2013 Mechatronics

Higher

Finalised Marking Instructions

Part One: General Marking Principles for Mechatronics Higher

This information is provided to help you understand the general principles you must apply when marking candidate responses to questions in this Paper. These principles must be read in conjunction with the specific Marking Instructions for each question.

(a) Marks for each candidate response must always be assigned in line with these general marking principles and the specific Marking Instructions for the relevant question. If a specific candidate response does not seem to be covered by either the principles or detailed Marking Instructions, and you are uncertain how to assess it, you must seek guidance from your Team Leader/Principal Assessor.

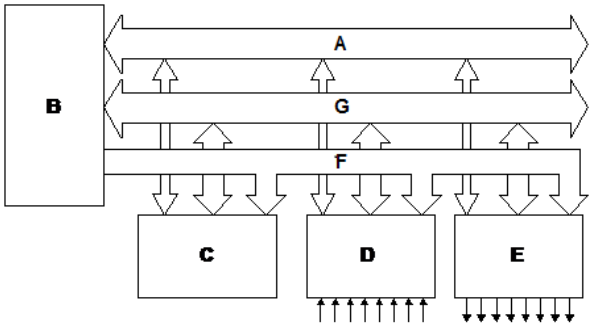
(b) Marking should always be positive ie, marks should be awarded for what is correct and not deducted for errors or omissions.

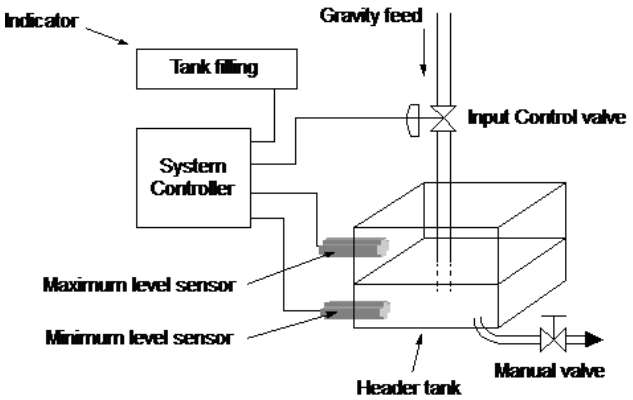
GENERAL MARKING ADVICE: Mechatronics Higher

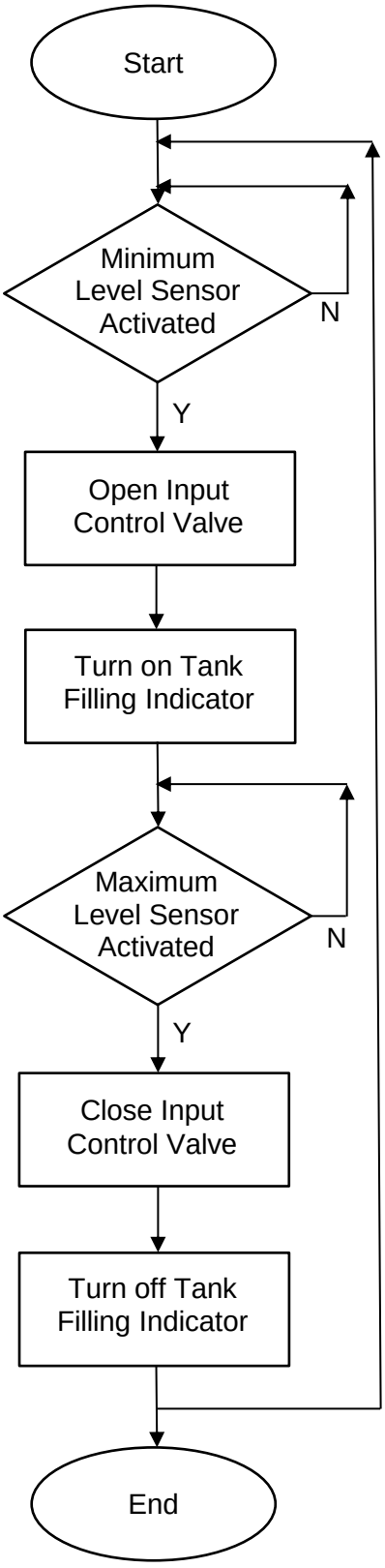
The marking schemes are written to assist in determining the "minimal acceptable answer" rather than listing every possible correct and incorrect answer. The following notes are offered to support Markers in making judgements on candidates' evidence, and apply to marking both end of unit assessments and course assessments.

Part Two: Marking Instructions for each Question

Section A

Question			Expected Answer/s	Max Mark	Additional Guidance
1			**Figure Q1 illustrates the basic architecture of a microcontroller. All parts have been identified with the letters A, B, C, D, E, F and G.**  Figure Q1		
1	**a**		**Match each of the unit names to the letters in Figure Q1.** • **Input Interface Unit** • **Output Interface Unit** • **Central Processing Unit** • **Memory Unit** Input Interface Unit D Output Interface Unit E Central Processing Unit B Memory Unit C	**2**	
1	**b**		**Match each of the busses to the letters in Figure Q1.** • **Address Bus** F • **Data Bus** A or G (Note A & G are interchangeable) **OR** A Data Bus (or G) B Central Processing Unit C Memory Unit D Input Interface Unit E Output Interface Unit F Address Bus (boxes 0.5 each, buses 1 each)	**2**	

Question			Expected Answer/s	Max Mark	Additional Guidance
1	c		**With reference to Figure Q1, state which one of the following three statements correctly describes the nature of the data flow on the control bus in a microcontroller.** **Statement 1: The data flow is bi-directional on the control bus.** **Statement 2: The data flow is omni-directional on the control bus.** **Statement 3: The data flow is uni-directional on the control bus.** Statement 1	**1**	
2			**Figure Q2 illustrates a liquid level control system.**  Figure Q2 **The header tank liquid level is controlled between preset limits by a control system which opens/closes the Input Control valve when required. The manual valve is usually open and it is only closed during system maintenance. The header tank filling indicator illuminates while the Input Control valve is open.**		
2	a		**Sketch a flowchart that shows the operation of the system. Start with an initial level maximum, Input Control valve closed and manual valve open.** **NOTE: the inserted Flowchart Symbol sheet Q2/Q11/Q12/Q13 gives a suitable selection of Flowchart Symbols.**	**5**	

Question			Expected Answer/s	Max Mark	Additional Guidance
2	a		 1 for decision and 0.5 for each action (because a quite linear action and some ordering flexibility is allowed) = 2 marks decisions + 1 mark actions = 5 marks Or other appropriate flow chart that works		

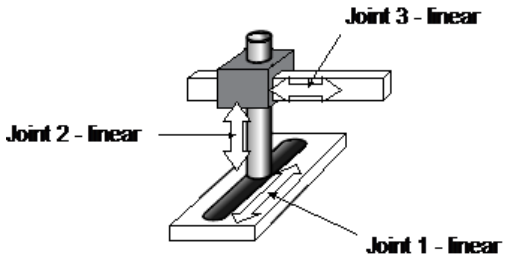
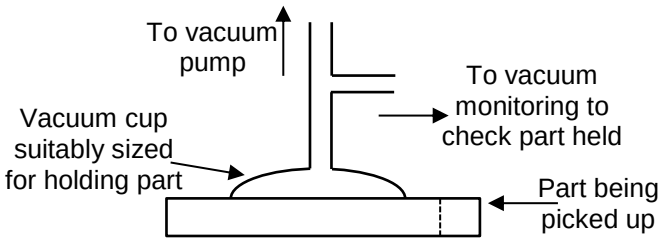
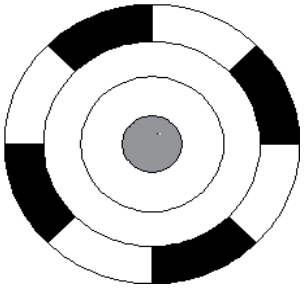
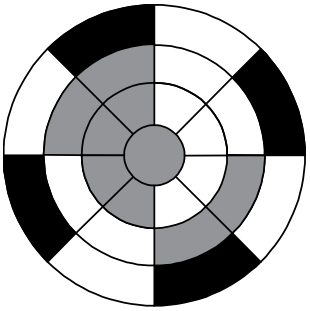
<table>
<tr><th colspan="3">Question</th><th>Expected Answer/s</th><th>Max Mark</th><th>Additional Guidance</th></tr>
<tr><td>2</td><td>b</td><td></td><td>
List the various inputs and outputs required by the system controller. Clearly identify which signals are inputs and which are outputs.
<table>
<tr><th>Inputs</th><th>Outputs</th></tr>
<tr><td>Minimum level sensor</td><td>Input Control Valve</td></tr>
<tr><td>Maximum level sensor</td><td>Tank filling indicator</td></tr>
</table>
0.5 marks per box = 2 marks
</td><td>2</td><td></td></tr>
<tr><td>3</td><td>a</td><td></td><td>
The movement of each joint of a robotic system can be described as either Rotary or Linear. Figure Q3(a) shows a labelled diagram of a Cartesian robot.


Figure Q3 (a)
The movement for each joint of a Cartesian robot is shown in Table Q3(a).
On Worksheet Q3(a), complete Table Q3(a) by filling in the appropriate joint movement for a Polar and a Revolute robot.
<table>
<tr><th>Robot</th><th>Joint 1</th><th>Joint 2</th><th>Joint 3</th></tr>
<tr><td>Cartesian</td><td>Linear</td><td>Linear</td><td>Linear</td></tr>
<tr><td>Polar</td><td>Rotary</td><td>Rotary</td><td>Linear</td></tr>
<tr><td>Revolute</td><td>Rotary</td><td>Rotary</td><td>Rotary</td></tr>
</table>
Table Q3(a)
0.5 marks per correct answer = 2 marks
</td><td>2</td><td></td></tr>
</table>

Question			Expected Answer/s	Max Mark	Additional Guidance
3	b		**In your workbook, briefly describe the basic operating principles of either a vacuum end effector or a magnetic end effector giving one practical application of your chosen end effector. You may wish to use a sketch to clarify your answer.** Vacuum End Effector A vacuum end effector uses the forces produced by differing pressures to produce a grip with which to lift/transfer an object. This method requires a suitable leak free seal between the end effector and the product. The vacuum (low pressure) is switched on and off as required and the weight of the product normally breaks the seal.  Note sketch is optional An associated application using vacuum end effector to transfer eggs as the product is fragile and has a relatively smooth surface. **OR** Magnetic End Effector This uses a coil wrapped round a soft iron core which is often bar or horse-shoe shaped. When this coil is energised by supplying an electric current then a strong magnetic field is produced in the iron core and it becomes like a magnet and it can attract certain materials such as steel. When the electric current is switched off then the magnetic field collapes and the material (steel) is no longer held but is released. A typical application can be sorting scrap materials by lifting only those that are magnetically attracted to the electromagnetic end effector. Certain materials such as steel are lifted whereas other materials such as brass, copper or wood would not be lifted.	**2** **1**	

Question			Expected Answer/s	Max Mark	Additional Guidance
4			**Figure Q4 illustrates a set of electronic kitchen scales.**  **Figure Q4**		
4	a		**State a suitable sensor for this measurement application.** Any suitable sensor for application. For example, a load cell would be suitable for this application.	1	
4	b		**Describe the basic operation of your chosen sensor in Q4(a) making reference to the output signal of the sensor.** Any suitable description of the operation of the chosen sensor in Q4(a). For the load cell stated above then an example answer might be: The system contains strain gauges that detect force and the output from the circuit is usually a small analogue electrical signal. The scales may use one or more gauges to sense the force/weight and if incorporated into a bridge circuit the characteristic that changes is the resistance of the individual gauges. This signal is conditioned and the scales calibrated to display a weight.	2	
4	c		**State two hazards that must be considered when using your chosen sensor in this environment.** Any appropriate answer for example, the scales must operate using a low voltage power supply (electric shock hazard). The scales must be moisture proof as they will be used in an environment that contains moisture (water or steam hazard could damage scales).	2	

Question			Expected Answer/s	Max Mark	Additional Guidance
5	a	i	**Identify the number of bits represented.** The disc has a 3 bit code	1	
5	a	ii	**Complete the shading of the disk.**  **Figure Q5(a)**  Note: there are quite a few variations possible but the code MUST be pure/natural binary coded NOT Gray Code.	2	
5	b		**Briefly explain one major problem with using this disc code and state one solution to this problem.** Any appropriate answer, for example, this disc code has the problem that more than one bit changes between some segments which makes error detection challenging. If Gray Code is used then only one bit changes between segments and error detection. Or other appropriate answer.	2	

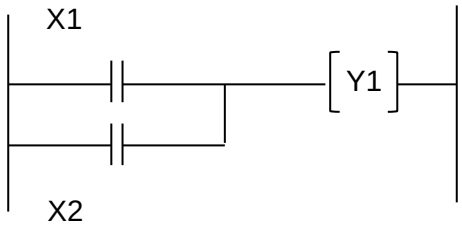
<table>
<tr><th colspan="3">Question</th><th>Expected Answer/s</th><th>Max Mark</th><th>Additional Guidance</th></tr>
<tr><td>6</td><td></td><td></td><td>A PLC based control system meets the following specification.

• The system has two inputs, X1 and X2 and one output, Y1.
• Output Y1 is only energised if either or both input switches, X1 and X2, are closed.</td><td></td><td></td></tr>
<tr><td>6</td><td>a</td><td></td><td>Construct a table showing the output for each of the four possible input combinations.

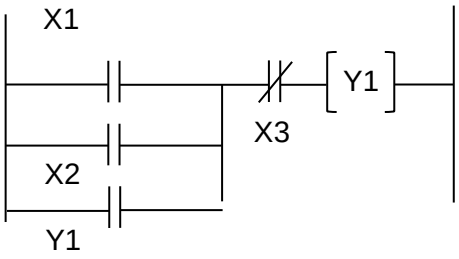
Appropriate table such as the one shown below.

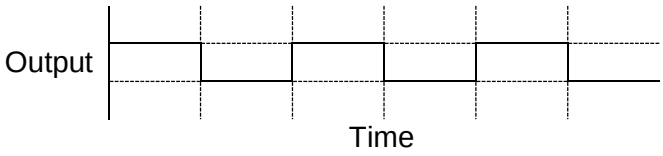
<table><tr><td>X1</td><td>X2</td><td>Y1</td></tr><tr><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>1</td></tr><tr><td>1</td><td>0</td><td>1</td></tr><tr><td>1</td><td>1</td><td>1</td></tr></table></td><td>1</td><td></td></tr>
<tr><td>6</td><td>b</td><td></td><td>Construct a ladder diagram which would allow the control to be realized using a PLC (Programmable Logic Controller).

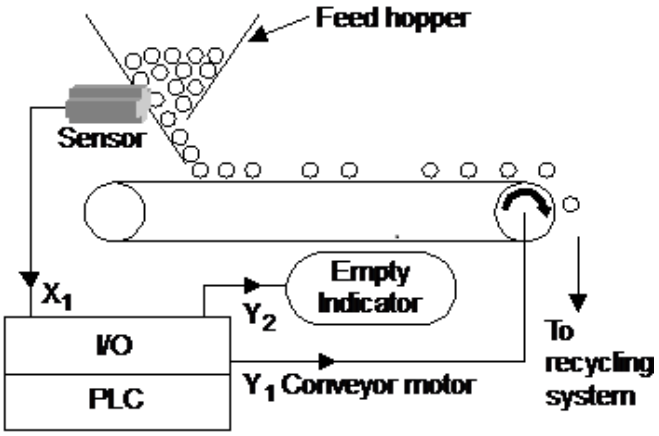
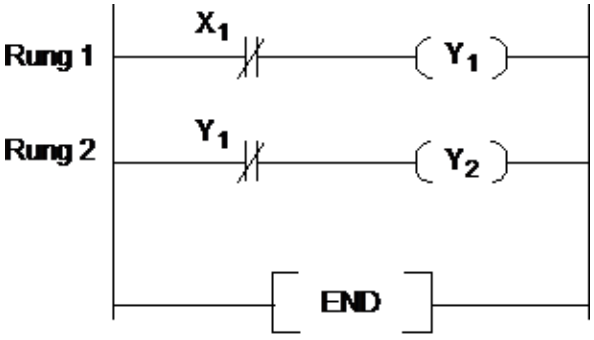
Note: the inserted PLC Datasheet Q6/Q8/Q12 gives the PLC instruction set.

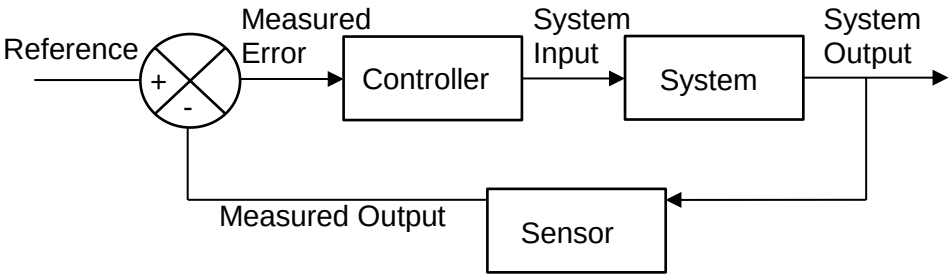
 

Ladder diagram only required. No description necessary.</td><td>2</td><td></td></tr>
</table>

Question			Expected Answer/s	Max Mark	Additional Guidance
6	c		**Redraw your ladder diagram in Q6(b) to change the operation such that the output Y1 can be latched and also enable the output Y1 to be de-energised at any time using an additional input X3.**  Ladder diagram only required. No description necessary. 1 mark for each of 2 added contacts = 2 marks	**2**	
7			**Figure Q7 illustrates a cut away view of an optical incremental encoder.**  **Figure Q7**		

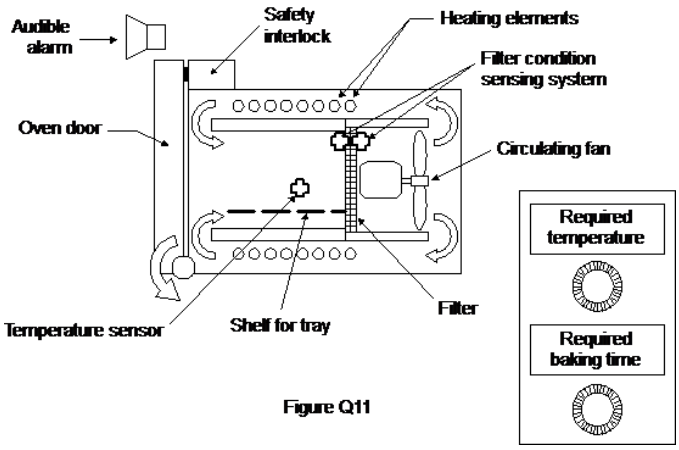
Question			Expected Answer/s	Max Mark	Additional Guidance
7	a		**Explain the basic operation of this type of encoder and describe the type of signal generated by this device. Illustrate your answer with a labelled sketch of a signal.** A beam is **transmitted** through the slotted area of the disc and passes to a **receiver** on the other side of the disc. As the disc rotates the beam is blocked by the solid sections but passes through the slots. This produces a pulsed beam and a **waveform** similar to that shown. The frequency of the pulsed beam can be calibrated into rotational speed/ distance. Or similar answer which includes a labelled sketch. 2 marks explanation 1 mark labelled sketch 	3	
7	b		**An encoder disk has 180 equally spaced slots and is rotated through 3 turns. State the count that would be accumulated in a counter if the initial count was zero.** Count = 180 × 3 = 540	1	
7	c		**It takes 1·5 seconds to accumulate the count in Q7(b), what is the rotational speed of the encoder in rpm?** Speed = $\frac{\text{Distance}}{\text{Time}} = \frac{3}{1{\cdot}5}$ = 2 rps × 60 = 120 rpm **OR** It takes 1·5 seconds to do 3 rotations 0·5 seconds to do 1 rotation 60 seconds to do 120 rotations (1 minute) per minute (rpm)	1	

Question			Expected Answer/s	Max Mark	Additional Guidance
8			 **Figure Q8** **Figure Q8 illustrates a simplified feed system for a recycling system controlled by a PLC.** • **When the feed system is in operation, the conveyor runs continuously and feeds material to the recycling system.** • **When the feed hopper sensor detects an empty hopper, Normally Closed contact X1 opens, the conveyor motor (Y1) will stop and the "EMPTY" indicator (Y2) will be illuminated.** • **Ladder Diagram Q8 shows the ladder diagram program. The first two rungs have been numbered for convenience.**  **Ladder Diagram Q8** **Describe the operation of the program in relation to the feed system, assuming initially:** • **the feed hopper is full;** • **the conveyor is running and;** • **the EMPTY indicator is not illuminated.** **Note: the inserted PLC Datasheet Q/6/Q8/Q12 gives the PLC instruction set.**	**5**	

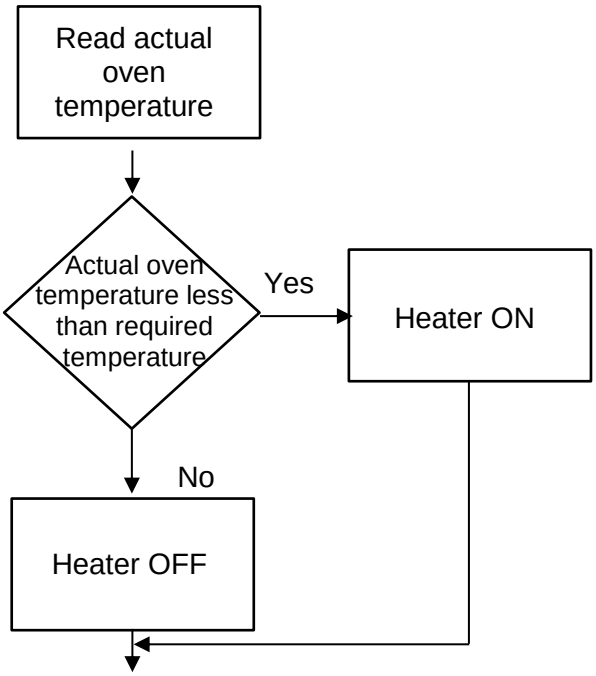
Question			Expected Answer/s	Max Mark	Additional Guidance
8			**(cont)** Normally Closed (NC) Contact X1 is closed if the hopper is NOT empty. This energises Y1 which runs the conveyor **(1)**. In Rung 2, while Y1 is energised, NC contact Y1 is open **(1)**, hence Y2 is not energised and the EMPTY indicator is not illuminated **(1)**. When the hopper becomes empty, X1 opens and Y1 is de-energised making the conveyor stop **(1)**. In Rung 2 when Y1 is de-energised, NC contact Y1 will be closed and Y2 will be energised turning the EMPTY indicator on **(1)**.		
9	**a**		**Sketch and label a basic block diagram of a closed loop control system.** Any suitable diagram such as the one below or similar that contains the key elements.	**2**	
					
9	**b**		**State how an open loop contol system generally differs from a closed loop control system when applied to the same process in terms of:**		
		i	**Accuracy;**	**1**	
		ii	**Complexity.**	**1**	
		i & ii	Open loop control systems are generally **less** accurate and **less** complex than closed loop control systems		
9	**c**		**State the main advantage of incorporating an integral element into a proportional control system.** An integral element introduced into a proportional control system has the effect of removing/reducing the steady state error/offset within a control system and thus the system output will settle closer to the desired value.	**1**	

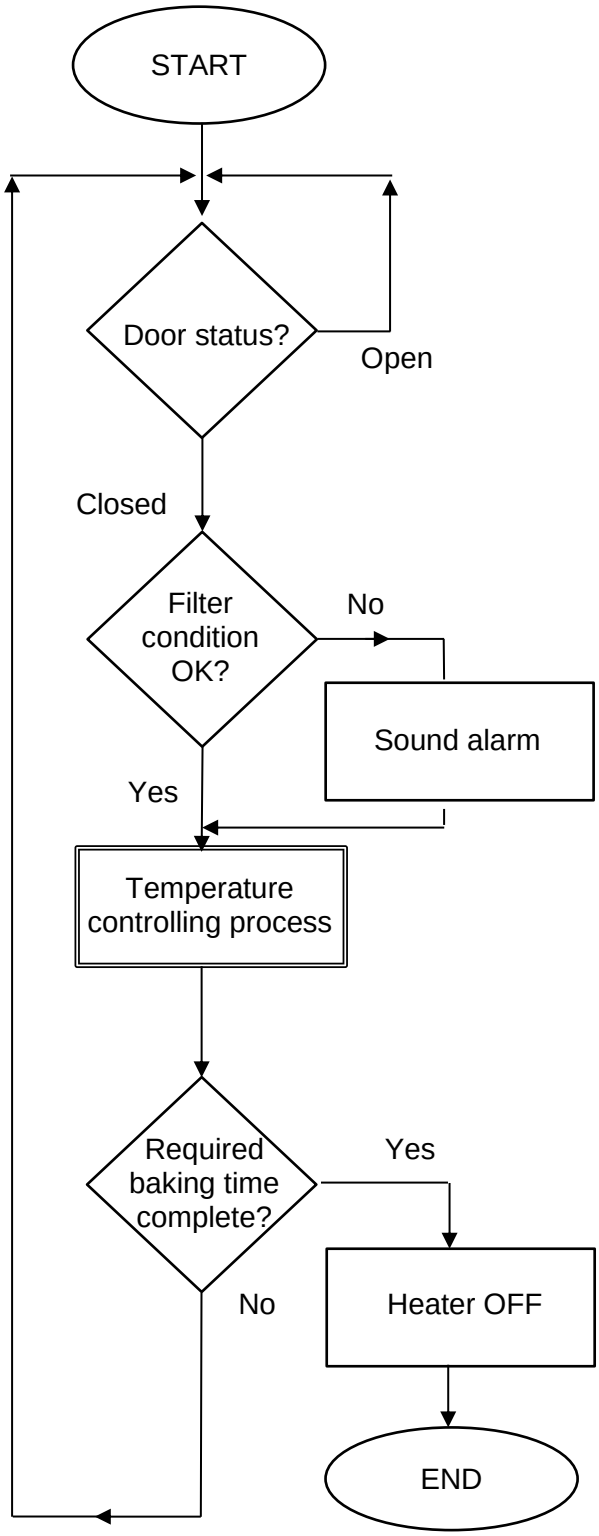
Question			Expected Answer/s	Max Mark	Additional Guidance
10			**This question consists of a series of multiple choice questions and answers for a number of mechatronic related themes. On Worksheet Q10, answer the multiple choice question by putting a tick ✓ in the correct box.**		
10	a		**A pneumatic based Mechatronic System** **A is maintenance free** ☐ **B uses compressible fluid** ✓ **C always provides linear motion** ☐ **D uses incompressible fluid** ☐ **E always provides rotary motion.** ☐	1	
10	b		**A PID control system** **A is an open loop system** ☐ **B has no feedback** ☐ **C provides closed loop control** ✓ **D runs with a large offset** ☐ **E uses ON/OFF control.** ☐	1	
10	c		**An absolute linear encoder system directly measures** **A pressure** ☐ **B flow** ☐ **C force** ☐ **D movement** ✓ **E temperature.** ☐	1	
10	d		**BCD is** **A a type of robot geometry** ☐ **B a type of pneumatic motor** ☐ **C a control strategy** ☐ **D a mechatronic actuator** ☐ **E a coding system.** ✓	1	
10	e		**A thermocouple is a device used to sense** **A time** ☐ **B heat** ✓ **C force** ☐ **D speed** ☐ **E light level.** ☐	1	

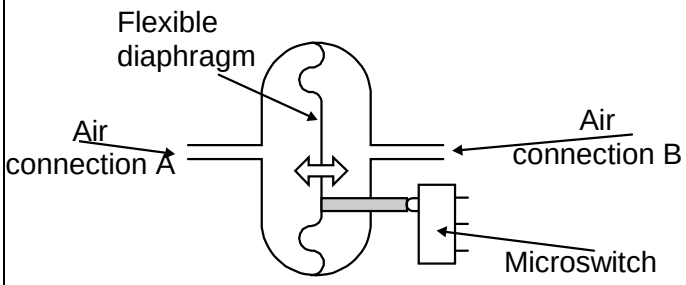
Section B

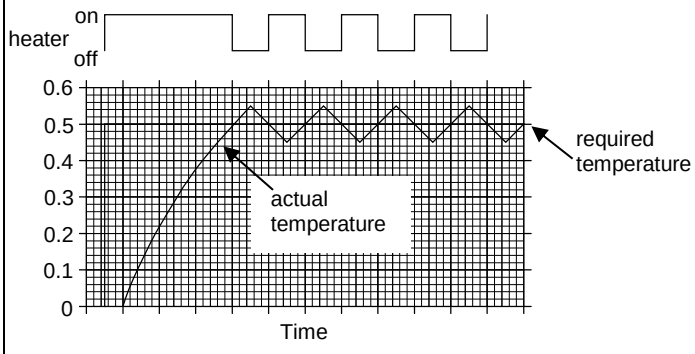
Question			Expected Answer/s	Max Mark	Additional Guidance
11			**Figure Q11 illustrated the main parts of a fan-assisted shortbread oven with circulating air flow as shown.**  Figure Q11 **A microcontroller is used to control the oven.** **The oven door has an independent safety interlock that provides a signal to the microcontoller to indicate the door status, "door open" or "door closed".** **The operator opens the oven door, places the shortbread tray on the shelf, selects the required baking time and required temperature and then closes the oven door.** **During oven operation, the temperature sensor informs the microcontroller of the actual oven temperature. The microcontroller uses ON/OFF control of the heating elements to control the oven temperature.** **The circulating fan runs constantly to ensure a continual flow of heated air.** **The filter condition sensing system detects the filter condition and provides a filter condition signal. The audible alarm is activated when the filter needs to be cleaned or replaced.**		

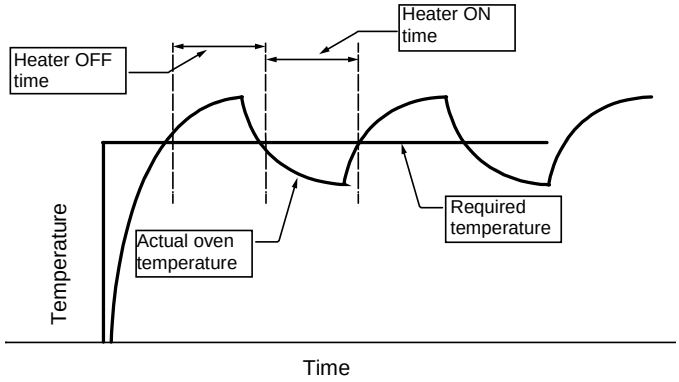
Question			Expected Answer/s	Max Mark	Additional Guidance
11	a	i	**Construct a table that clearly identifies all of the Input signals to the microcontroller.** **Inputs** Door status Temperature sensor Filter condition sensing system Required temperature Required baking time	4	
11	a	ii	**Construct a table that clearly identifies all of the Output signals from the microcontroller.** **Outputs** Audible alarm Heating elements Circulating fan **0·5 marks each**		
11	b		**Assuming the oven door is closed, sketch a flowchart which shows how the ON/OFF decision is made for the control of the heating elements during one cycle of operation of the "temperature controlling process".** **The flowchart should start with "read actRual oven temperature" and should use the signals:** • **required temperature and;** • **actual oven temperature.** **Note: the inserted Flowchart Symbol sheet Q2/Q11/Q12/Q13 gives a suitable selection of Flowchart Symbols.**	2	

Question			Expected Answer/s	Max Mark	Additional Guidance
11	b		**(cont)**  Or any other suitable flow chart 1 mark for decision, 0·5 for each heater ON/OFF box.		
11	c		**Sketch a flowchart which describes the overall operation of the oven which includes:** • **the door status signal;** • **filter condition check;** • **the "temperature controlling process" in Q11(b); (This should be shown as a single labelled box)** • **the duration of operation (required baking time) at the required temperature.** **Assume the circulating fan runs constantly and need not be shown on your flowchart.**	**5**	

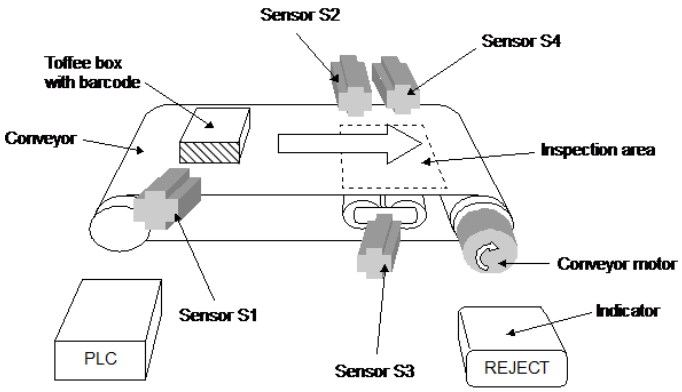
Question			Expected Answer/s	Max Mark	Additional Guidance
11	c		**(cont)**  Or alternative flowchart that provides a suitable functionality, eg Sound Alarm could be followed by "Stop system". 1 mark each decision, 0·5 mark for each action box, 1 mark correct positioning of "temperature controlling process" box = Total 5 marks		

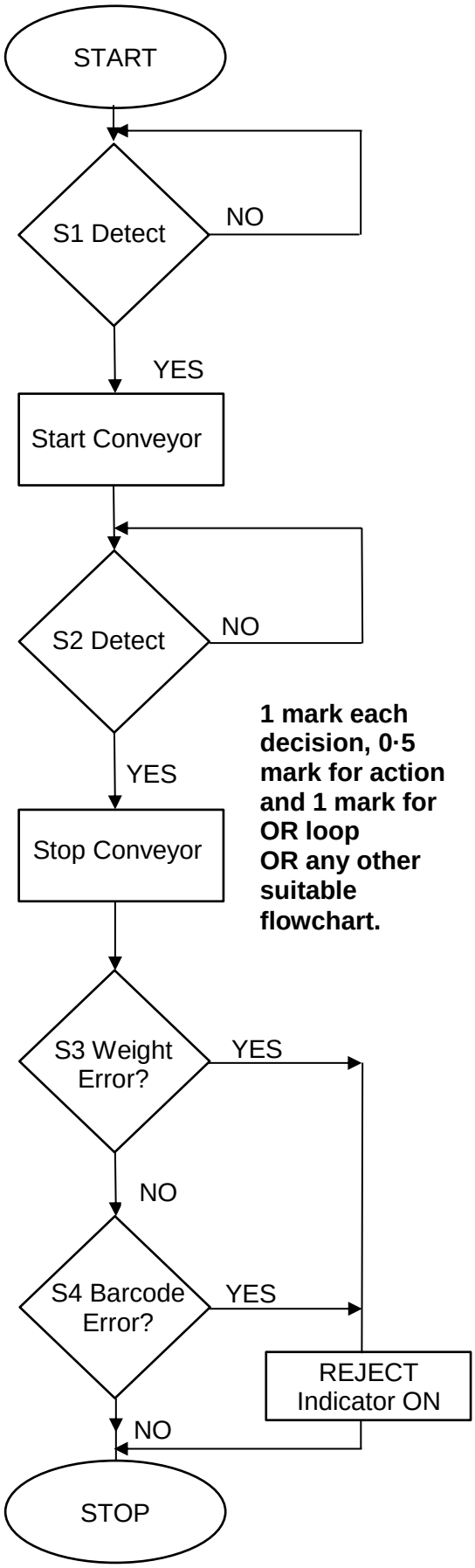
Question			Expected Answer/s	Max Mark	Additional Guidance
11	d		**Sketch and briefly describe a suitable differential pressure sensor that could be used in the filter condition sensing system.** Any suitable differential pressure sensor sketch and associated brief description.  1 mark In this differential pressure sensor, horizontal movement is produced in the flexible diaphragm by the differences in pressure between Air connection A and Air connection B. This movement is transmitted to a microswitch which can be calibrated to give a digital output when the different pressures across the filter element reached a preset value. This signal could be used to indicate that the filters required changing/cleaning. 2 marks Answer must include sketch AND brief description for 3 marks.	3	

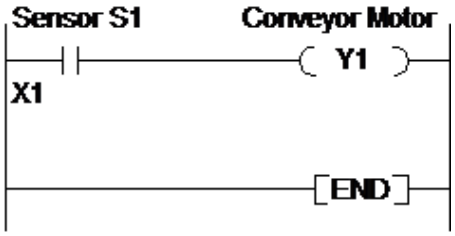
Question			Expected Answer/s	Max Mark	Additional Guidance
11	e		**The Microcontroller uses On/Off control of the heating elements to control the oven temperature. Describe with the aid of a sketch how the oven ON/OFF control operates. Your description and sketch should make reference to:** • **heater ON time** • **heater OFF time** • **required temperature** • **actual oven temperature.** A system using ON/OFF control of heating elements means that the power to the heaters is either fully on or fully off. When the **actual** oven temperature is less than the **required** temperature the power is supplied to the heating elements and they are fully on (Heater ON time). The heat produced by the elements causes the temperature to rise. When the **actual** oven temperature is more than the **required** temperature then power is NOT supplied to the heating elements and they are fully off (Heater OFF time). No heat produced by the elements which causes the temperature to fall. The sketch may vary considerably owing to the complex issues discussed below in the topic note. Examples include:  	**4**	

Question			Expected Answer/s	Max Mark	Additional Guidance
11	**e**		**(cont)** Alternatively  Topic note – candidates may include some of this information but it is NOT mandatory as the various interactions are complex and candidates at this level would not be expected to understand or provide these discussions.		
11	**f**		**The manufacturer wishes to improve the energy efficiency of the oven when there is no tray in the oven. This is to be achieved by ensuring that the heating elements' energy input is reduced to 20% of full power and the fan speed reduced to 10% of full speed.**		
11	**f**	**i**	**Briefly describe one method of reliably detecting when there is no tray in the oven.** Any suitable method of detecting when there is no tray in the oven that takes account of the likely fluctuating temperature and impaired visibility. A method such as using ultrasonic beams to detect the absence of the tray. Alternative method to weigh the load on the shelf where the tray would be placed. Note, a solution that failed to take account of the temperature variations or potentially impaired visibility (such as an infrared detector or optical system) would not earn full marks.	**2**	

Question			Expected Answer/s	Max Mark	Additional Guidance
11	f	ii	**Describe one method of reducing either the energy input to the heating elements or the speed of the circulating fan.** Any suitable method such as: Power: switch off 4 out of 5 elements (assumes each element has the same power rating) or switch off elements for 80% of the time. Fan Speed: reduce fan voltage (for information, it is NOT likely to reduce voltage to 10% of normal as response often non-linear and some fans will not work with a very low voltage) or use PWM (Pulse Width Modulation) on fan.	3	
11	g		**State one hazard in this system and briefly describe how this hazard could be overcome.** Any suitable hazard and way of overcoming the hazard such as the following: It may be possible to touch the heating elements – provide cover or grill to stop this. No indication when oven hot – provide indicator to show heaters on. No indication when oven hot – provide indicator to show oven temperature. No overall ON/OFF button – provide overall ON/OFF button. Heat still on when door opens – link heaters and fan to door opening sensing. 1 mark for the hazard, 1 mark for the solution.	2	

Question			Expected Answer/s	Max Mark	Additional Guidance
12			**Figure Q12 shows an inspection system controlled by a PLC.**  Figure Q12 **The system operates as follows.** • **The conveyor is initially stopped with no box present.** • **When a toffee box is loaded, Sensor S1 sends a "Box loaded" signal to the PLC.** • **The PLC then starts the conveyor which should carry the box to the Inspection area.** • **When the box is in the Inspection area Sensor S2 sends a "Box Present" signal to the PLC.** • **The PLC stops the conveyor when it receives the "Box Present" signal.** • **If the weight of the box is unacceptable, Sensor S3 sends a "Weight Error" signal to the PLC.** • **If the barcode is incorrect, Sensor S4 sends a "Barcode Error" signal to the PLC.** • **If either the "Weight Error" or the "Barcode Error" signal is received then the "REJECT" indicator is illuminated by the PLC.** **A separate handling system loads each box.**		
12	a		**Sketch a flowchart which shows the operation of the system. Start with the initial conditions:** • **Conveyor stopped;** • **Conveyor empty.** **Note: the inserted Flowchart Symbol sheet Q2/Q11/Q12/Q13 gives a suitable selection of Flowchart Symbols.**	**6**	

Question			Expected Answer/s	Max Mark	Additional Guidance
12	a		**(cont)**  **1 mark each decision, 0·5 mark for action and 1 mark for OR loop OR any other suitable flowchart.**		

<table>
<tr><th colspan="3">Question</th><th>Expected Answer/s</th><th>Max Mark</th><th>Additional Guidance</th></tr>
<tr><td>12</td><td>b</td><td></td><td>With reference to the initial Ladder Diagram Q12(b), briefly explain why a box loaded at Sensor S1 will NOT reach the inspection area and Sensor S2.
 

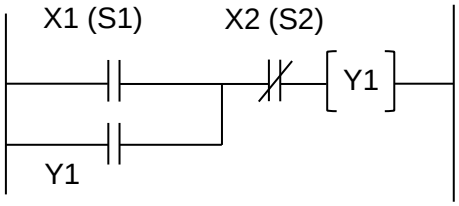
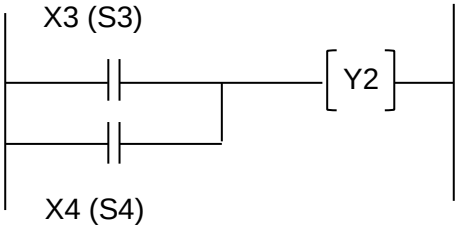
Ladder Diagram Q12(b)

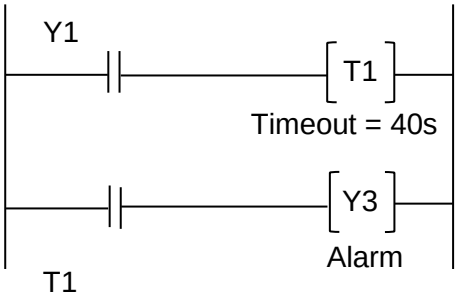
Note: the inserted PLC Datasheet Q6/Q8/Q12 gives the PLC instruction set.

Sensor S1 (X1) will activate Y1 (1) starting the conveyor and moving the box.
Sensor S1 (X1) will deactivate (1) as soon as the box moves away towards S2 and before reaching the Inspection area.</td><td>2</td><td></td></tr>
<tr><td>12</td><td>c</td><td></td><td>Produce a table which shows the PLC I/O allocation for the inspection system shown in Figure Q12.

<table>
<tr><th>Inputs</th><th>Outputs</th></tr>
<tr><td>X1 = S1 box loaded</td><td>Y1 = Conveyor</td></tr>
<tr><td>X2 = S2 box present in Inspection area</td><td>Y2 = Reject indicator</td></tr>
<tr><td>X3 = S3 weight error</td><td></td></tr>
<tr><td>X4 = S4 barcode error</td><td></td></tr>
</table>
6 × 0·5 marks each = total 3 marks

Note: X1 and Y1 defined by part (b) above is the logical allocation for the remaining contacts but alternatives are possible and if chosen may change the answers to parts (d), (e) and/or (f).</td><td>3</td><td></td></tr>
</table>

Question			Expected Answer/s	Max Mark	Additional Guidance
12	d		**Redraw the initial Ladder Diagram Q12(b) showing how it could be modified to ensure that the conveyor motor continues to run until the box is detected in the inspection area.**  No explanation needed, only a correct ladder diagram needed.	**2**	
12	e		**Add another rung to your ladder diagram which reads the "Weight Error" and "Barcode Error" signals to produce the required output for the "REJECT" indicator.** The additional rung is shown below.  No explanation needed, only a correct ladder diagram rung needed.	**3**	
12	f		**It normally takes a box 30 seconds to travel from Sensor S1 to Sensor S2. As an upgrade to the existing system, an audible alarm, Y3, is to be activated if a box has not arrived at S2 after 40 seconds.** **Sketch a ladder diagram that includes only this upgrade and briefly describe its operation – there is no need to redraw other parts of the ladder diagram that remain unchanged.**	**4**	

Question			Expected Answer/s	Max Mark	Additional Guidance
12	**f**		**(cont)**  Or other suitable ladder diagram with correct functionality. Note: Y1 here could NOT be S1 unless there are additional elements because of the problem identified in Q12(b). Appropriate description to match the ladder diagram supplied. Exemplar brief description – when S1 is activated and Y1 (the conveyor is started and latched) then a timer T1 with a 40 second timeout is started. This timer will continue to increase while the conveyor is running. If S2 is reached then X2 will de-activate, the rung will be broken and Y1 will de-activate which resets the timer. If however T1 counter reaches 40 seconds then contact T1 in the next rung operates Y3 the alarm. Ladder diagram = 2 marks. Associated brief description = 2 marks.		
12	**g**		**State a suitable type of sensor for use as Sensor S1.** Any suitable sensor such as an optical beam which is interrupted by the box.	**1**	

Question			Expected Answer/s	Max Mark	Additional Guidance
12	**h**		**Identify two safety hazards inherent in the entire inspection system and state how each safety hazard could be reduced.** Any **two** appropriate inherent safety hazards with their associated ways of reducing the hazards. Exemplar answers - Auto start & stop is a potential hazard – this can be reduced by machine starting announcements. Auto start & stop is a potential hazard – can be reduced by personnel isolation system. There is no "PLC independent" way of stopping the conveyor – hazard can be reduced by fitting an emergency stop button. No control on the number of simultaneous boxes on the conveyor – hazard can be reduced by additional sensor and PLC program enhancement. 2 marks for hazards and 2 for reduction methods.	**4**	

Question			Expected Answer/s	Max Mark	Additional Guidance
13			**Figure Q13 illustrates a powder coating system in which domestic radiators are manually loaded onto the overhead linear conveyor. The radiators come in three sizes (small, medium and large). The radiators move through the various work sections and are then manually uploaded as a coated product.**		

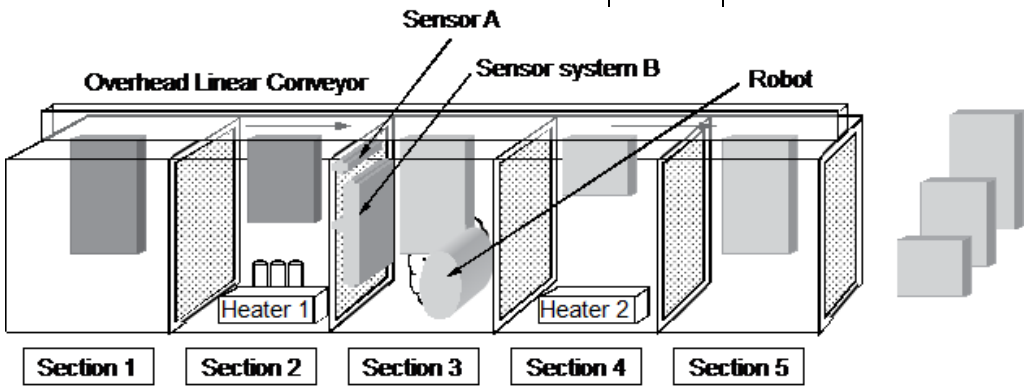


Figure Q13

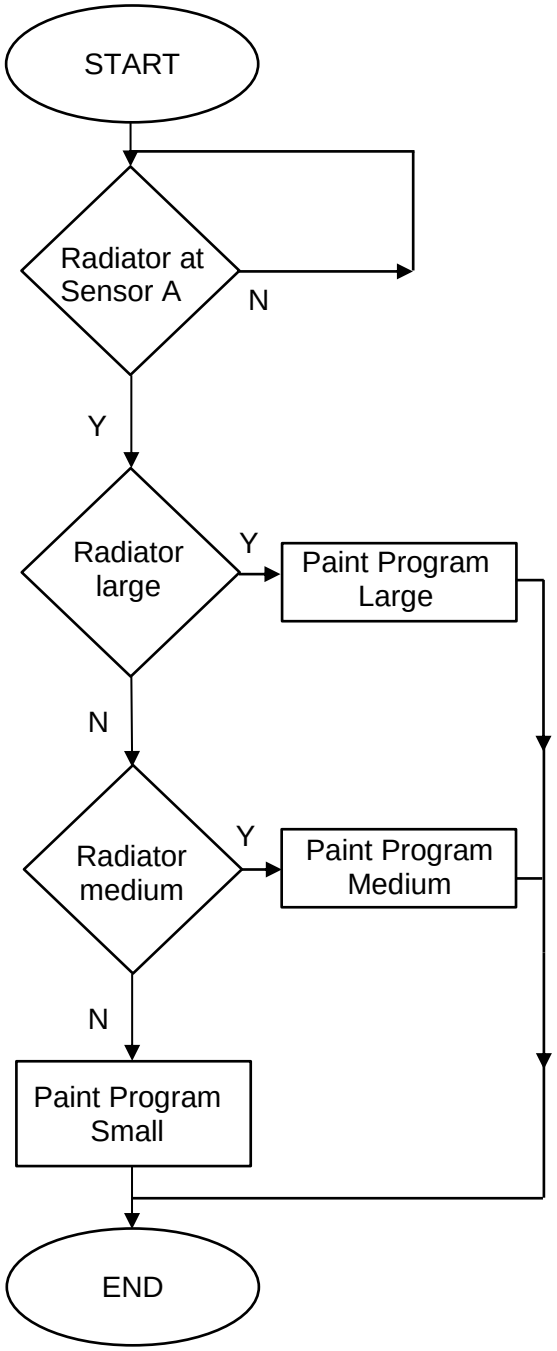
The overhead linear conveyor runs continuously at a constant speed. Closed loop control ensures the overhead conveyor speed remains constant regardless of how many radiators are loaded on or unloaded from the conveyor.

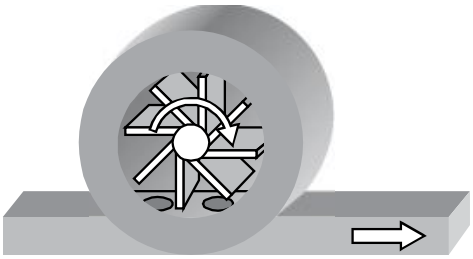
- **In Section 1 (load area), each radiator is manually loaded onto the overhead linear conveyor.**
- **In Section 2 (clean and dry), each radiator is preheated to 35°C and is cleaned by blasting it with compressed air.**
- **In Section 3 (powder coat), Sensor A detects the arrival of a radiator. Sensor system B detects the radiator size and this information is used to decide which one of three coating programs is to be carried out by the robot. the radiator is powder coated by the automated robot.**
- **In Section 4 (dry and cure), the coated radiator spends 5 minutes at 85°C where the coating hardens and dries.**
- **In Section 5 (unload area), the radiators are manually unloaded and are collected in batches for transportation to the final baking ovens (not shown).**

Question			Expected Answer/s	Max Mark	Additional Guidance
13	a		**State and briefly describe one type of sensor which would be appropriate for sensing the speed of the overhead linear conveyor.** For example: a linear encoder installed on the conveyor belt system with a suitable optical sensor and signal conditioning system could be used. The linear conveyor would be constantly moving producing a pulse waveform from the encoder which could be used to sense the linear belt speed. Or any other suitable sensor capable of sensing speed and associated brief description. 1 mark for stating sensor, 2 marks for brief description of stated sensor.	3	
13	b		**Briefly explain two safety hazards associated with this system and describe how they could be minimised or resolved at the design stage.** Any suitable two safety hazards and associated minimisation/resolution measures. Exemplar answers include: • There are fire hazards associated with heat in the various sections – the system could be fitted with a fire detection system to sound an alarm and automatically shut down the system. • There are hazards to people in the robot section due to the automatic movement of the robot – the robotic section should be fitted with a key-lock entry system to ensure no unauthorised entry during operation. • Radiators are not monitored in most sections – add sensors to ensure radiators have not fallen off the conveyor or got stuck somewhere. 2 marks for hazards, 2 marks for associated minimisation/resolution measures.	4	

Question			Expected Answer/s	Max Mark	Additional Guidance
13	**c**		**The rotary position of one axis of the robot used in Section 3 is sensed using an optical rotary encoder which uses an 8 bit Gray code.**		
13	**c**	**i**	**Calculate the resolution in degrees for this Gray code if the 8 bit code is distributed evenly over the full 360 degrees of the encoder disc.** $2^8 = 256, \quad \frac{360}{256} = 1 \cdot 41$ degrees or $\pm 0 \cdot 7$ degrees	**2**	
13	**c**	**ii**	**State one suitable robotic drive system and give two reasons, other then cost, that justify your choice.** Any suitable example of a robot drive sysyem with justified reasons. Exemplar answers - An electrical drive system could be used as the power supply is readily available and they require less maintenance than pneumatic/hydraulic systems. 1 mark for drive system, 2 marks for appropriate reasons.	**3**	
13	**d**		**The robot programs were created using a "lead-to-nose" technique. Describe this method of programming robots and justify its suitability for this application.** "Lead by nose" is where the robot is manually taught the task and this is recorded on the robotic system and this recorded program can be retrieved and played back when required. "Lead by nose" is an appropriate method as the actions of a skilled worker are passed to the robot using minimal programming. Or any other suitable description of "lead by nose" programming and suitable justification of the method. 2 marks for description of "lead by nose" programming, 1 mark for justification of this application (powder coating spraying).	**3**	

Question			Expected Answer/s	Max Mark	Additional Guidance
13	e		**Sensor system B in Section 3 (powder coat) is used to detect the size of each radiator. Briefly describe the operation of a suitable sensing system stating the sensors being used.** A variety of solutions are possible. Exemplar answer: Sensor A detects radiator presence. It would then be possible with only two height sensors (light beams) and then rely on simple logic to detect the radiator size. The light beam sensors would need to be able to work in the spray environment but as the powder coat process is quite clean and the robot only powder coats after the radiator has been identified, this type of sensor would be appropriate. **OR** Three light sensors set at the correct height could be used to detect the radiator sizes. If only the higher sensor beam is broken then it is a small radiator requiring powder coating. If only the upper two sensor beams are broken the radiator is medium sized and if all three are broken then it is a large radiator. Other alternatives – a barcode system could be used. The weight of the radiator detected. Electronic labels could be used. 3 marks for solution that takes account of the environment and radiator size and nature.	**3**	
13	**f**		**Describe the operation and process decisions carried out as a radiator passes through Section 3 (powder coat). Start your description with the radiator entering Section 3 and make reference to your sensing system chosen in Q13(e). Either a written descriptive answer or Flowchart can be used.** **Note: the inserted Flowchart Symbol sheet Q2/Q11/Q12/Q13 gives a suitable selection of Flowchart Symbols.**	**3**	

Question			Expected Answer/s	Max Mark	Additional Guidance
13	f		**(cont)** Either a written solution or a flowchart would be acceptable. Logic must be correct and the solution may be sensitive to the answer given in Q13(e).  		

Question			Expected Answer/s	Max Mark	Additional Guidance
13	g		**A sensor is required to monitor the flow rate of the powder being fed to the robot during the powder coating process in Section 3.** **State and describe with the aid of a sketch a suitable sensor.** Any suitable flow sensor with associated description and sketch. Example solution shows a paddle wheel sensor. The flow turns the paddle wheel which in turn outputs a signal proportional to the flow rate. Or similar suitable description.  1 mark for the type, 3 for description and diagram.	4	

[END OF MARKING INSTRUCTIONS]