benefits from the following: − more flexibility, less mechanical wear, more programming options without mechanical changes, reliability or other suitable responses.

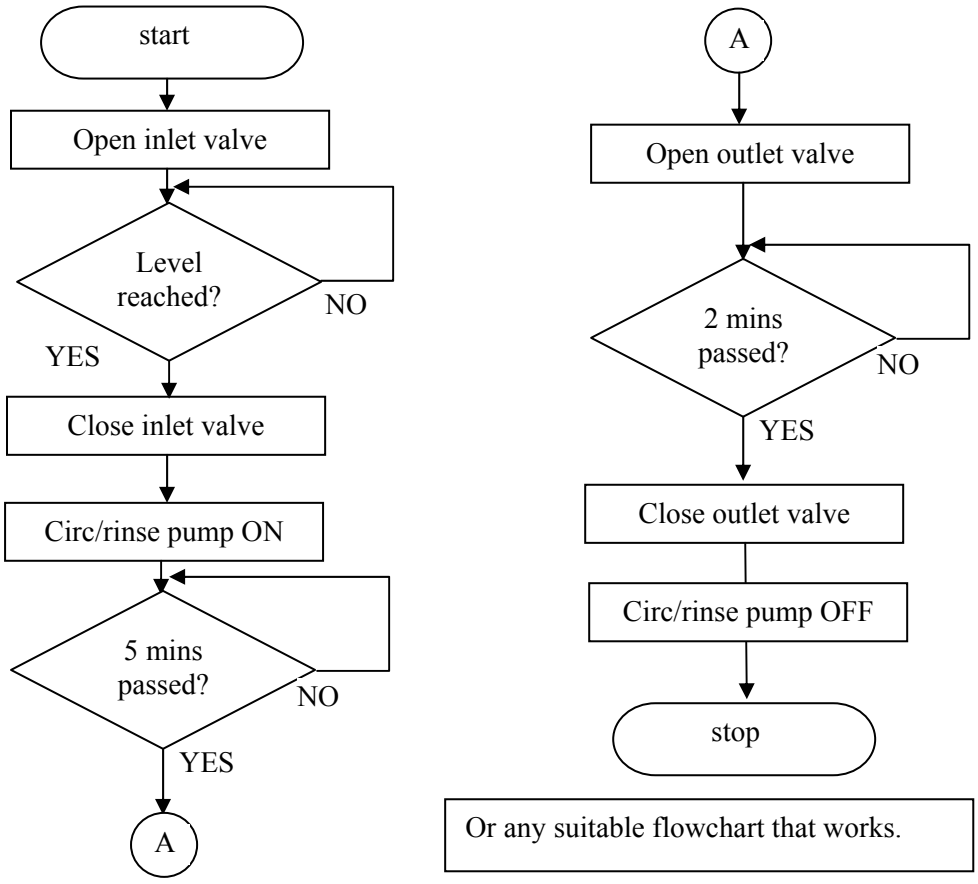
(1 mark each benefit = 2 marks)

(b) (i) Input signals
- level sensor
- temperature sensor
- door sensor
- <u>two</u> program selection switches
- start program switch.

(ii) Output signals
- inlet solenoid valve (cold water only)
- circulating/emptying pump
- heater element
- outlet solenoid valve

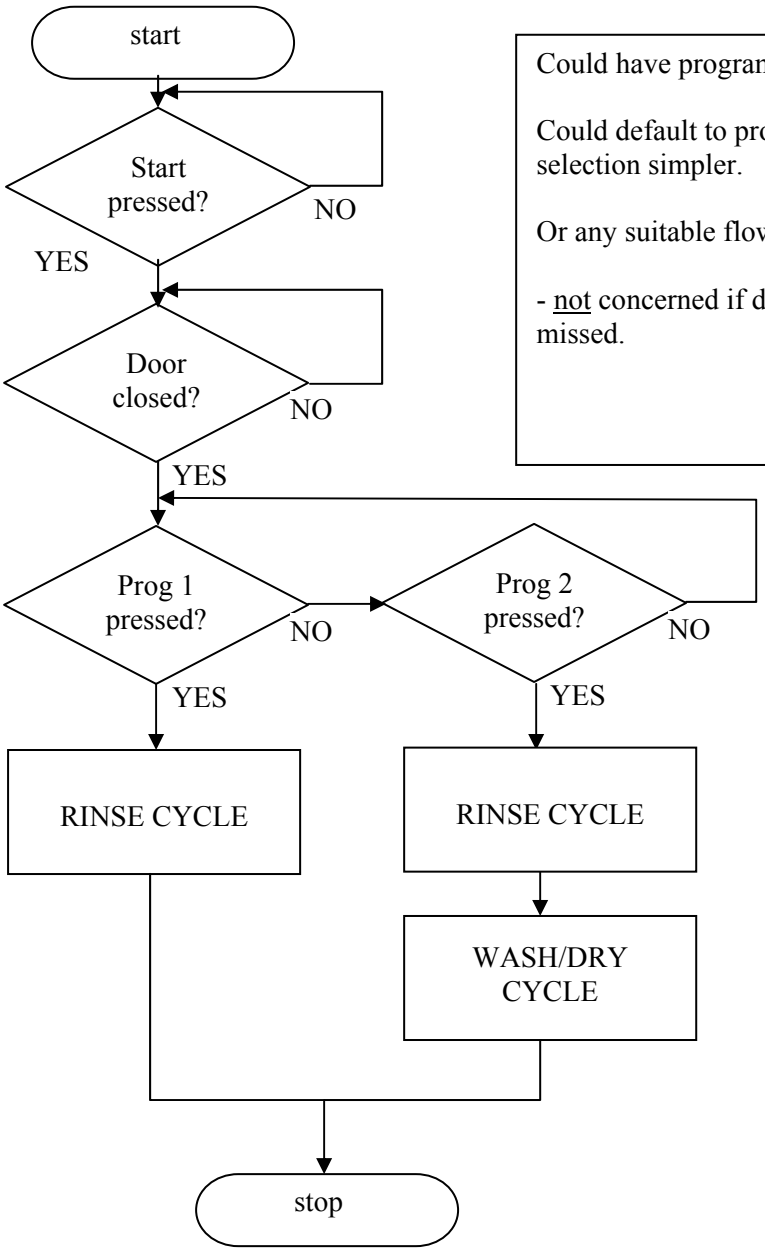
(10 signals at 0.5 mark = 5 marks)

(c)



(1 mark each of 3 decision/loop = 3 marks
0.5 mark for each 6 action boxes and correct order = 3 marks)

(d)



Could have program selection first!

Could default to program 1 making selection simpler.

Or any suitable flowchart that works.

- not concerned if door open question missed.

(1 mark for each program leg = 2 marks
1 mark for other decisions = 3 marks)

(e) Any suitable sensor. Example Float with attached resistive element. As float rises and falls the value of the resistance varies. A suitable diagram would help here.

(1 for suitable sensor, 2 for explain and/or diagram = 3 marks)

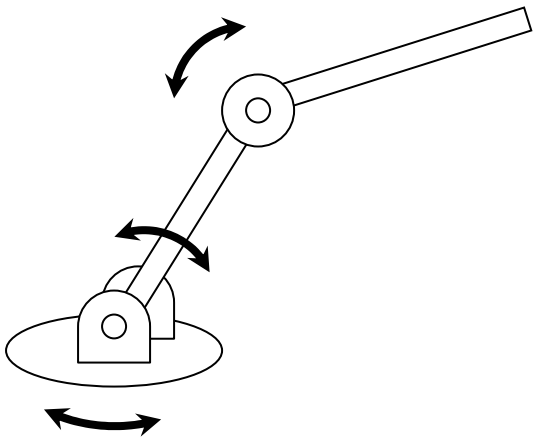
(f) Any two suitable safety issues such as: − door lock to prevent opening when operating or filled with water, over temperature alarm in case of fault, emergency stop button, temperature indicator. Or other suitable safety issues.

(two safety issues at 1 mark = 2 marks)

(g) Time based relies on time intervals to allow completion of tasks. Event based will test for certain event to have occurred before moving on to the next stage and therefore sensors could be added to detect the completion of an event. Example the water draining goes on for a set time – this could be modified to include sensor to check when the water has been drained. This could mean the emptying might be completed sooner particularly if there is little water in the system. Or other suitable modifications and benefits.

(2 marks for modification and 2 marks for benefits = 4 marks)

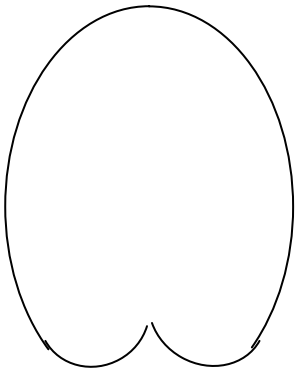
12 (a) Revolute Robot Arm Geometry



All joints rotary

(1 mark for each joint = 3 marks)

Work envelope



Or alternative shapes more spherical or ovoid

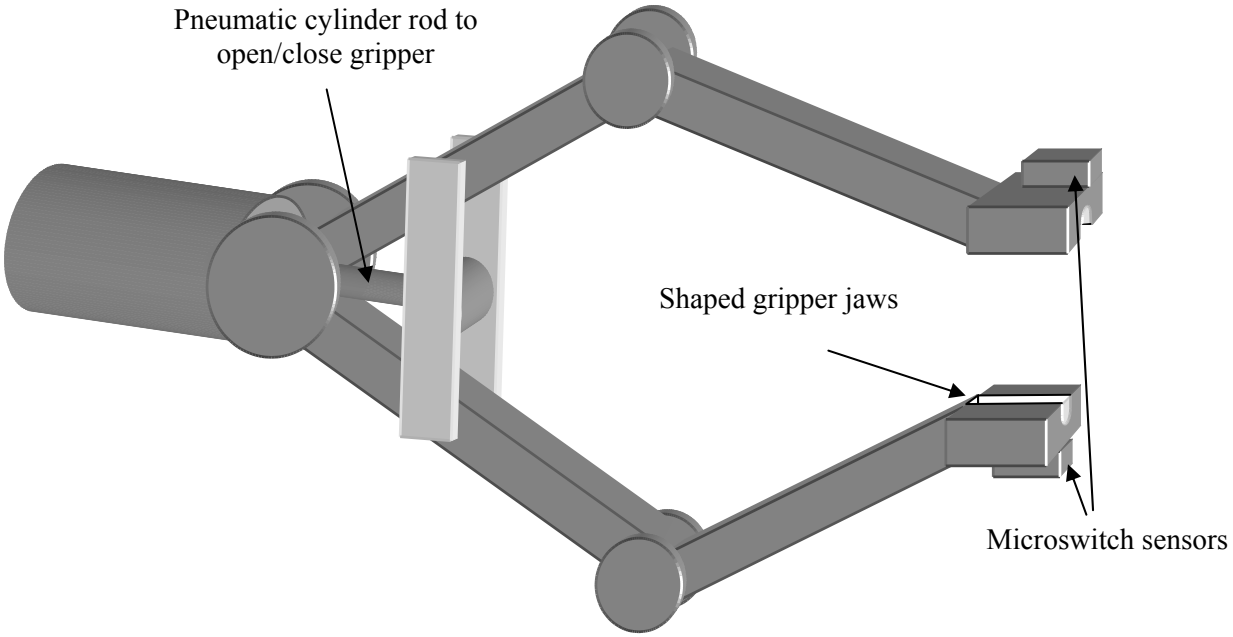
1

(b) Gripper Design – a suitable design such as a 2 or 3 finger gripper capable of picking and detecting parts using a sensing element (such as a micro switch). The sketch and description should clearly communicate how the parts can be picked up (a simple flat gripper is unlikely to effectively pick up rounded parts), the shapes coped with and how sensed.

Example description and sketch: − the end effector is a two figured gripper and is attached to the robots arm. Opening and closing of the gripper is carried out by a pneumatic cylinder attached to the gripper. Because Part B has a round shaft a shaped gripper has a rounded slot to locate the shaft (the actual rotary orientation is unimportant. Parts A and C can be picked up by holding on the flat parts of the edges. To detect the presence of parts, microswitches are included. One is in the rounded slot for part B and another offset to detect parts A and C.

Or similar suitable description and sketch

(indicative allocation subject to reallocation depending on design is 2 marks gripper design, 2 marks parts handling, 2 marks part present sensor system = 6 marks)



(c) A system of micro-switches or optical beam sensors could be fitted to the feeders, one on each feeder to give a "feeder OK" signal, this would produce 3 signals which could be combined through AND logic to produce one signal that shows "all feeders OK". Or other suitable suggestion which could include an OR function if appropriate.

(1 mark for sensor, 1 mark for 1 signal per feeder, 1 mark for AND function = 3 marks)

(d) (i) Rotation of Fan – an optical sensing system which passes a beam through the fan and this beam is broken by the rotating blades (4 off) would produce a relative high frequency pulse signal at the sensor ((4*1500)/60 = 100 Hz) this signal can then be converted to a rotational value ie rpm and displayed or a pass signal generated by the sensing system if speed > 1500rpm (100Hz). Or other suitable sensor system. Use of a diagram is optional.

(1 mark for sensor, 2 for calculation (no of blades, rpm to Hz, greater than) = 3 marks)

(ii) Direction of Airflow – a sensitive pressure sensor could be used on the exit side of the fan, the rotating of the blade would produce an air flow which would cause a pressure rise and this pressure would indicate the air flow of the fan

OR

A simple paddle could be attracted or repelled by the air stream depending on fan rotation direction. A sensor on the paddle, such as an optical or microswitch could give a signal indicating flow.

Or other suitable solutions that take account of application.

Note: both the above assume that the fan is working correctly as described in part (i) If the fan may not be working, then more than one sensor may be needed as there are three possible fan conditions in this case (correct direction, reverse direction and stopped). Candidates should not be penalised if they fail to state the inherent assumption that the fan is working correctly as implied by the test in part (i)

(Mechanism/sensor/system = 3 marks)

(e) Any appropriate safety measures such as: − emergency shut down switch, a locked entry gate, warning indicators around the system, clearly identified work areas of robots, training or other suitable answers.

(1 mark per measure = 3 marks)

(f) Any appropriate improvements with explanation such as: − Floor sensors to detect if a part is dropped, a reject conveyor to remove parts from the system, a single robot with an interchangeable gripper which is able to carry out all the assembly tasks, a visual final assembly inspection system to spot failures or other suitable answers.

(1 mark per improvement = 3 marks)

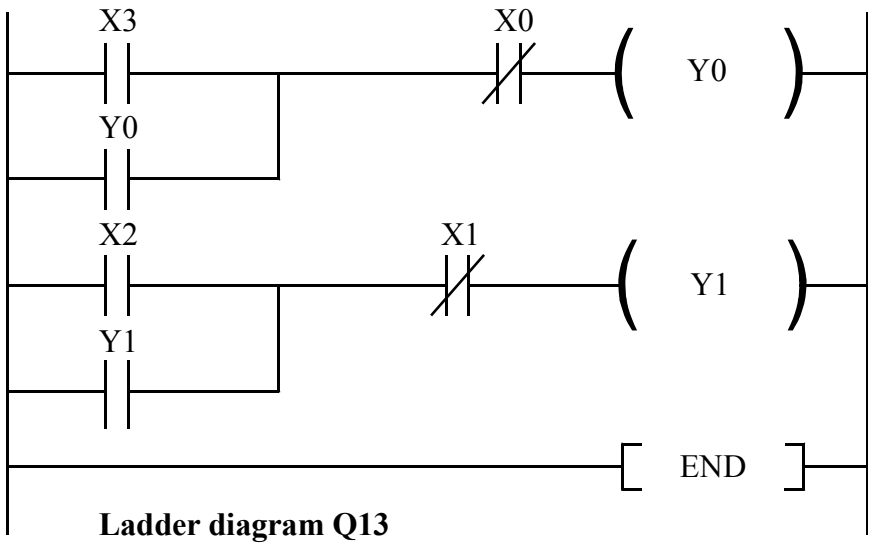
13 (a) (i) & (a) (ii)

Device	Letter	Reason	PLC I/O
Microswitch 1	C	Detects when door is fully open (upper limit switch)	X0
Microswitch 2	D	Detects when door is fully closed (lower limit switch)	X1
Pressure pad	E	Detects when vehicle fully inside the building	X2
Ultrasonic detector	A	Scans entrance area for approaching vehicles	X3
Reversible motor	B	Motor moves roller door up and down.	Y0
			Y1

Note: C & D may be the other way round as both switches are similar. IF they are reversed then later answers (for part (b) and maybe part (c) if letters or allocations are used in the flowchart) will also be different to match the changed allocation.

(1 mark for Letter column = 4 marks)
+ (0.5 mark for each correct PLC I/O = 3 marks)

13 (a) (iii)



Ladder diagram Q13

Note: See note on last part of question about possible variations. Additionally Y0 and Y1 may be reversed but the associated latching circuit must match the output (eg Y0 must have the same associated latching contact Y0).

(labelling correctly = 1 mark)

(b) When a vehicle approaches detector A (Ultrasonic detector) this sensor operates contact X3 (0.5). This in turn energises Y0 and motor B turns in F direction which starts to raise the door and closes the Y0 latching contact which latches Y0 ON (0.5).

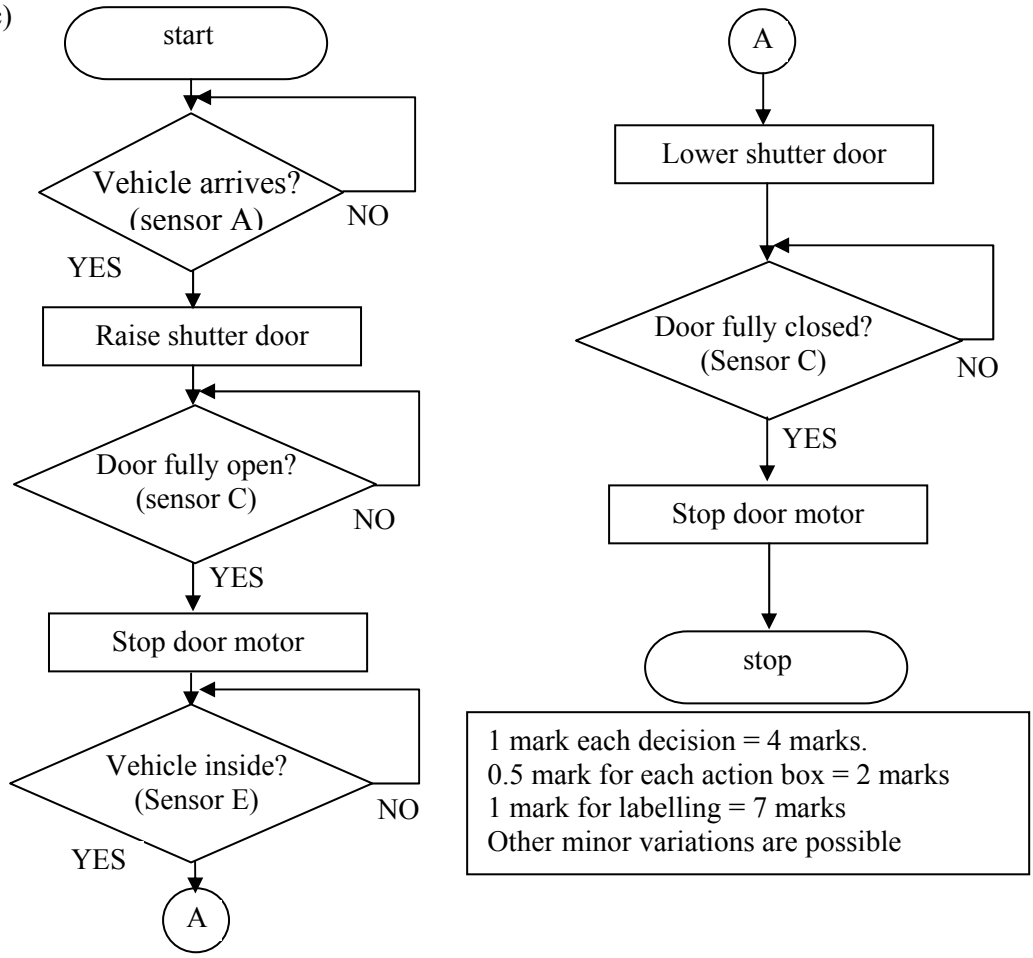
When the door reaches the upper microswitch C, this operates contact X0 (0.5) which de-energises Y0 and stops the motor B (0.5) and opens the latching contact.

When a vehicle is fully inside the building and on top of the pressure pad E, this sensor operates contact X2 (0.5). This in turn energises Y1 and motor B turns in R direction which starts to lower the door and closes the Y1 latching contact which latches Y1 ON (0.5). When the door reaches the lower microswitch D, this operates contact X1 (0.5) which de-energises Y1 and stops the motor B (0.5) and opens the latching contact.

Or other appropriate explanation (note the comments in previous sections about possible variations in labelling.

(8 steps at 0.5 mark = 4 marks total)

13 (c)



1 mark each decision = 4 marks.
0.5 mark for each action box = 2 marks
1 mark for labelling = 7 marks
Other minor variations are possible

(d) Any appropriate hazardous conditions such as: − A vehicle on pressure pad would cause door to descend. An approaching vehicle would cause door to open. This would stop door motion due to Y0 and Y1 being energised.

OR

A vehicle approaching as another vehicle enters the doorway could be under door when first vehicle reaches pressure pad. Door would start to descend while second vehicle is under door.
Or other appropriate hazardous conditions

(more than one condition = 3 marks)

(e) Any three changes which could lead to improvements such as: −
Change ladder diagram to ensure that door open/approaching vehicle overrides 'close door' initiated by vehicle on pressure pad.
Emergency stop button to stop and/or open door
Pressure sensor on door to stop drive motor if door hits a vehicle or person in door opening
Audible warnings of activity (sirens, announcements).
Or other suitable changes which could lead to improvements

(1 mark per change = 3 marks)

[END OF MARKING INSTRUCTIONS]