2009 Mechatronics

Higher

Finalised Marking Instructions

1. **(a)** The controlling action is altered by

ASIC – replace integrated circuit if possible (accept ASIC can not be reprogrammed)

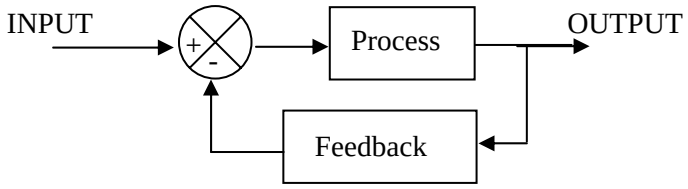
PC – change application program software or high/low level programming change

PLC – change/modify ladder diagram and download to PLC or directly reprogram PLC.

Or any other suitable answers.

3 answers @ 1 mark each **3**

(b)

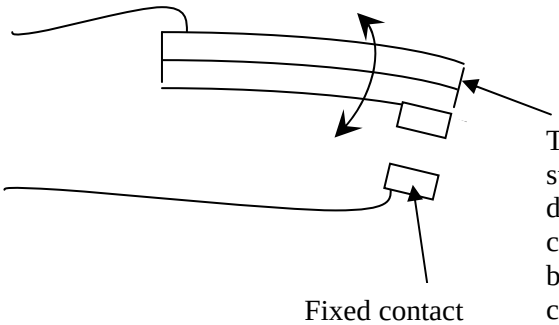


Or any other suitable answer. **2**

2. **(a)** **One** answer from:

- Thermocouple
- Thermistor
- Bimetallic strip
- Or any suitable temperature sensor **1**

(b) A simple sketch with a suitable basic description of the operational characteristics ie, mechanical movement of bimetallic device or electrical signal output for thermocouple.



Or other suitable answer where sketch and description matching answer in (a). **2**

(c) Any suitable use for the chosen device eg, a thermocouple on an industrial oven because temperature range and accuracy is appropriate.

or other suitable answer with suitable reason, ie, accuracy, interfacing capability, output signal etc (1 mark for appropriate application for sensor, 1 mark for reason). **2**

3. (a)

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

(4 answers @ 0.5 marks = 2 marks) **2**

(b) End effector is the hand or tool mounted at the end of the robotic arm or system. (This is not normally included in the manufacturers' definition of the work envelope.) **1**

(c) **Two** appropriate answers from Electrical motors require minimal maintenance, they operate on a readily available power supply, wide range of suitable motors available, or any realistic preferences not including ambiguous statement on cost such as the single word "cost" – such answers should be qualified with reference to the question issues.

(2 answers @ 1 mark) **2**

4. (a)

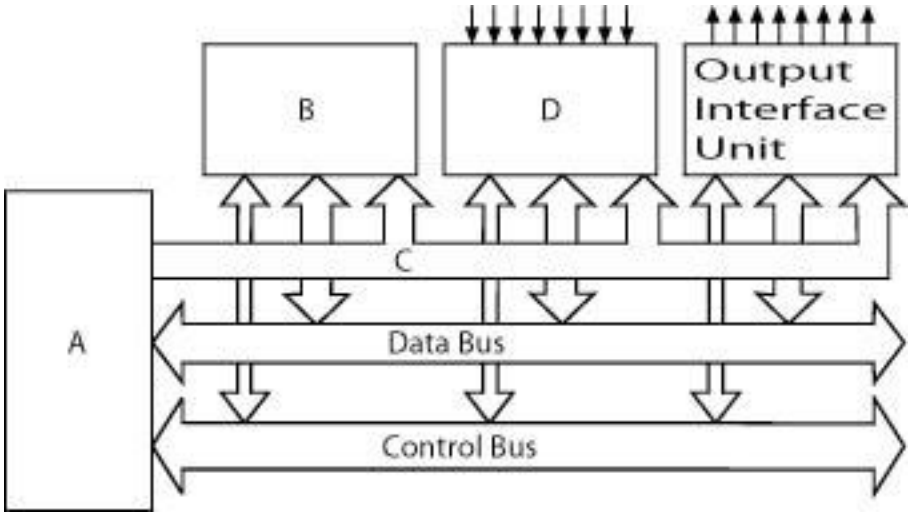


Figure Q4(a)

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

Or equivalent answers.

(4 answers @ 0.5 marks) **2**

(b) Bidirectional allows data flow in both directions on a bus but not at the same time.

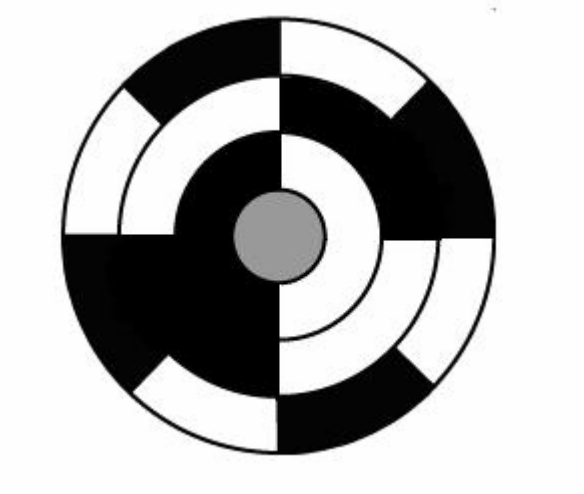
Or appropriate description. **1**

(c) $2^8 = 256$ combinations or combinations in range 0 to 255 **1**

(d) **One** answer from:- A PLC system is easily re-programmed, allows modular expansion, or any suitable advantage of PLC over hard wired **1**

5. (a) Number of bits represented = 3 **1**

Completion of shaded disc



or suitable equivalent shading (e.g., mirror image of above inner rings) – the important factor is that there should be 8 unique codes **2**

(b)

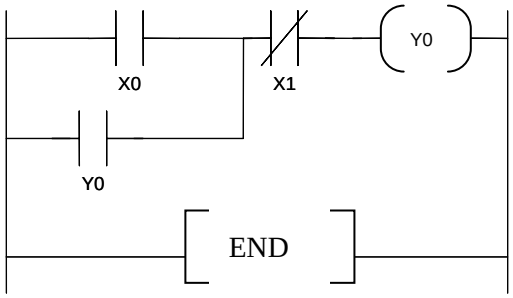
Decimal	Pure Binary	BCD
0	0000	0000 0000
1	0001	0000 0001
2	0010	0000 0010
3	**0011**	0000 0011
4	0100	0000 0100
5	0101	**0000 0101**
6	0110	0000 0110
7	0111	0000 0111
8	1000	0000 1000
9	1001	0000 1001
10	1010	0001 0000
11	1011	0001 0001
12	**1100**	0001 0010
13	1101	0001 0011
14	1110	0001 0100
15	1111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

Table Q5(b)

(4 answers @ 0.5 marks) **2**

6. **(a)** A NO contact in a PLC Ladder diagram rung normally prevents the completion of the rung by being in the open (non-connected) state. But when the contact is operated then that part of the rung is made. Or similar appropriate explanation. **1**

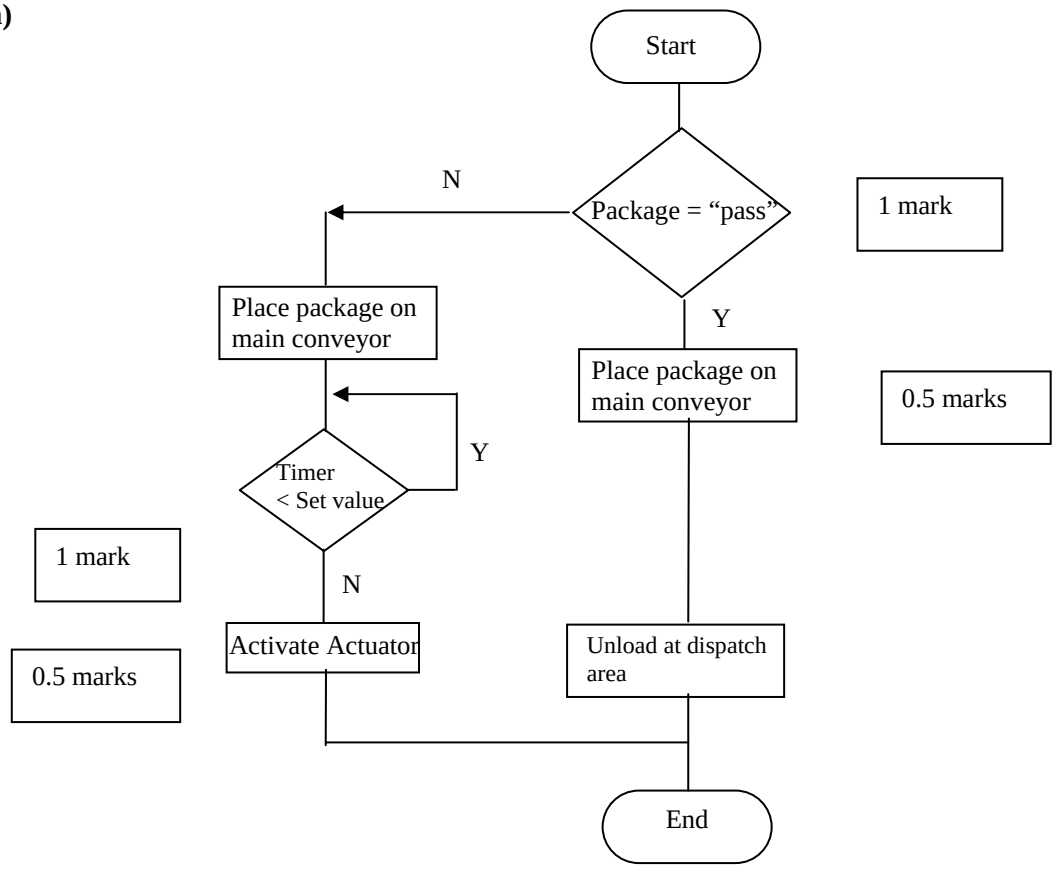
(b) Diagram similar to that below or equivalent (known as a latch circuit).



3

(c) This timer is set at 25 seconds (= 250 * 0.1 but working does NOT need to be shown). **1**

7. **(a)**



Or similar flow chart. Note the "place package on conveyor could be placed before the decision made on the basis of the pass/fail status. The timer could have a start timer box and/or alternative configuration. There may or may not be a "deactivate actuator" box (the actuator could be spring loaded) and an "unload at despatch area" box included.

(2 decisions @ 1 mark + 2 boxes @ 0.5 marks) **3**

(b) An event based system needs a sensor to detect progress rather than a timer. A suitable proximity sensor could be fitted at or close to the actuator so that when a failed box had been noted, it could implement the 'test fail signal decision' by operating the actuator at the right point in the cycle. Or appropriate explanation of conversion of system. **2**

8. (a)

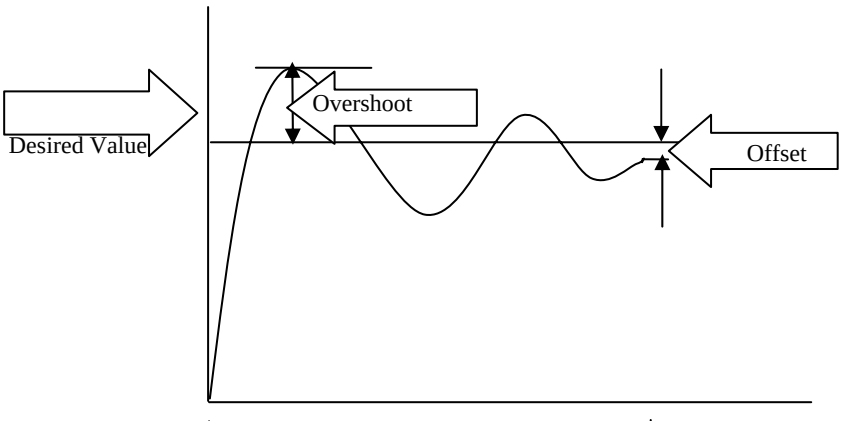
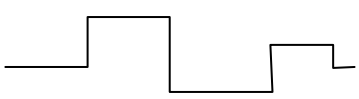


Figure Q8

(3 answers @ 1 mark each) **3**

(b) A digital signal has discreet number of values unlike an analogue signal which has an infinite number of values. (sketch is optional)

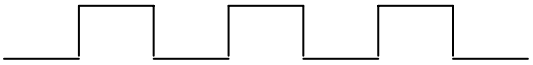


Digital (note digital does NOT have to have only two levels)

Analogue

Or other appropriate answer **2**

9. (a)



Only sketch needed. A pulse train showing discreet values of high/low (mark - space ratio need not be equal and may have sloped rise and fall edges in the sketched output waveform.) **1**

(b) The frequency of the pulse train (the number of pulses in a given time) could be obtained and a mathematical indication of the velocity obtained by knowing the distance each pulse represented. Or equivalent statement. **1**

(c) 10 Hertz = 10 pulse per second = (10 * 1) mm/sec = 0.01 m/s **2**

(d) An additional sensor could be fitted (at a phase difference ≠360 degrees) which would allow two pulse trains to be obtained and the lead/lag effect would indicate the direction of travel. Any other reasonable answer ie, another rack slightly offset from original, use of linear optical encoder where code changes show direction. **1**

10. **(a)** **A - Temperature** **1**

(b) **C - Provide motion** **1**

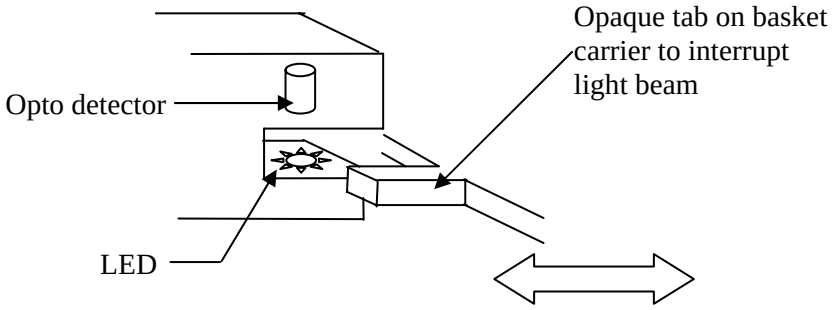
(c) **C - High power** **1**

(d) **D - Movement** **1**

(e) **B - A microswitch** **1**

11. **(a)** **(i)** Any suitable sensor such as a slotted optical sensor or a tactile sensor such as microswitch. **1**

(ii) Suitable sketch and description of operation of the sensor chosen in (i) eg, for slotted optical switch

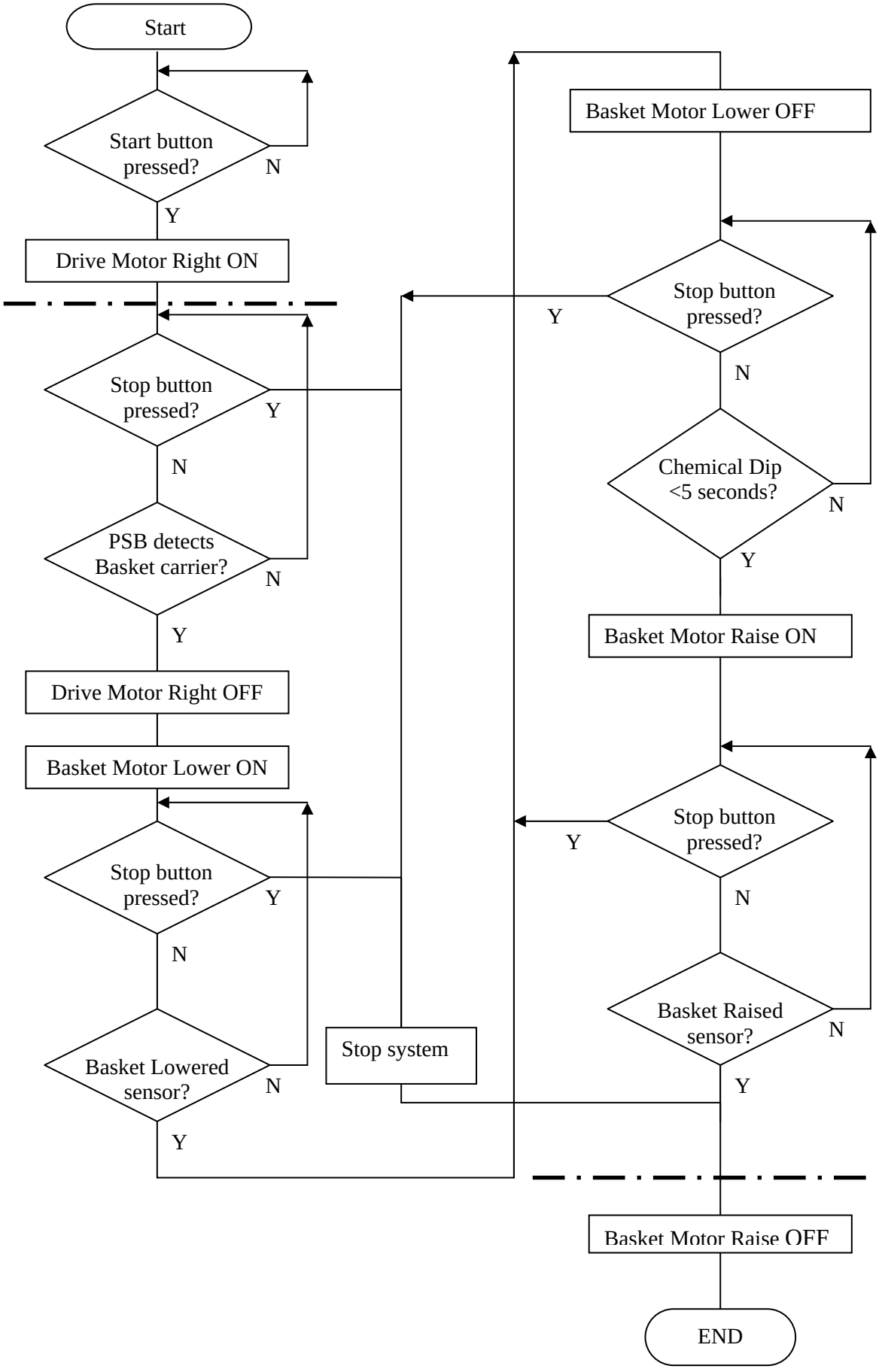


For PSA, an opaque tab located on the basket carrier is located such that when the carrier is at the home position (station A) then the tab interrupts the light signal and provides a sensor signal. When the carrier moves to the right the tab moves out of the light beam and gives a changing signal. (note: the discussion of logic status is not required).

Or other suitable sketch and description which performs function and matches the sensor chosen in (a)(i).

(2 sketch + 1 description or 1 sketch + 2 description) **3**

(b)



Complete solution shown including elements given in worksheet.

Other variations acceptable provided the functionality and sequencing are correct.

Solution shows STOP decisions and actions throughout the chart. If this part of the solution is as shown or if the need for STOP functionality is noted as a requirement then 1 mark allocated.

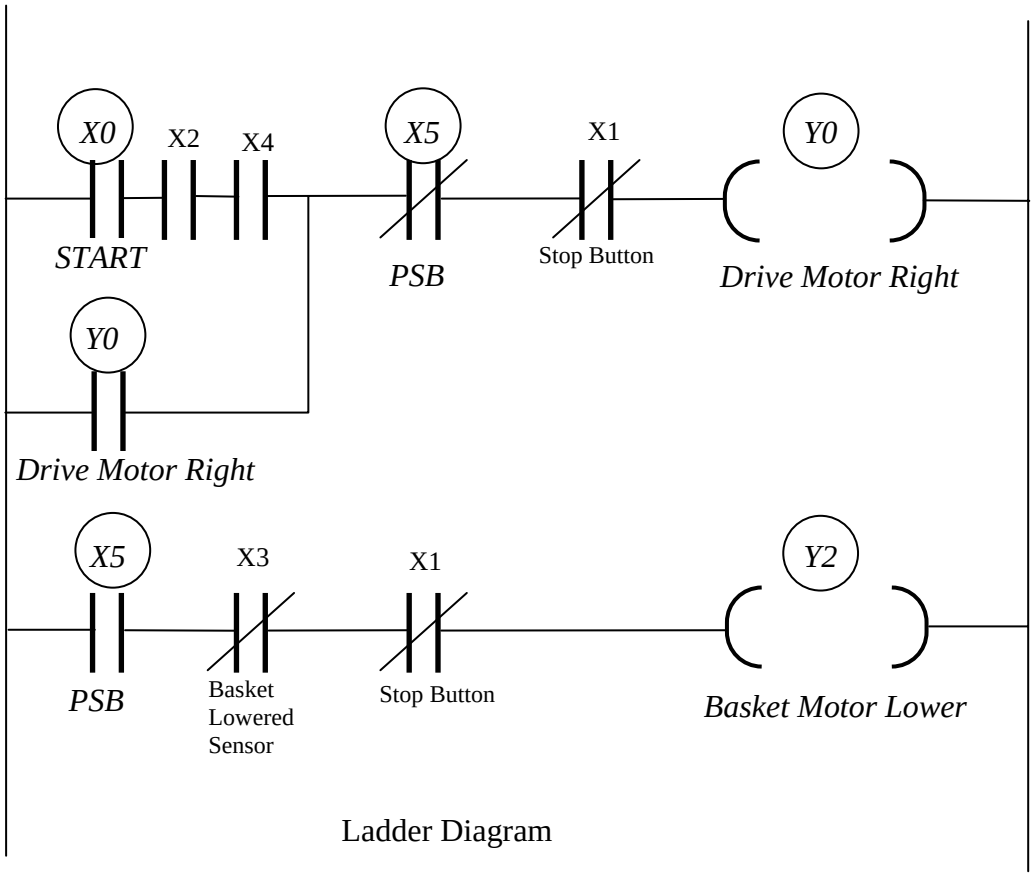
Of the remaining,

4 decision boxes with appropriate decisions/routes @ 1 mark/box = 4 marks

4 action boxes @ 0.5 marks/box = 2 marks

Total = 1 + 4 + 2 = 7 marks

(c) **(i)**



Ladder Diagram

Note only the ALLOCATION, eg, X5 is needed, not the associated label eg, PSB.

(6 allocations (circled) @ 1 mark)

(ii) The Stop Button (X1) is present on every rung and can stop the system operation at any time. The handler is at Station A with the basket in the raised position. Position Sensor A (X4) and the Basket Raised Sensor (X2) are closed and on pressing the Start Button (X0)….

this completes the first rung shown and operates Drive Motor Right (Y0) (0.5 marks) which starts the carrier moving right from the initial position towards Station B. The latching contact Y0 makes sure the Drive Motor Right continues even when the start button is released and the carrier has moved away from PSA (0.5 marks).
When the carrier arrives at Station B then PSB (X5) is activated (0.5 marks) and the normally closed contact stops the Drive Right Motor (0.5 marks).
On the second rung, PSB (X5) drives the Basket Motor Lower (Y2) (0.5 marks) until the basket is lowered when the Basket Lowered Sensor (X3) stops the motor (0.5 marks).

Or other alternative explanation that describes the key stages of operation.

(6 issues @ 0.5 marks) **3**

(d) **(i)** Hardware needed to be added:

- Level sensor (with interfacing if it is more than just a contact) (1 mark)
- Heater (with interface/drive capability) (1 mark)
- Temperature sensor (with interfacing if it is more than just a contact) (1 mark)

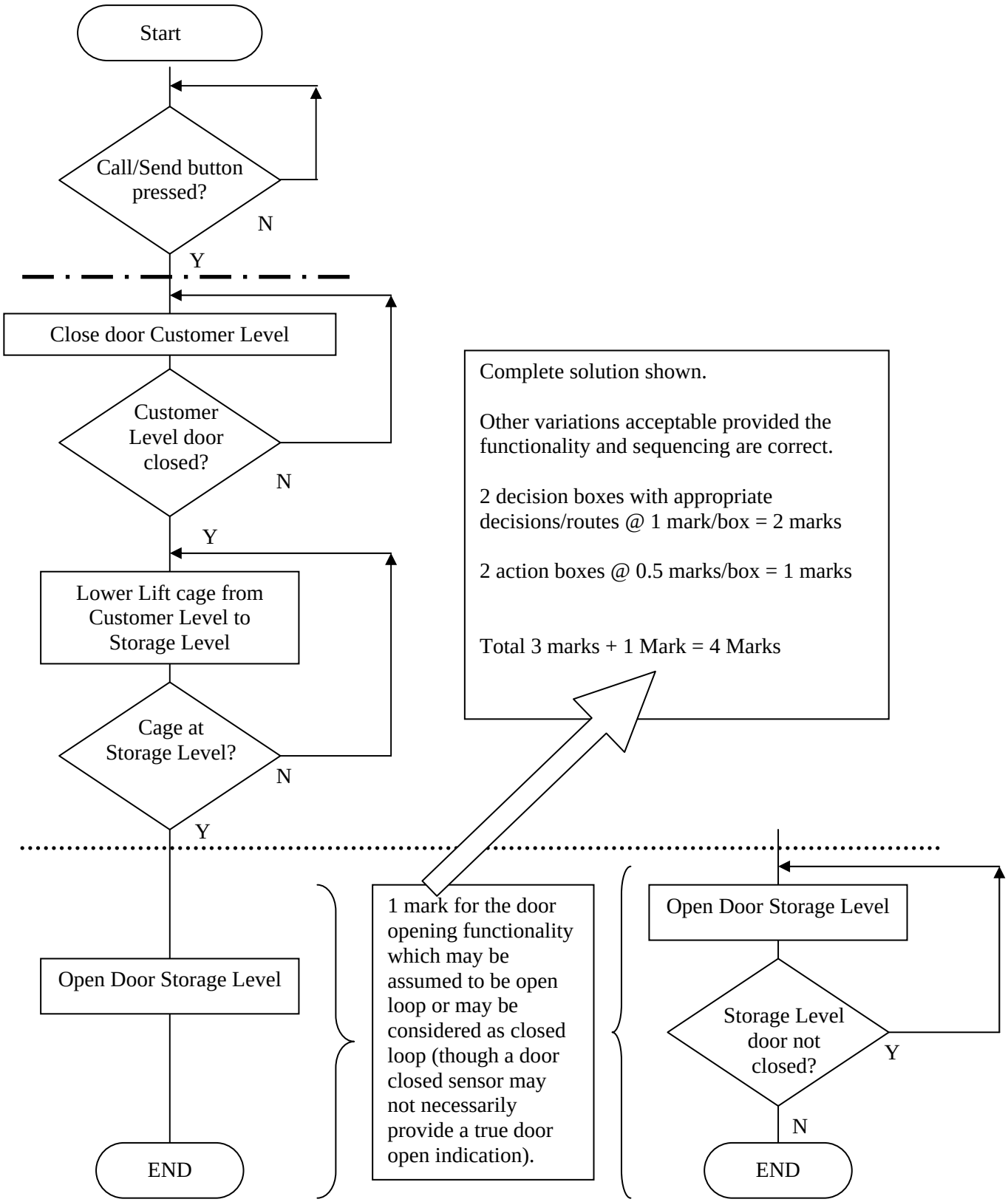
Or other appropriate hardware stated **3**

(ii) Additional PLC I/O required:

- 2 Extra inputs for Level Sensor and Temperature sensor (1 mark)
- 1 Extra output for Heater (1 mark)

Or other appropriate PLC I/O stated **2**

12. (a)


Start
Call/Send button pressed?
N
Y
Close door Customer Level
Customer Level door closed?
N
Y
Lower Lift cage from Customer Level to Storage Level
Cage at Storage Level?
N
Y
Open Door Storage Level
END
Complete solution shown.
Other variations acceptable provided the functionality and sequencing are correct.
2 decision boxes with appropriate decisions/routes @ 1 mark/box = 2 marks
2 action boxes @ 0.5 marks/box = 1 marks
Total 3 marks + 1 Mark = 4 Marks
1 mark for the door opening functionality which may be assumed to be open loop or may be considered as closed loop (though a door closed sensor may not necessarily provide a true door open indication).
Open Door Storage Level
Storage Level door not closed?
Y
N
END

(b) **(i)**

- Storage Level Door Closed Sensor
- Customer Level Door Closed Sensor
- Storage Level Call/Send Button
- Customer Level Call/Send Button
- Storage Level Lift Cage Sensor
- Customer Level Lift Cage Sensor

(6 signals @ 0.5 marks each) **3**

(ii)

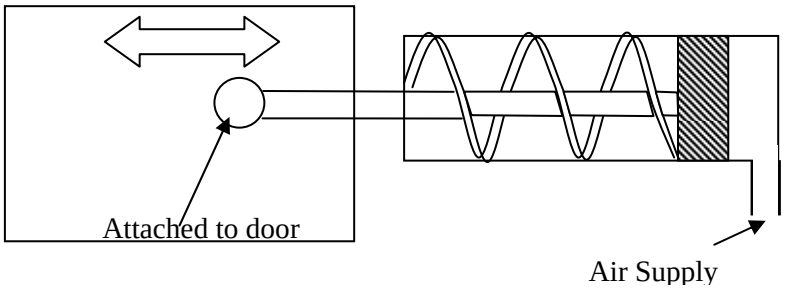
- Motor Drive Up OR
- Motor Drive Down
- Motor Drive
- Motor Up/Down
- Storage Level Door Actuator (may be listed as two signals)
- Customer Level Door Actuator (may be listed as two signals)

(4 signals @ 0.5 marks each) **2**

Total = 2 + 3 = 5 marks **5**

(c) **(i)** Any suitable actuator such as single acting pneumatic cylinder, electric solenoid (the diagram suggests a linear device but a rotary would also be acceptable provided it produces suitable motion). **1**

(ii) Sketch and description should match the choice made in (c) (i). Example shown below is a single acting pneumatic actuator.



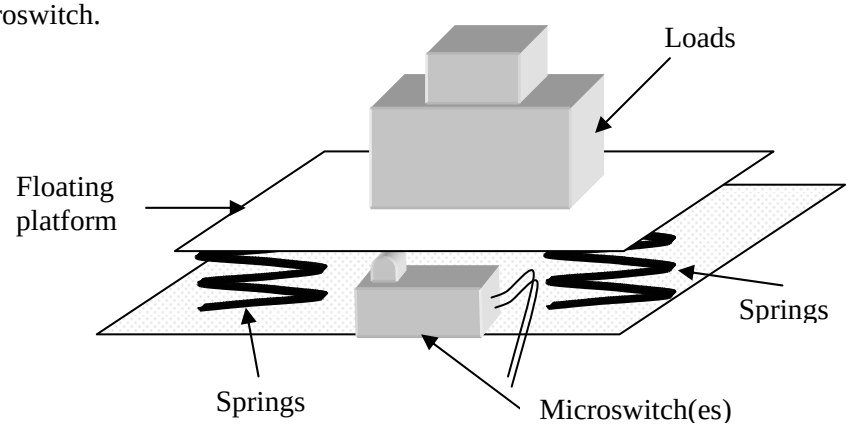
Single acting cylinder with internal spring when the air supply pushed the piston forward the door opens (or closes) and when the air supply is removed the spring retracts the piston and closes (or opens door).

Or other similar sketch and description. **2**

(d) A wide variety of answers are possible given below.

A floating platform with sensors such as microswitch, load cells, strain gauges, optical sensors that detect movement or extension, etc. The suitability of a particular sensor will often be governed by the surrounding system and descriptive notes.

An example solution is shown here using a floating platform and microswitch.



The floating platform rests on a microswitch and springs. As loads are placed on the platform it sinks until the movement is sufficient to indicate a load of 160kg has been exceeded when the microswitch operates. Careful design would be needed to ensure the system acts reliably especially if the load was placed off centre.

4

Or other suitable sensor system with sketch and description.

(e) **(i)** Any **one** suitable sensor such as a tactile sensor (microswitch connected to a door edge strip), a light curtain or a proximity sensor. **1**

(ii) **Three** from a variety of actions might be given including the following:-

- stop the door movement instantly
- stop and retract the door
- decrease the force applied to the door so it does not cause further damage
- sound an audible alarm
- give a visual alarm
- send an alarm to a remote location or operator
- record the occurrence of the problem for operator training.

Or any other suitably distinct actions

(3 sections @ 1 mark) **3**

(f) **Two** answers from:

- Voltage/Power interfacing (micro low motor high).
- Transient/voltage spike suppression.
- Optoisolation, effects of inductive circuits.
- Or any other relevant two issues.

(2 issues @ 1 mark per issue) **2**

(g) **Three** safety measures from:

- Emergency STOP buttons.
- Operator instructions.
- Guards on doors and other moving parts.
- Audible warnings when doors about to move.
- Speed limiters/brakes.
- Failsafe circuitry to prevent problems if sensor fails (eg, if customer level life cage sensor fails.)

Or any other relevant three safety measures

(3 issues @ 1 mark per issue) **3**

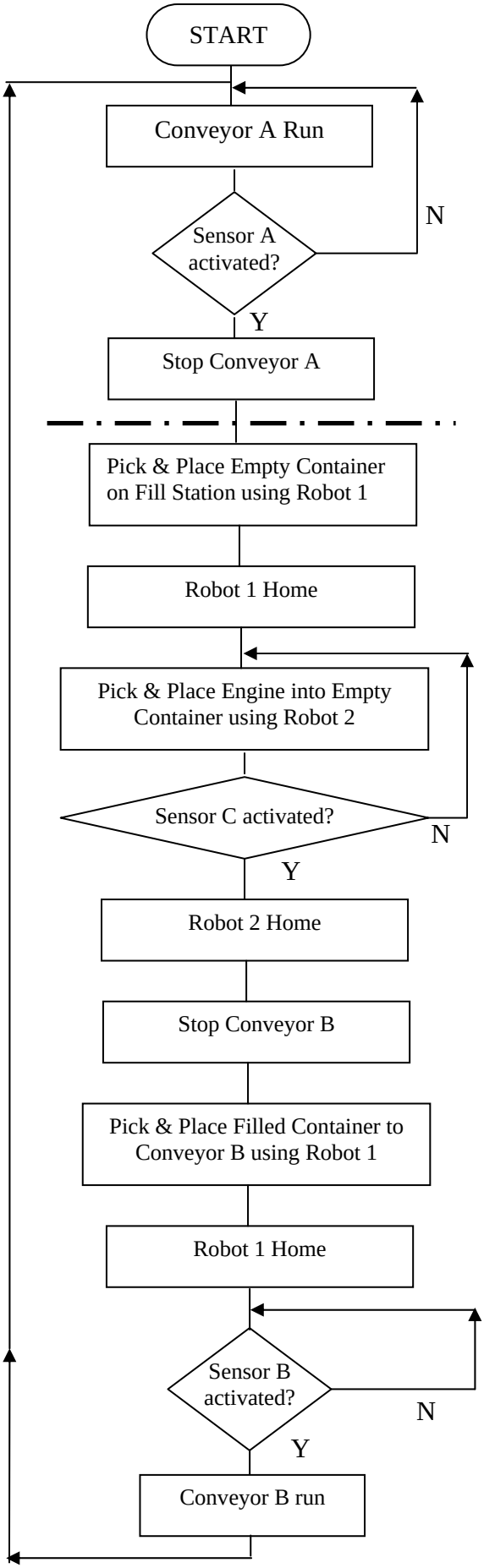
13. **(a)** **(i)** Any appropriate proximity sensor which must be able to detect the arrival of a container and provide a signal to the controller system eg, an optical light beam sensor which may be reflective or through beam.

(State sensor : 1 mark + brief explanation : 1 mark) **2**

(ii) Any appropriate sensor which will provide a signal indicating the container has been filled and hence the correct weight, eg, a simple strain gauge load cell which would provide an analogue signal that may be passed onto the system controller which makes the decision as to the container condition (empty or full). Or any other suitable ways of sensing the presence of one engine such as optical/pattern recognition.

(State sensor : 1 mark + brief explanation : 1 mark) **2**

(b) Flow Chart



Complete solution shown including elements given in worksheet.

Other variations acceptable provided the functionality and sequencing are correct.

Note the overall outside loop (shown for completeness) is NOT mandatory as only one cycle is required. The order of "Robot 2 home" and "Stop Conveyor B" is arbitrary.

2 decision boxes with appropriate decisions/ routes @ 1 mark/box = 2 marks

8 action boxes @ 0.5 marks/box = 4 marks

Total = 2 + 4 = 6 marks

(c) **Three** safety features from:

- Emergency STOP buttons.
- Guards around cell.
- Interlock cutting power if cell accessed.
- An audio/visual "system is operating" feature could be added to ensure personnel were aware that an automated system may suddenly start operating.
- Guards on moving parts.
- Audible/visual warnings when conveyors about to move.
- Collision detectors.
- Failsafe circuitry to prevent problems if sensor fails (eg, if Sensor A fails).
- Cages to prevent damage/injury if engine dropped.

Or any other relevant **three** safety features

(3 issues @ 1 mark per feature) **3**

(d) **(i)** Only one data bit changes per segment (sequential code) thus error detection may be easier.

Or other appropriate answer **1**

(ii) $2^{10} = 1024$; $360 / 1024 = 0.35$: resolution is 0.35 or ± 0.176 degrees. **3**

(iii) A system consisting small hydraulic robots would provide the required power to lift and transport the container/engine combination and hydraulic robots have accurate positional control. Any suitable robotic drive system but pneumatic robots may not give the required positional control and electrical mains driven robots may not be intrinsically safe and may have difficulty lifting more than 1kg.

Note: only one choice and associated justification is required

(1 mark for stating system and 1 mark for one reason) **2**

(e) **Two** issues from a number of issues may be raised such as those discussed below.

The containers may move/slide on the conveyor one solution would be to fit a simple securing/jig system to ensure the containers are securely located on the conveyor system at appropriate times in the cycle.

The synchronization of the robotic arm movement and the conveyor speed may prove a challenge; a solution may be to introduce a visual system which would allow the robot to "see" the container as it was placing the engine inside.

The weight/inertia of moving the engines could prevent dropping the engine from any height into the container, this would require fine tuning of the system and optimum speeds, heights obtained possibly by trial and error.

If empty containers were not dealt with sufficiently swiftly or engines run out then they may arrive and interfere with the filled containers or move out of reach of Robot1; a solution may be a variable speed or timings that take account of delays

Or any other suitable **two** issues requiring addressing with an appropriate solution proposed.

(2 issues/solutions @3 marks) **6**

[END OF MARKING INSTRUCTIONS]