2008 Mechatronics

Higher

Finalised Marking Instructions

1 (a)

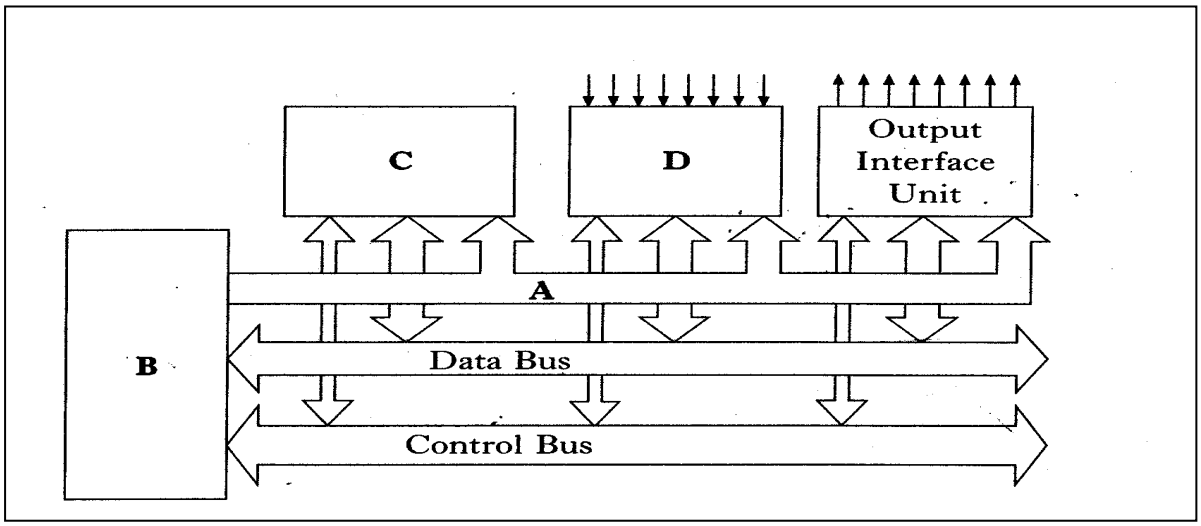


Figure Q1(a)

Label	Name of element
A	**Address Bus**
B	**CPU or Central Processing Unit or Processor**
C	**Memory**
D	**Input Interface Unit**

Table Q1(a)

4 answers @ 0.5 mark each **2**

(b) Any 2 answers from the following – Reprogrammable, user interface, modular design, easily upgraded, easily replaced, does not require rewiring.

Or any other suitable answers.

2 answers @ 1 mark each **2**

(c) **Editor** enables the inputting and changing of program files.

Or any other suitable answers. **1**

2. **(a)**

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

4 entries @ 0.5 marks each **2**

(b) 3 dimensional swept volume of the robotic arm (without the end effector fitted). Use of term "area" without further information or diagram to show 3 dimensional nature will not gain full marks

Or any other suitable answers. **1**

(c) Any two from – relatively low cost, various power/speeds available, clean/leak free, readily available power sources, accuracy, repeatability under different loads, easily interfaced/controlled.

Or any other suitable answers.

2 reasons @ 1 mark each **2**

3. **(a)** Any two from – positional accuracy, high power/weight ratio, positional control.

Or any other suitable answer.

2 reasons @ 1 mark each **2**

(b)

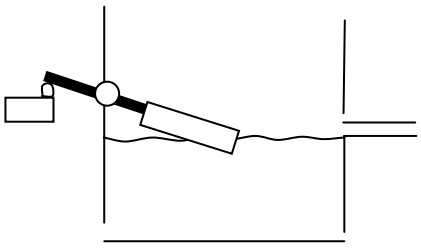
Decimal	**Code Name = Binary** or **Pure Binary** or **Natural Binary**	BCD
0	0000	0000 0000
1	0001	0000 0001
2	0010	0000 0010
3	0011	0000 0011
4	0100	0000 0100
5	0101	0000 0101
6	0110	0000 0110
7	0111	0000 0111
8	1000	0000 1000
9	1001	0000 1001
10	1010	0001 0000
11	1011	0001 0001
12	1100	0001 0010
13	1101	0001 0011
14	1110	0001 0100
15	1111	0001 0101

Table Q3b

1 mark for code name + 4 table entries @ 0.5 marks = 1 + 2 = 3 marks **3**

4. **(a)** Float Type Sensor, optical, capacitive, ultrasonic or other suitable liquid level sensor. **1**

(b) Suitable description such as that for float sensor – As level rises/drops float assembly moves and micro switch is activated, thus the level is detected.



Or any other suitable answers to match chosen sensor type.

1 mark sketch, 1 mark for description **2**

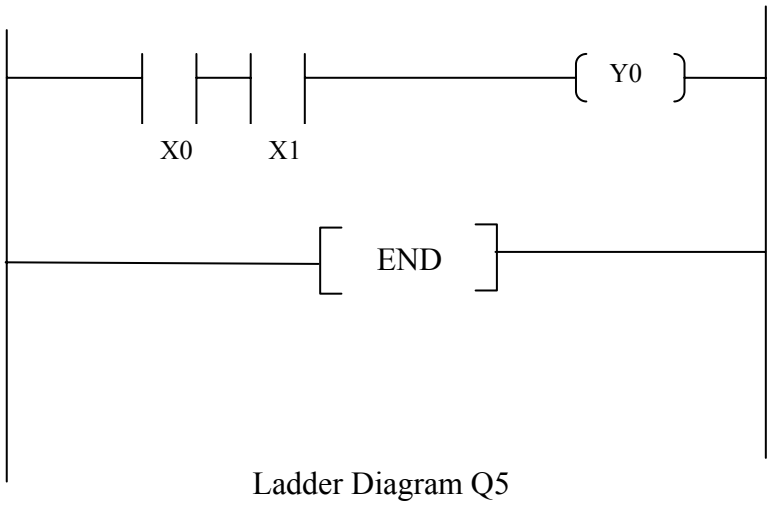
(c) Fuel storage tank level control – the change in level detected can be used to open and close valves to maintain the level.

Or any other suitable answers to match chosen sensor.

1 mark for application, 1 mark for reason **2**

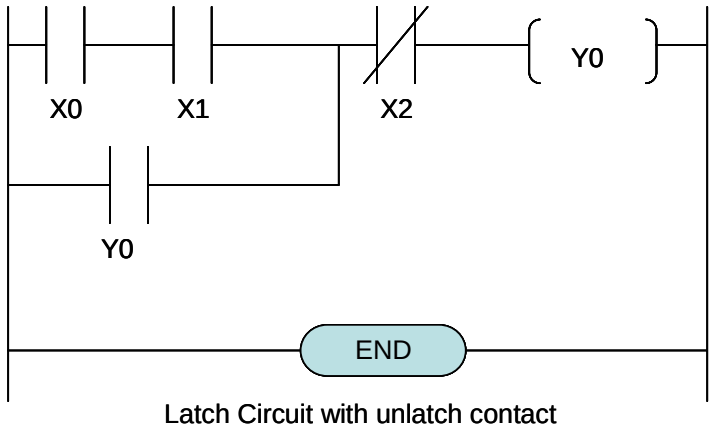
5. **(a)** When Inputs X0 **AND** X1 are activated then this activates output Y0, this gives the **AND** logic function.

Or any other suitable answers. **1**



Ladder Diagram Q5

(b) Diagram of standard latch circuit with Y0 NO contact in parallel with both X0 and X1 and X2 NC contact just to the left of Y0 output to enable switch off.



Latch Circuit with unlatch contact

Or any other suitable answers.

4 x 0.5 marks **2**

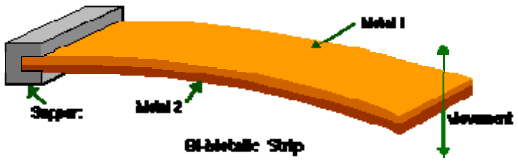
(c) Normally closed (NC) contact is normally closed until it is activated when it becomes open.

Or any other suitable answers. **1**

(d) A memory/auxiliary output (M) is similar to a normal Y output contact except it does not have any external electrical connections and cannot be physically connected to.

Or any other suitable answers. **1**

6. **(a)** 2 metals with different expansion co-efficient are joined to form a metallic strip. When subjected to a temperature change the different expansions cause the strip to bend, this movement can be detected or electrical contacts opened/closed.

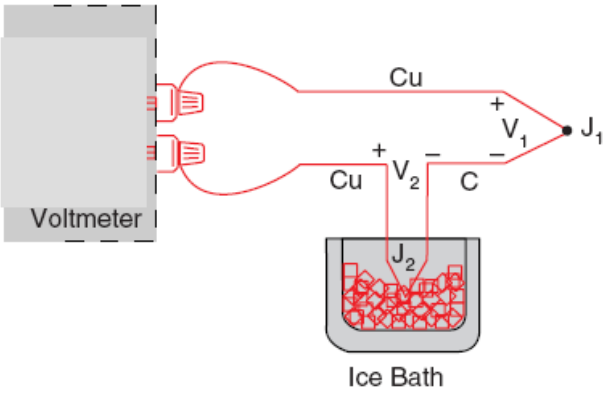


A thermocouple consists of a small bead of two different metals welded together, this junction causes a small voltage (mV) to be produced (Zeebeck effect). This small voltage is proportional to the junction temperature and thus is an indication of the temperature produced.

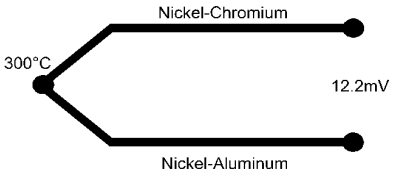
+simple sketch

Or any other suitable answers.

1 mark for properties, 1 mark for operation and 2 marks for diagram **4**



or



Note: diagrams shown are of a fairly complex version which, in the case of the thermocouple, has the reference ice bath and specific metals. Solutions do NOT need to show this level of complexity but its inclusion should not of course be penalised.

Or any other suitable answers.

1 mark for properties, 1 mark for operation and 2 marks for diagram

(b) Suitable application.

For bimetallic sensor providing 'on/off control' for central heating.

Or for thermocouple used on oven temperature control.

Or other appropriate answer. **1**

7. **(a)** **(i)** Closed loop is MORE complex than open loop. **1**

(ii) Closed loop is MORE accurate than an open loop (because of feedback). **1**

(b) **(i)** Stepper motor uses dc pulses in a pair of coils to provide rotation through a known angle for each pulse. The next pulse through a different pair of coils provides further rotation. A whole series of pulses can produce rotation. Knowing which coils are receiving pulses and their rate can control motion (by how much rotated and at what speed).

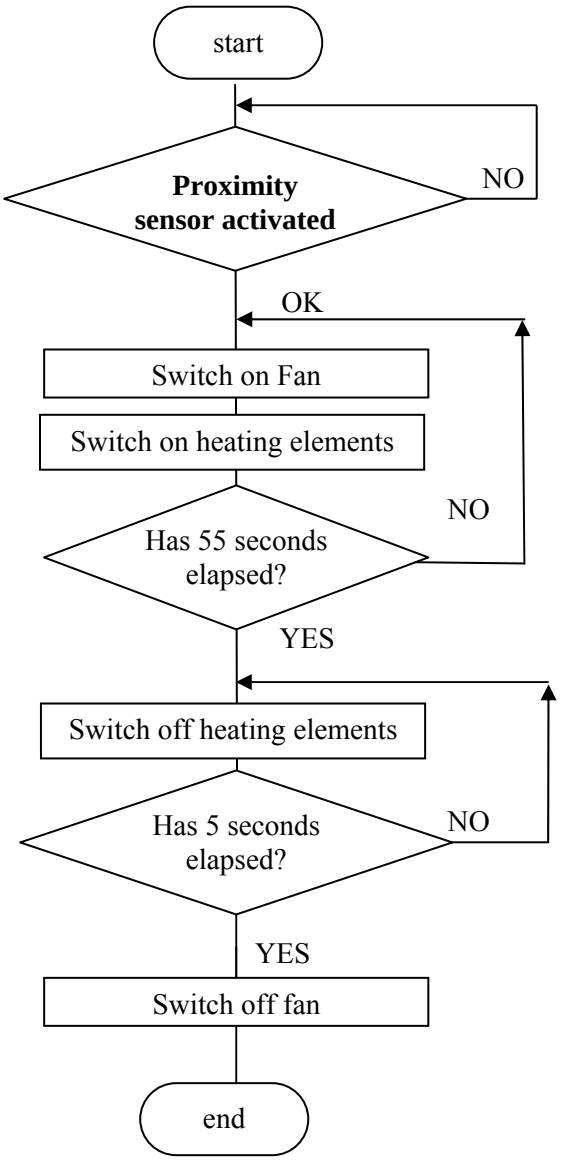
Note: the detailed variations introduced by permanent magnet or variable reluctance stepper motors is NOT required. Neither is any reference to driver circuits or chips. The inclusion of such material should NOT be penalised.

Or any other suitable answers. **2**

(ii) Stepper motors are open loop because they rotate a known angle for each pulse and there is normally no need for feedback to check how far the motor has rotated – the system is therefore without feedback and provides open loop control (provided the working load is not exceeded).

Or any other suitable answers. **1**

Question 8



Or any other suitable answers.

Note: flowcharts can have either an "end" or a loop back to beginning – either is acceptable. Timers can be as shown or other variations are possible including one where there is a "start timer" action box. The "NO" loop backs on the decision boxes can go back to a number of acceptable points in the program. The time for the fan can be 55 seconds or 60 seconds depending on looping arrangements.

Note: this year the suggested flowchart symbols are given so these (or more complex equivalents) should be expected and any candidate answering using incorrect box types should be penalised.

Decision boxes @ 1 mark each = 3 marks
Action boxes @ 0.5 marks each = 2 marks **5**

9. **(a)** Each tooth represents a given rotation of the wheel. If the number of teeth is known and the number of pulses are counted in a given period then

$$\text{Speed of wheel} = \frac{\text{Number of pulses}}{\text{Number of teeth x time}}$$

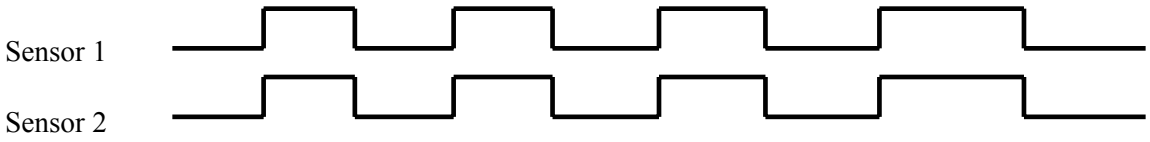
Or any other suitable answers. **2**

(b) See Worksheet.

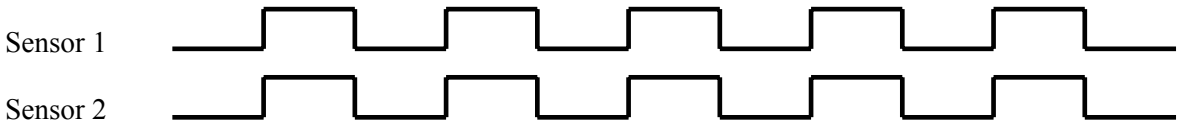
Four waveform diagrams illustrate various sensor outputs when the car is moving forward in a straight line. Complete the Table Q9b to indicate the waveform that shows: **3 (1 per waveform)**

Car Movement	**Waveform showing sensor outputs (A, B, C or D)**
i. Constant speed	B
ii. Car accelerating	D
iii. One wheel locking	C

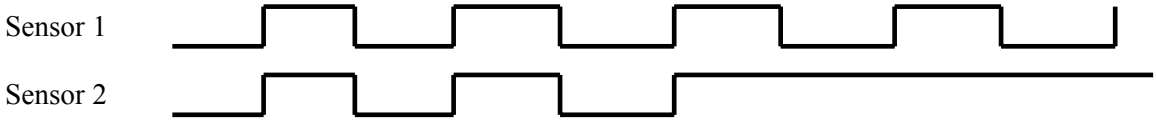
Table Q9b



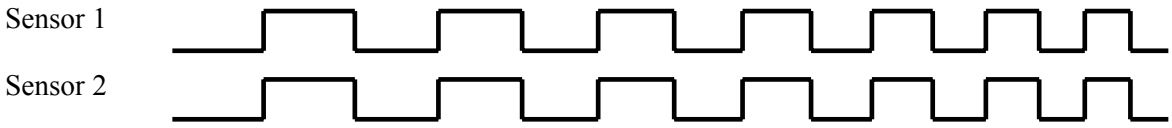
Waveform A (not used = decelerating)



Waveform B = Constant speed



Waveform C = One wheel locking



Waveform D = Accelerating

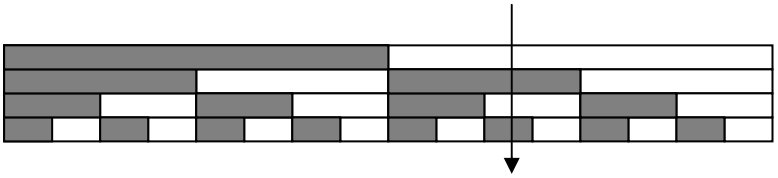
10. **(a)** 12 bit code = 2^{12} values = 4096

resolution = $\frac{400}{(4096 - 1)}$ mm (note $\frac{400}{4096}$ mm also acceptable)

= 0.09768mm or ± 0.04884 mm ≈ 0.1 or ±0.05 mm **2**

(b) Statement C is true no explanation of choice required (rationale is that as the above calculation would show a 800 on the top and a resolution twice as big which is worse than the 400 mm axis.) **1**

(c) Suitable description of linear encoder with 12 bits such as – A series of at least 12 linear strips are laid down over the whole axis (800mm in one case). These strips then have some areas opaque (does not allow light through) whilst others are transparent. This is the way the code is built up.



Code here is 0101 (reading top to bottom)

Here is a 4 bit (binary) version. Opto-detectors (one per track) can then detect the position.

Note: the diagram is NOT essential.

Or any other suitable answers. Answers showing just a single set of serial holes would be unlikely to provide sufficient resolution. **2**

11. **(a)** Reflective LED sensor that consists of a transmitter and receiver. Increased light is reflected back when fingers/hand come into proximity of beam and a logic signal is produced.

Or

Ultrasonic detector senses the presence of fingers/hands by receiving back an increased proportion of the ultrasonic signal being sent out. This then produces a logic signal output.

Or any other suitable answers.

1 mark for selection, 2 marks for description **3**

(b) Inputs –

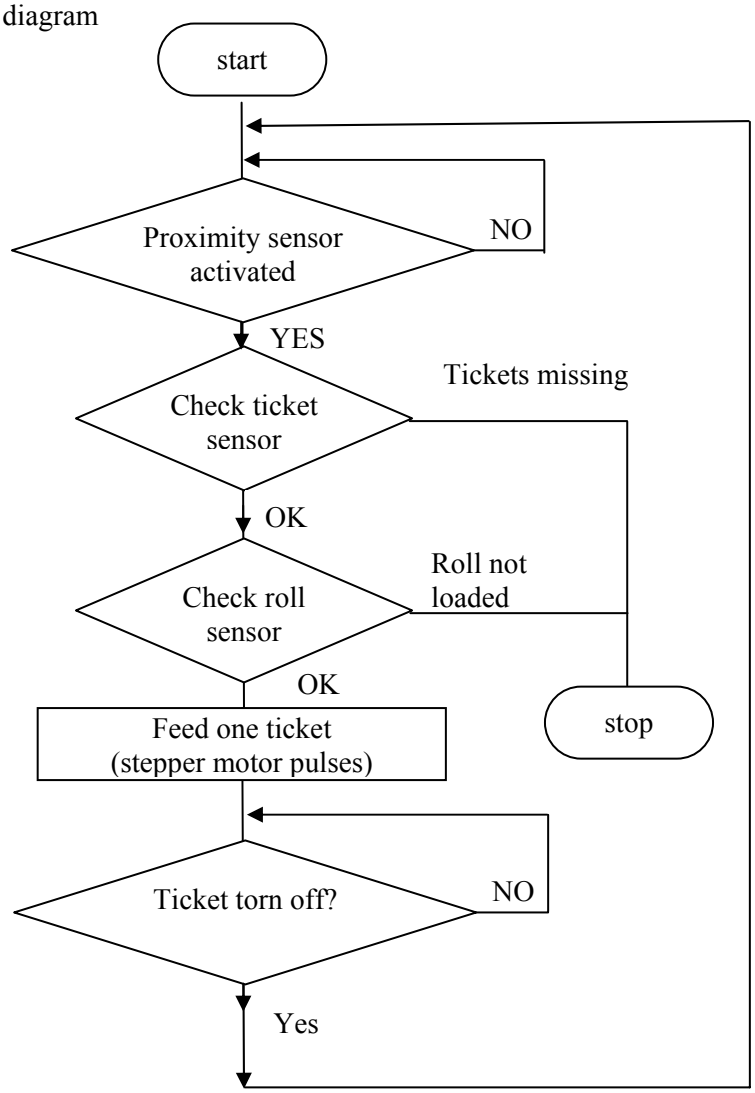
Input	**Example Sensor**	**(Comments)**
Roll Sensor	Microswitch	Senses when the roll is present
Ticket Sensor	Light curtain or microswitch	Senses when tickets have been loaded
Ticket torn off sensor	Light sensor	Senses whether ticket has been torn off

Note: comments column NOT required.

Or any other suitable answers.

1 mark for each input + 1 mark for suitable sensor * 3 sensors **6**

(c) Flow diagram



Note: flowcharts need not have an overall loop back to beginning but if this is included then this must enter before the proximity sensor check. The Check Ticket and Check Roll can be in either order and may be placed earlier in cycle.

Or other suitable flowcharts.

Note: this year the suggested flowchart symbols are given so these (or more complex equivalents) should be expected and any candidate answering using incorrect box types should be penalised.

4 Decision boxes @ 1 mark each = 4 marks
2 Routing Decision boxes to STOP @ 0.5 marks = 1 mark
Action box including reference to stepper motor @ 1 mark each = 1 mark **6**

(d) Any two suitable reasons for the choice of 24v stepper motor such as – good positional control ie 1 pulse = 1.5 degree rotation, can be relatively small and be fitted directly onto shaft, can be used with open loop control strategy (less complex), can have holding detent to prevent ticket roll unravelling.

Or any other suitable answers.

1 marks per reason **2**

(e) A counter could be included that (counts the tickets (150 on roll), sprocket holes or the stepper motor pulses). The counter could be reset when a new roll is added and a counter made to count up or down when a ticket is removed. When the required number is reached the roll low warning light could be illuminated.

Note: practical systems that measure the roll diameter using a microswitch or optically or weighing the roll (and carrier) would be unlikely to have sufficient accuracy and repeatability to detect between say 10 and 11 tickets and so could not be awarded full marks.

Or any other suitable answers. **4**

(f) **(i)** Any two suitable safety issues such as – Sharp edges (perforation strips), moving parts coming into contact with fingers, voltages within equipment, fault conditions, the system might move when a new ticket roll is being loaded.

Or any other suitable answers.

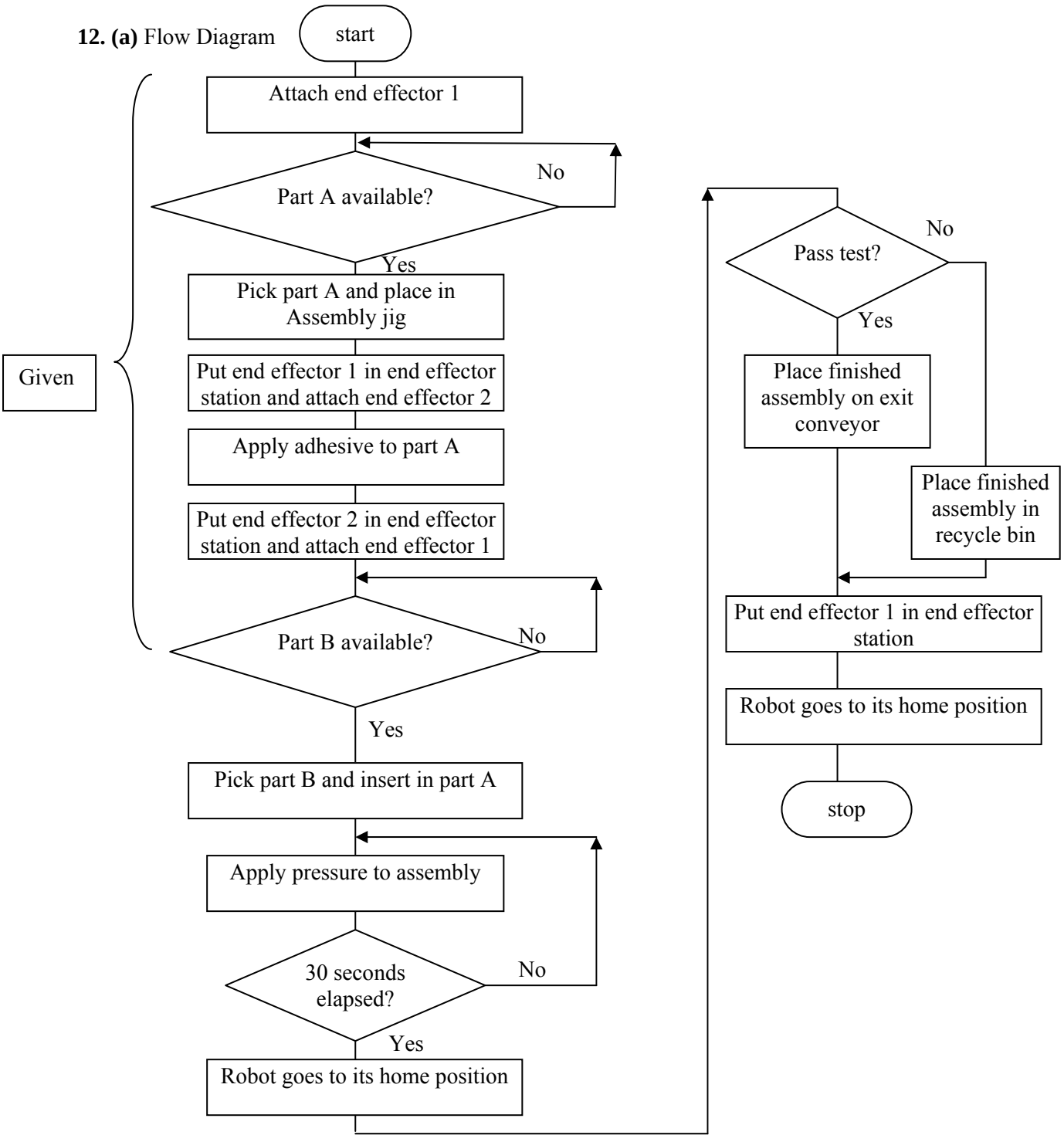
2 issues @ 1 mark each **2**

(ii) Any two ways of overcoming the <u>chosen</u> safety issues such as – (sharp edges) shield sharp edges, (moving parts) shield or guard to prevent contact with fingers, (voltages within equipment) design with low voltages, limited power and earthing or double insulated, (fault conditions) ensure fail-safe operation, (system movement when loading ticket) the system should be interlocked to prevent movement when a new ticket roll is being loaded.

Or any other suitable answers.

2 ways of overcoming issues @ 1 mark each **2**

12. (a) Flow Diagram



Note: flowcharts may just test for parts rather than individual parts. Some boxes may be subdivided further such as Put end effector 1 in end effector station and attach end effector 2. Also parts testing could go to a stop rather than looping.

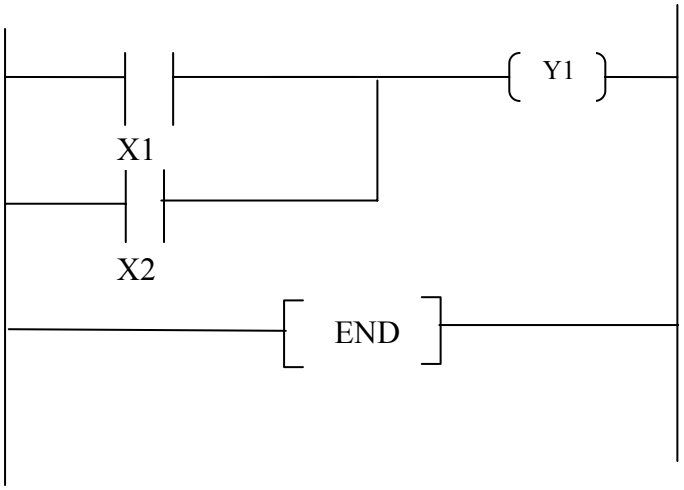
Note: this year the suggested flowchart symbols are given so these (or more complex equivalents) should be expected and any candidate answering using incorrect box types should be penalised.

Or other suitable flowcharts.

2.5 Decision boxes @ 1.0 mark each = 2.5 marks
7 Action boxes @ 0.5 marks each = 3.5 marks **6**

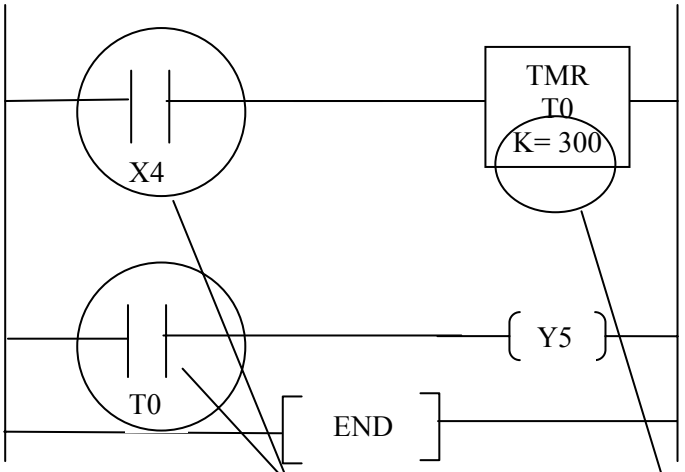
(b) Ladder diagram showing the **OR** function.

Or other suitable answer



1 mark for OR function, 1 mark for Inputs inc correct labels
1 mark for Outputs inc correct labels **3**

(c)



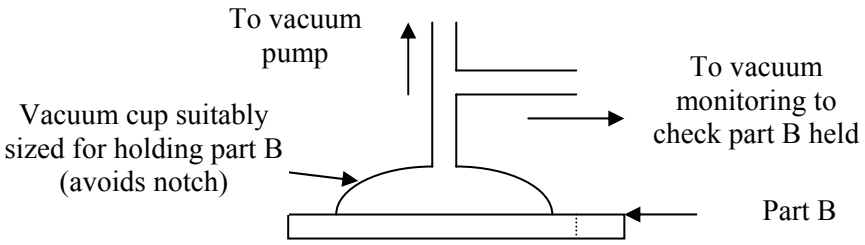
Ladder Diagram Q12(c)

Or other suitable ladder diagram.

Variations owing to different timer connection (often based on manufacturers' variations) should NOT be penalised.
The K value comes from the datasheet

1 mark X4, 1 mark T0 contact, 1 mark K=300 **3**

(d) Sketch of vacuum gripper – sucker with vacuum supply picking up flat parts. Various methods for monitoring if part present including monitoring the vacuum: vacuum = part held, loss of vacuum = part not held (as shown below), microswitch or optical. Note that only a sketched diagram is required (with clarifying labels if ambiguous) and no accompanying description is needed.



Or other suitable answer.

2 marks vacuum gripper, 2 marks part detection **4**

(e) A series of visual checks to show if correctly located and bedded in or an electronic vision system (camera based) could be used to observe if the part was correctly positioned ie the placed image would be compared with a database and if within an allowable tolerance the part would be categorised as a pass. Considerable ingenuity may need to be shown to produce a practical solution and marks awarded should take account of potential practicality without penalising unstated assumptions.

Or any other suitable answers. **3**

(f) A force sensor in the robot arm or the assembly jig to monitor pressure (or force) applied.

Or any other suitable answers. **3**

(g) Example solution. Each end effector could be coded in some way (some electrical connections, projections to operate switches, magnetic code). This code could be detected by electrical detector, switches or magnetic reed switches respectively and the information passed to the control system so the robot knows which end effector is connected. The robot then knows, of course, if it is using the end effector.

Considerable ingenuity may need to be shown to produce a practical solution and marks awarded should take account of potential practicality without penalising unstated assumptions.

Or any other suitable answers. **3**

13. **(a) (i)** oven → computer

Input signals	**Marks possible**
Zone Temperature zones 1, 2 & 3	1 mark for all three
Filter Element condition (from filter sensor)	1 mark
Belt speed (from motor control feedback)	1 mark

3

(ii) computer → oven

Output signals	**Marks possible**
Heating element zones 1, 2 & 3	1 mark for all three
Belt drive motor	1 mark
Extraction fan motor	1 mark

3

Or any other suitable answers.

6 items at 1 mark each **6**

(b) (i) PID gives accurate control and can be tuned to give the required automated response to changing conditions. **1**

(ii) Proportional P = corrective signal is <u>proportional to the error</u> signal.

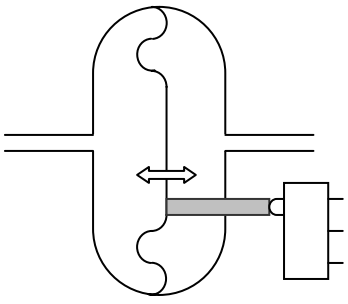
Integral I = minimises the area between the actual signal and the required and hence <u>removes offset</u> from the system.

Derivative D - enables system <u>response time to be tuned</u> to give the required control.

Or any other suitable answers.

1 mark per P, I, & D **3**

(c) A pressure differential switch could be calibrated which would give a <u>digital output</u> 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.



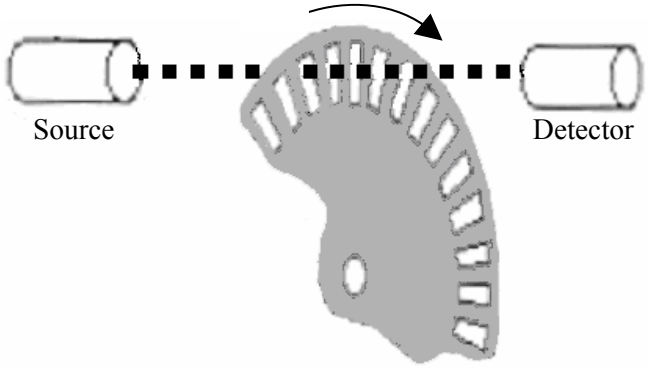
A good alternative may be a flow meter using a paddle in the air flow. Testing the speed of the fan rotation may be less practical.

Or any other suitable answers.

3 marks sketch/description + 1 mark output signal nature **4**

(d) Diagram of slotted disc.

Slotted disc rotates (always in the same direction) and breaks the beam between the transmitter and receiver on the sensing assembly. This produces a pulsed signal and each pulse shows a given rotation of the disc has taken place. The frequency of these pulses is directly related to the rotational speed of the disc. This rotational speed (rpm) can then be converted into a linear speed (mm/s) if the gearing and diameters of the system elements (eg rollers) are known.



Or any other suitable answers. Note a more complex encoder is NOT required as rotation direction is constant and unidirectional but working answers that use more complex encoding should not be penalised.

4 marks description + 2 marks diagram **6**

(e) 3 measures from – Stop button, guarding to prevent contact with moving parts eg conveyor, guarding to prevent contact with heated areas, interlocks to prevent heater operation if extractor fan stopped, interlocks to prevent heater operation if conveyor stopped.

Or any other suitable answers.

1 mark per safety measure **3**

(f) 2 issues from – Interfacing issues include voltage/power mismatch, electrical noise, safety isolation, fail-safe if computer crashes.

Or any other suitable answers.

1 mark per interfacing issue **2**

[END OF MARKING INSTRUCTIONS]