SCOTTISH QUALIFICATIONS AUTHORITY

# 2005 Mechatronics

# Higher

# Finalised Marking Instructions

**These Marking Instructions have been prepared by Examination Teams for use by SQA Appointed Markers when marking External Course Assessments.**

**2005 Mechatronics**

**Higher**

**Marking Instructions**

**1.** (a) For each of the following, state **one** appropriate sensor device which could be used to measure:

(i) level;

Answer: Float Switch, Resistive float, Pressure sensor calibrated for level. **1**

(ii) pressure;

Answer: Strain gauge, Piezo crystal, Carbon rod. **1**

(iii) Temperature;

Answer: Thermocouple, RTD, Thermistor **1**

Or other appropriate answers.

(b) Briefly explain the operation of your selected **level** sensor within a practical application.

Answer: A suitable short explanation explaining how the measured quantity is detected and the output quantity of the sensor. E.g., a resistive float – a physical float is connected to a resistive element, such as a variable resistor, so that as the float rises the resistance changes. **2**

Or other appropriate explanation.

Note the explanation should be of the level sensor stated in 1(a)(i)

Figure Q2(a) in the **Worksheet Q2(a)** shows a partially completed block diagram of a microcontroller system.

**2.** (a) On **Worksheet Q2(a)**, label the following elements on the diagram:

- input interface unit
- output interface unit
- memory unit
- central processing unit (CPU)
- data bus
- the direction of information flow on the data bus.

Answer: SEE WORKSHEET Q2(a) ANSWERS (see next page) **3**

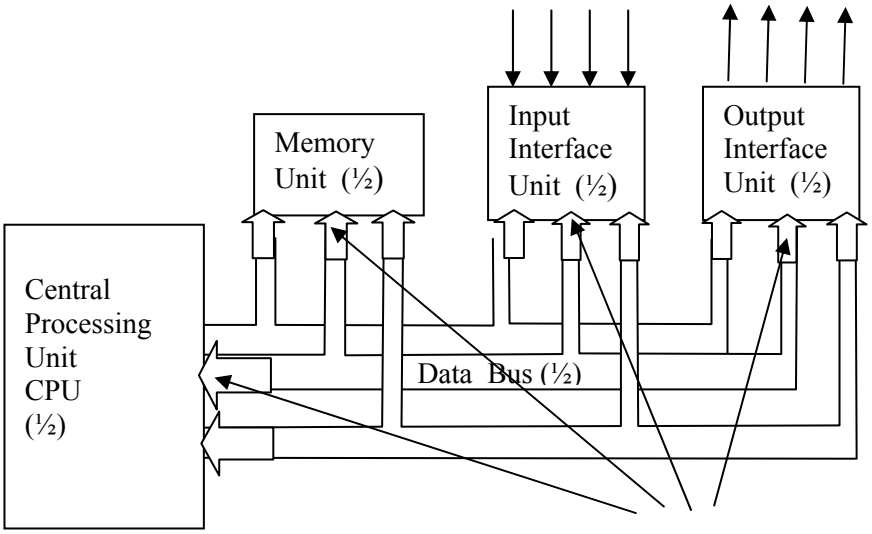
(b) In a microcontroller system, a bus may be described as being "bi-directional". In your **answer book**, explain the meaning of the term "bi-directional" in this context.

Answer: Bi directional – data flows both ways on a bus but not necessarily at the same time. **1**

(c) State the purpose of a simulator used in a microcontroller software development environment.

Answer: A simulator – allow simulation (mimicking) of a micro-controllers operation and testing during the development stage of design but is not an exact replica of the micro-controller. **1**

Worksheet Q2 (a)




(½) for bidirectional

Block diagram of a microcontroller system.

Figure Q2(a)

Or similar diagram with ½ mark per item

**3.** (a) Using the **Worksheet Q3(a)**, identify each type of robot in Figure Q3(a).

Answer: SEE WORKSHEET Q3(a) ANSWERS **2**

(b) Using the **Worksheet Q3(b)**, sketch the work envelope for robot B in the space provided.

Answer: SEE WORKSHEET Q3(b) ANSWERS **1**

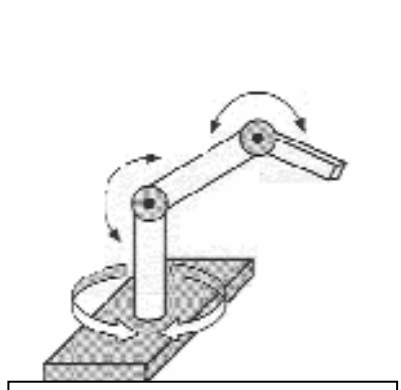
(c) On **Worksheet Q3(c),** state how you would alter the controlling action of:

(i) An ASIC based system;

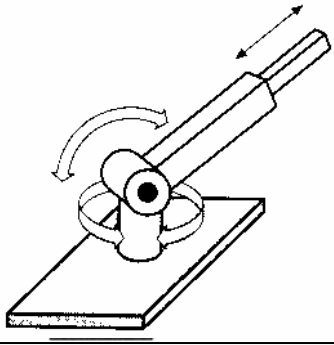
(ii) A microcontroller based system.

Answer: SEE WORKSHEET Q3(c) ANSWERS **2**

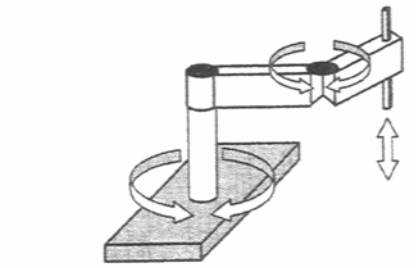
Worksheet Q3 (a)



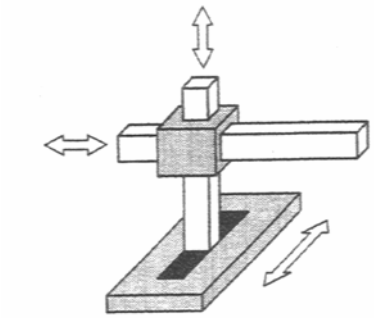
A: Revolute or Jointed Arm or Articulated arm (½)



B: Polar or Turret (½)



C: SCARA (½)

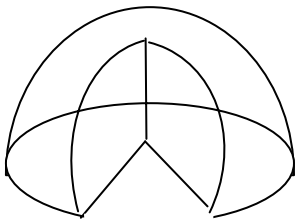


A: Cartesian or Rectangular (½)

Or other appropriate answers (½) mark for answer

(b) Sketch the work envelope for robot B

No words needed but <u>hemisphere</u> or anything almost up to a sphere. May have slice missing (as here) or column missing in centre but not essential.



(1 mark)

(c) (i) The controlling action of an ASIC based system is changed by

ANSWER: Replacing the ASIC with another with changed or different content

(1 mark)

(ii) The controlling action of a microcontroller based system is changed by

ANSWER: Changing the program loaded into the microcontroller

(1 mark)

Or other appropriate answers

**4.** (a) Figure Q4 shows a coded disc for use in a rotary encoder.

Figure Q4.

(a) Identify the code represented in Figure Q4 in terms of:

(i) number of bits; **1**

Answer: 4 bits.

(ii) code type;

Answer: Grey code. **1**

(b) State one advantage and one disadvantage associated with this code.

Answer: one <u>advantage</u> of the following:

- only one bit changes per segment thus error detection simplified
- not possible for disc to stop at change point that gives rise to a false translational code **1**
- or acceptable alternative advantage.

Answer: one <u>disadvantage</u> of the following:

- there are a range of Grey codes and no standard,
- actual code values differ from natural binary **1**
- or acceptable alternative disadvantage.

(c) State how the angular resolution of the above disc could be improved.

Answer: more bits added or modification to sensor arrangement or other appropriate proposal. **1**

**5.** (a) **Worksheet Q5(a)** shows a ladder diagram. On **Worksheet Q5(a)** complete the ladder diagram so that the output Y0 is latched when contact X0 is closed.

ANSWER: SEE WORKSHEET Q5(a) ANSWERS

**1**

(b) In your **answer book**, explain the sequence of operations of your completed ladder diagram. Start with the closure of contact X0.

ANSWER: Standard answer describing latch. Contact X0 is made completing rung, output Y0 is activated, this latches Y0 contact in parallel with X0 so that the rung remains activated even if X0 is deactivated. Rung remains activated until X1 is opened . On the opening of X1, Y0 output is deactivated. **3**

or other appropriate explanation. (3 marks)

(c) State **one** practical application of the completed ladder diagram.

ANSWER: A start/stop machine control is one example to which the ladder diagram could be applied.

**1**

Other examples possible.

(1 mark)

Worksheet Question 5 (a)

ANSWER: ladder diagram as below

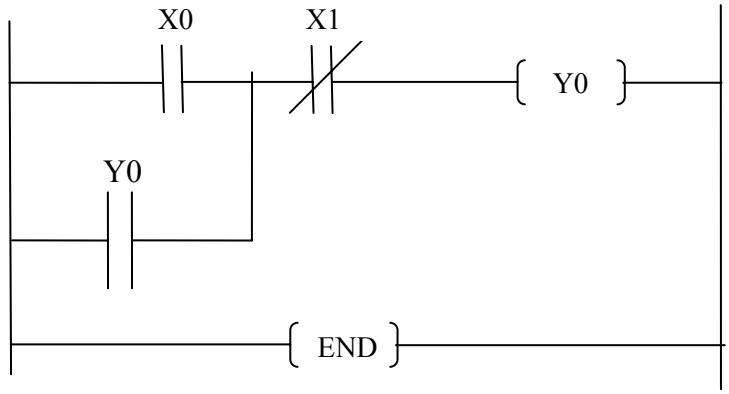



Figure Q5(a)

1 mark for addition of Y0 contact. Note must be labelled as Y0 or such as shows that operating Y0 causes a contact to operates that gives a latching function. (1 mark)

**6.** (a) Describe the "lead by nose" method of programming a robot

ANSWER: This is a programming method by which the robot is manually led through the required task (taught) and numerous points recorded. These recorded points can then be played back with the effect of the robot repeating the task taught, often the teaching is at a slower rate than the play back. (2 marks)

Or other description with key points **2**

(b) State what type of actuator motion would be used in a Cartesian robot

ANSWER: Linear actuators because all the joints are linear or translational. (1 mark) **1**

(c) State **four** characteristics of a hydraulic system

ANSWER: Any four from

high power, high maintenance, very expensive, positional accuracy, closed system (return path needed for fluid), **2**

or other appropriate characteristics. (2 marks)

**7.**

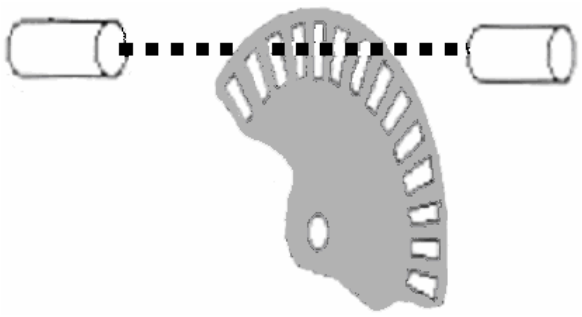


Figure Q7

(a) Explain the basic operation of the optical encoder disk shown in Figure Q7 and describe how the output signal could be used to calculate the speed of rotation.

ANSWER: A beam of light is transmitted and detected, this beam is broken by the rotating disk which has the effect of producing pulses at the receiver. These pulses can be counted and the position of the disc calculated. The output pulses will have a frequency, this frequency will be dependant upon the speed of rotation. (3 marks) **3**

Or other alternative explanation

(b) An encoder disk has 60 equally spaced slots and is rotated through 2.5 turns.

(i) Calculate the angular resolution in degrees of the encoder disc

ANSWER: The angular resolution is 6 degree's or plus/minus 3 degrees (= 360/60). (1 mark) **1**

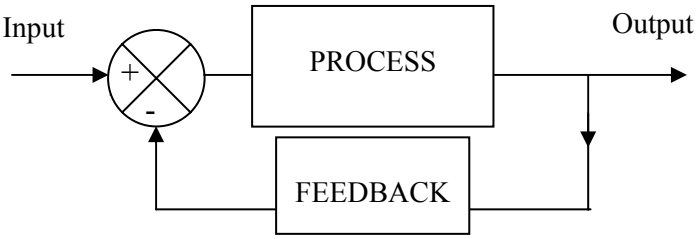
(ii) Calculate the count that would be accumulated in a counter if the initial count was zero.

ANSWER: The count would be 150 pulses (= 60 * 2.5).

(1 mark) **1**

**8.** (a) Sketch and label the basic block diagram of a closed loop control system.

ANSWER:




Or equivalent sketched block diagram showing feedback path and summing function.
(2 marks) **2**

(b) State how an open loop control system generally differs from a closed loop control system in terms of complexity

ANSWER: Open loop has no feedback system and is thus simpler in that it does not require a sensor or comparator to generate an error signal

**1**

or appropriate statement regarding complexity. (1 mark)

(c) State the main advantages of introducing Integral **and** Derivative control actions into a Proportional control system.

ANSWER: The offset can be removed (by Integral) and the system tuned to give control of the response time (by Derivative). **2**

or appropriate statement (2 marks)

**9.** Figure Q9 shows an ON/OFF level control system. The tank level is controlled between two preset limits by a microcontroller which opens/closes the "hopper valve" when required.

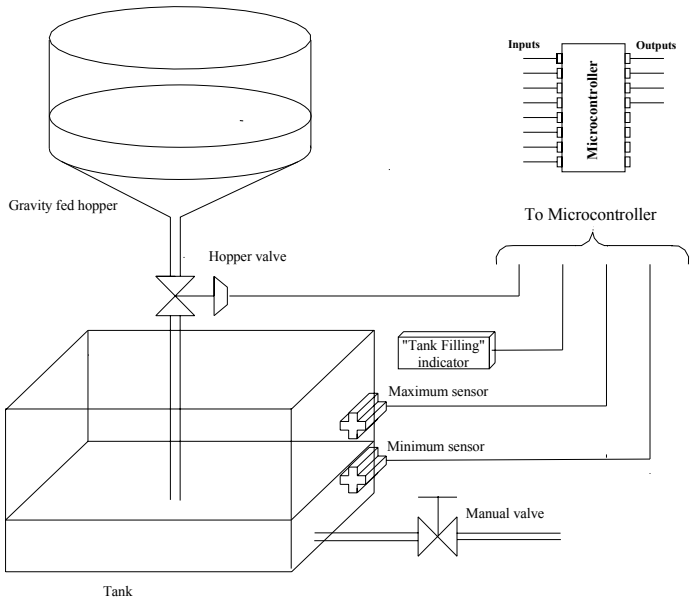



Figure Q9

(a) Identify and allocate microcontroller I/O in Figure Q9.

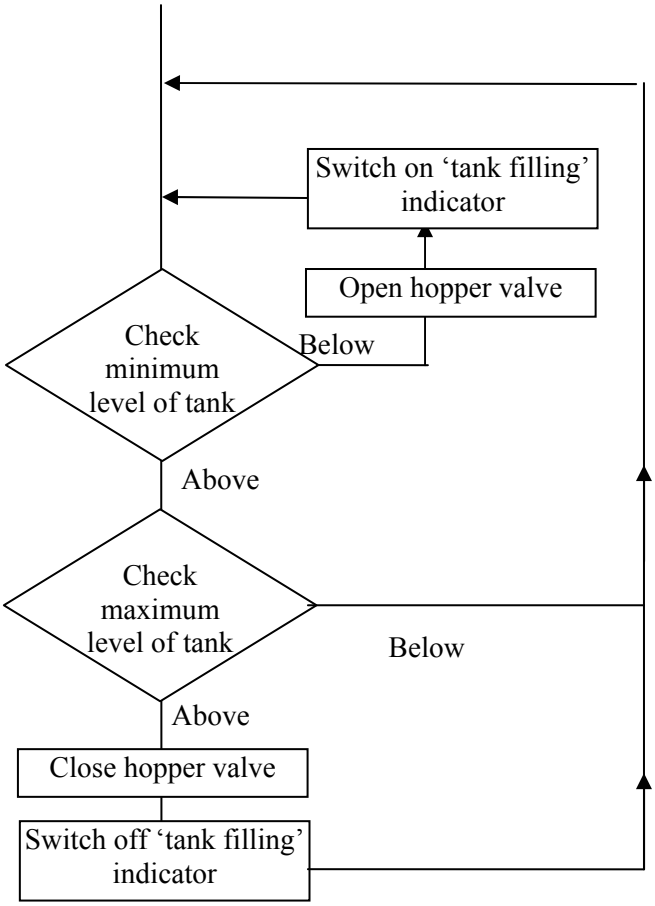
ANSWER:

inputs – max sensor, min sensor.
outputs – hopper valve, tank filling indicator.

(2 marks) **2**

(b) Sketch a flowchart that illustrates the operation of the system, starting with "check minimum level of tank".

ANSWER:




(Logic 1 mark, Decisions 2 marks)

**3**

Many alternative solutions possible – solutions must check for sensors and produce outputs at the right times taking account of the manual emptying valve. (3 marks)

**10.** A design for a 2D vinyl along cutter is to have 1000mm travel along the X axis and 5000mm travel along the Y axis. The cutter should have a linear positional accuracy of 1mm on each axis. Using linear encoders for each axis, calculate the minimum number of code bits required to achieve the designed positional accuracy. Show all your working in your answer.

ANSWER:
x-axis – 1000 mm with 1mm accuracy (1/2)
Therefore count = 1000 (1/2)
$2^n \geq 1000$ (1/2) thus n = 10 (1/2) i.e. 1024 (1/2)

y-axis – 5000 mm with 1mm accuracy (1/2)
Therefore count = 5000 (1/2)
$2^n = 5000$ (1/2) thus n = 13 (1/2) i.e. 8192. (1/2)

**5**

If one encoder used for both axis then only half marks allocated (5 marks)

END OF SECTION A

## SECTION B

**Attempt any TWO questions in this Section**

**11.** (a) A PLC controlled industrial shredding machine is illustrated in Figure Q11. The shredding machine operates as follows:-

- Two push-buttons control the machine and are assigned to PLC inputs X0 and X1. The buttons are far enough apart to ensure "two-handed" operation.
- The motor of the shredder is controlled by PLC output Y0.
- The shredder should only shred the paper **if** the "Paper feeder" is in position correctly **and** both push-buttons have been pressed.
- The "Paper feeder in position" sensor is connected to X2.
- There is a 'Motor overloaded" sensor connected to X3 which opens on detecting that the shredder's motor has overloaded.

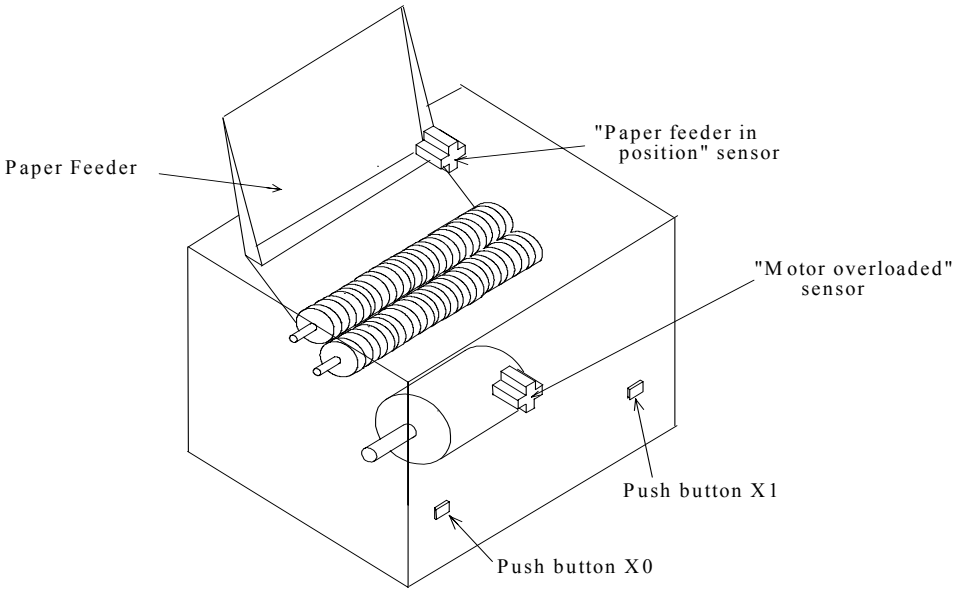



Figure Q11 (a)

(a) A ladder diagram representing an initial PLC program controlling the shredder is shown on **Worksheet Q11(a)**. On **Worksheet Q11(a)** explain the program action it represents and their effect on the shredder.

ANSWER: SEE WORKSHEET Q11(a) ANSWERS **2**

(b) The initial PLC program, Figure TQ 11(a) needs modification to make sure that when both push-buttons are pressed simultaneously, the motor starts and then continues to run after the buttons have been released. On **Worksheet Q11(b),** sketch a modified ladder diagram and explain the program operation with this modification in place.

ANSWER: SEE WORKSHEET Q11(b) ANSWERS **3**

(c) On **Worksheet Q11(c)**, redraw your ladder diagram with the normally closed "Paper feeder in position" contact connected to PLC input X2 such that it will prevent the operation of the shredder motor if the paper feeder is removed. Explain the program operation with this addition made.

ANSWER: SEE WORKSHEET Q11(c) ANSWERS **3**

(d) If the "Motor overloaded" sensor detects an overload then it opens a normally closed switch. On **Worksheet Q11(d)**, redraw your ladder diagram, adding this contact X3. Explain the program operation with this addition made.

ANSWER: SEE WORKSHEET Q11(d) ANSWERS **3**

(e) (i) On **Worksheet Q11(e),** redraw your ladder diagram adding a timer and associated contacts which will stop the shredder motor from operating for more than 15 seconds after the shredder motor is activated.

ANSWER: SEE WORKSHEET Q11(e) (i) ANSWERS **3**

(ii) Explain the program operation with this addition in place.

ANSWER: SEE WORKSHEET Q11(e) (ii) ANSWERS **6**

(f) (i) On **Worksheet Q11(f),** list **three** safety features already included in the system.

ANSWER: SEE WORKSHEET Q11(f) (i) ANSWERS **3**

(ii) On **Worksheet Q11(f),** choose two of these safety features and briefly explain why each one is necessary for safe operation of the system.

ANSWER: SEE WORKSHEET Q11(f) (ii) ANSWERS **2**

Worksheet Question 11 (a)

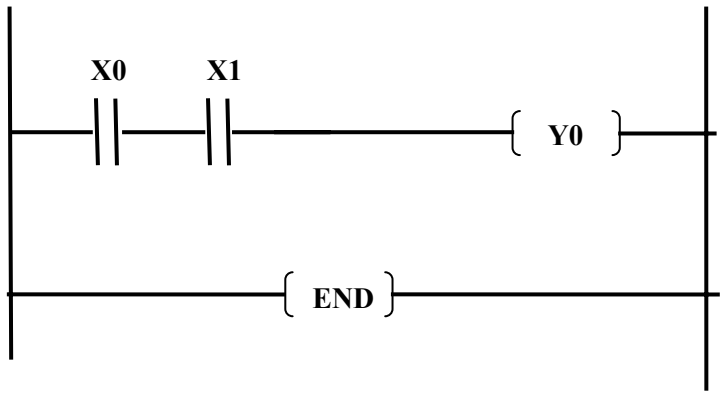



Figure Q11 (a)

ANSWER: Pushbuttons closing X0 AND X1 activates Y0 (shredder motor) (2 marks)

Question 11 (b)

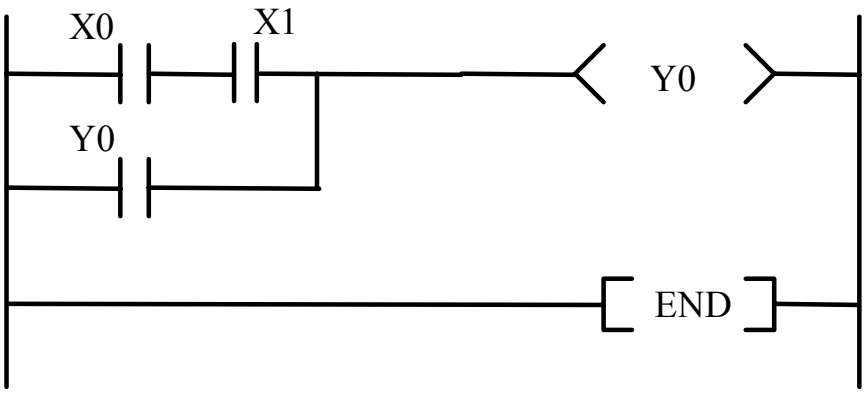



Figure 11(b)

As Answer (a) plus when Y0 energised, contact Y0 closes which latches Y0 on.

(3 marks)

Q11 (c) ANSWER

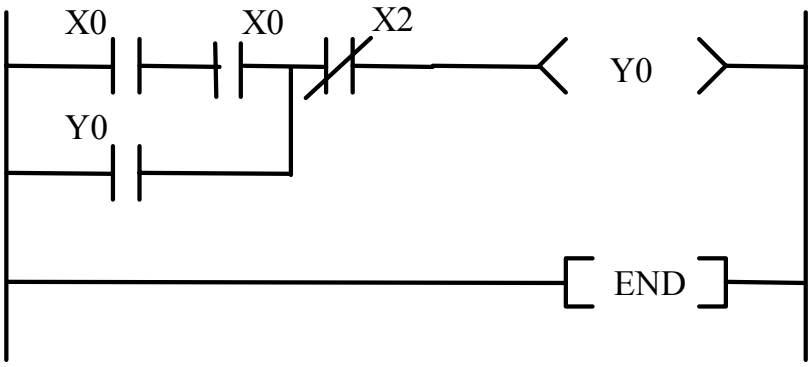



Figure 11 (c)

As Answer (b) plus if feeder is not present or removed, X2 opens and Y0 will not be activated or unlatched respectively. (3 marks)

Question 11 (d)

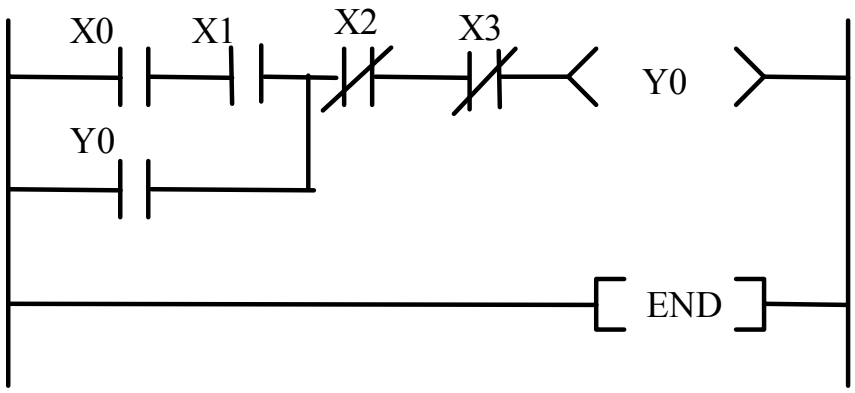



Figure 11 (a)

As Answer 11 (c) plus if overload occurs X3 will open and Y0 will be unlatched.

(3 marks)

Question 11 (e)

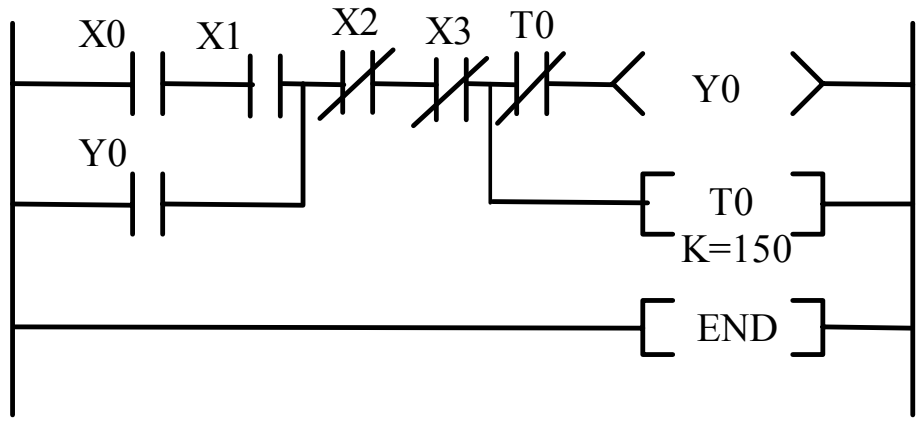



Figure 11 (e)

(3 marks)

(ii) As Answer 11 (d) plus when Y0 is activated T0 starts to count down for 15 seconds (Count of 150). When count reaches 0, then timer contact T0 opens, unlatches Y0 and resets T0.

Or other suitable answer. Different system used different forms of timer so many variations possible.

(6 marks)

Question 11 (f)

(i) Three safety features already included are:

2 buttons to start, paper feeder in position check, motor overload or timer.

Any three of these or other appropriate. (3 marks)

(ii) A brief explanation of two of these safety features is:-

Suitable explanations, 1 mark each.

Example 2 buttons to start – Because two buttons are needed and
these are physically located apart then it means that both hands are needed to start machine.

(2 marks)

**12.** Figure 12(a) illustrates a simplified lift system used to transport warehouse goods between the "storage level" and the "customer level" in a retail outlet. The system is presently controlled by a microcontroller.

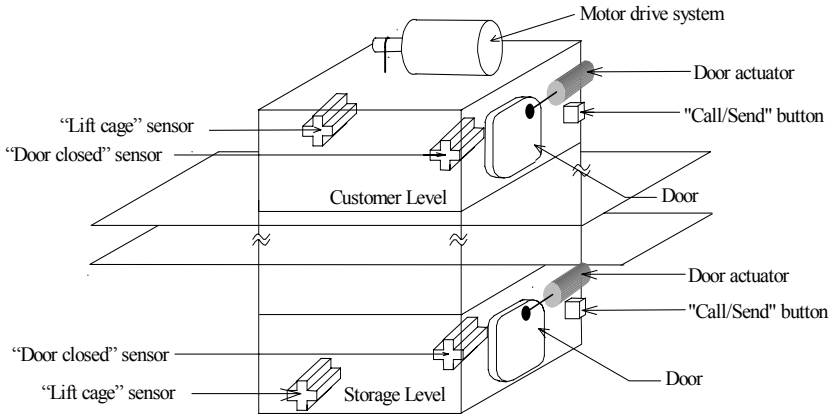



Figure 12 (a)

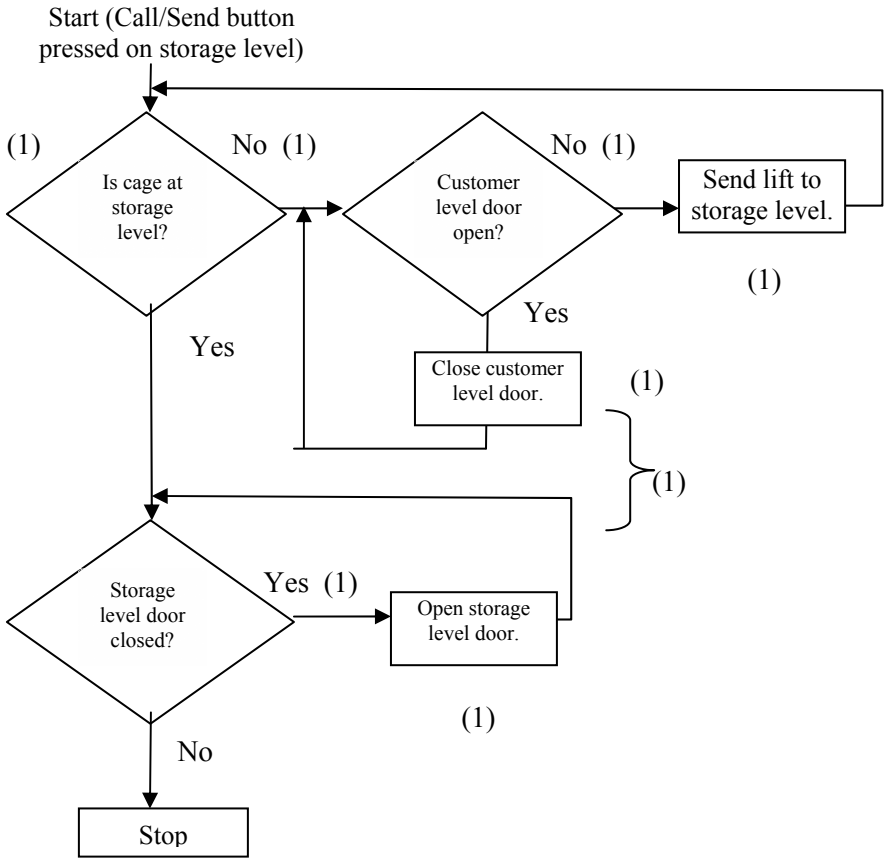
The system uses a cable mechanism driven by an electric motor to move the cage between the two levels. On each level :-

- there is a "Call/send" button to control the movement of the lift.
- there is a "Lift cage" sensor that informs the microcontroller about the cage presence.
- there is a "Door closed" sensor linked to the door.
- the door on each level is opened on arrival of the cage and closed before departure of the cage from any level.

ANSWERS COMMENCE ON NEXT PAGE

**12.** (a) Sketch a flowchart that shows the process of the lift cage moving from the customer level to the storage level. Start with "Call/Send button" being pressed on the storage level and the customer level door open.

ANSWER:




Logic (5) and Decisions (3). Total (8 marks).

Many other solutions possible and acceptable if logic and decisions are sound

**8**

(b) List the inputs and the outputs which would require interfacing to the microcontroller.

ANSWER: (½ mark each)

| | |
|---|---|
| A – storage level sensor door closed | W – Drive motor up |
| B – customer level sensor door closed | X – Drive motor down |
| C – Storage level call/send button | Y – Storage level door actuator |
| D – Customer level call/send button | Z – Customer level door actuator |
| E – Storage level lift cage position sensor | |
| F – Customer level lift cage position sensor | |

**5**

Note other minor variations are possible for instance
W & X could be W = Motor Drive & X = Motor Direction

(5 marks)

(c) The lift has a maximum load carrying capacity. It is intended to fit a sensing system that will prevent the lift operating when the load exceeds 120kg. Select a suitable sensor and briefly describe your chosen sensing system.

ANSWER: Micro switch / Floating floor or load cell or any suitable sensor and associated description of operation that takes account of scenario

(selection 1 mark, description 3 marks) **4**

(d) The system is presently controlled by a microcontroller. It is planned to change the design to PLC based control.

(i) List any **two** advantages of this change.

ANSWER: Advantages – ease of programming, ease of interfacing, PLC mainly digital, PLC robustness – these and any other appropriate advantages. (2 marks) **2**

(ii) State the design stages in the PLC design process

ANSWER: Sequential and systematic – identify I/O, allocate I/O, flowchart/sequencing, ladder diagram, simulate, implement, test and hand over.

**4**

Or other appropriate variations such as test might be divided into test and modify

(4 marks)

(e) Suggest **two** additional safety measures that could be incorporated into the system

ANSWER: Any 2 suitable safety features such as Stop switches, Door edge sensor, Guarding of motor and/or cabling, Fall arrestors in case of motor cable failure. **2**

(2 marks)

**13.** A toy car assembly station is shown in Figure Q13. Revolute robots A and B are used in the assembly of the toy cars.

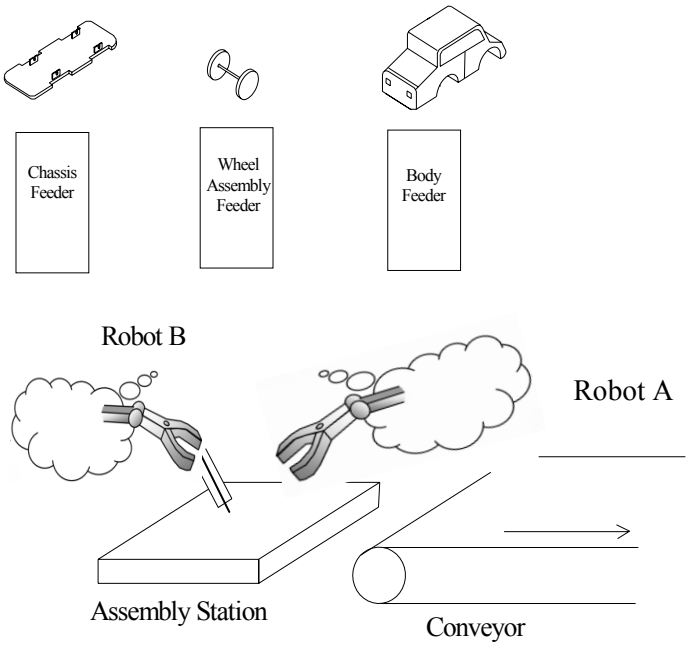



Figure Q13

The sequence of operation at the assembly station is as follows:

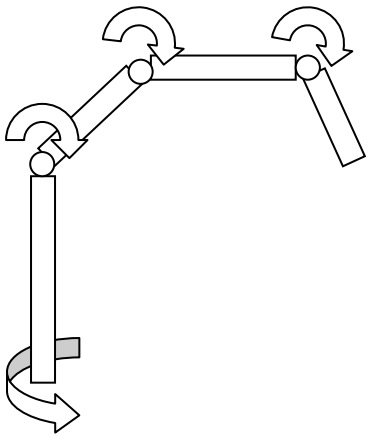
- robot A selects chassis from feeder and places it in assembly station
- robot A selects the first wheel assembly from feeder and places it in the chassis
- robot A selects a second wheel assembly from feeder and places it in the chassis
- if sensors indicate that one or both wheel assemblies are missing then a warning indicator/alarm is activated and both robots are sent to their home position
- if sensors indicate that both wheel assemblies are correctly fitted then Robot B applies adhesive to the chassis
- robot A selects a body from the feeder and places it on the chassis
- robot A then applies pressure to the assembly for 5 seconds to cure the adhesive
- robot A places the assembled toy car on the conveyor
- both robots move to their home positions which is clear of the assembly station.

Once started, the system runs continuously. If any of the feeders becomes empty, then the warning indicator/alarm is activated and both robots are sent to their home position.

**13.** (a) Both robots are revolute robots.

(i) Sketch a diagram that shows the motion of the joints of a revolute robot.

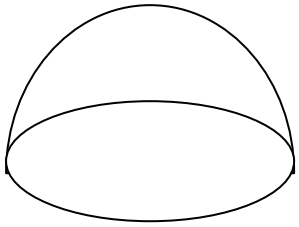
ANSWER:



Or equivalent showing <u>all rotary/revolute</u> joints. **1**

(ii) Sketch the work envelope of a revolute robot.

ANSWER:



A sphere or part of a sphere such as a hemisphere or similar 3D shape

**1**

(iii) Robot A uses electric motors for its revolute joints. State **two** reasons why this is a suitable choice for these joints.

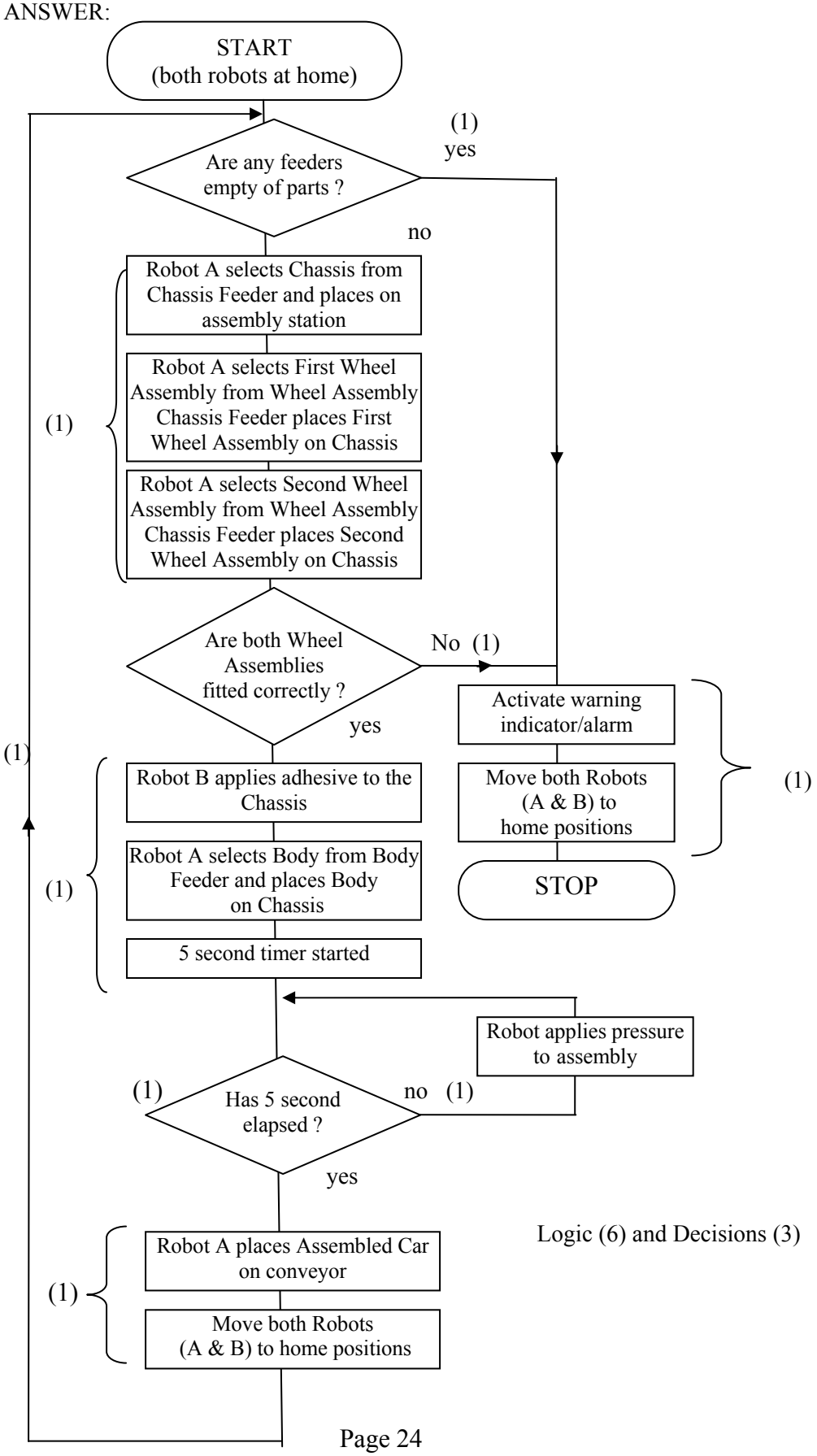
ANSWER: Any two suitable reasons such as Electric motors have a natural rotational movement, they are relatively low maintenance, easily geared to required speed/torque, relative easy speed control, choice of AC or DC.

**2**

**B (continued)**

(b) Sketch a flowchart for a complete assembly cycle for one toy car.
Start with both robots in their home position.

ANSWER:




Logic (6) and Decisions (3)

**13.**

(c) A gripper is required that could handle all the various parts and to detect when a part has been picked up correctly. Sketch and briefly describe a suitable design for the gripper stating any assumptions made.

ANSWER: A suitable design such as a mechanical gripper suitable for all types of parts with sensors in the gripping parts to detect parts. Appropriate choice, matching sketch and description with assumptions. **5**

(sketch 2 marks, description/assumptions 1 mark)

(d) Briefly describe a suitable sensor system that would enable the presence of **both** wheel assemblies to be confirmed as "fitted correctly".

ANSWER: Proximity detector, a micro switch or optical device could be chosen. May need a number up to four – appropriate choice and description that reflects requirement including ability to check first AND second wheel assemblies **2**

(e) Briefly describe how the pressure applied to the body to cure the adhesive could be controlled.

ANSWER: The robot would require a suitable pressure actuator and/or sensor to be controlled by the timer. As control is required some linkage is required between sensor and actuator. **2**

(f) Suggest **three** safety measures that could be incorporated into the assembly station.

ANSWER: Any three of Enclosure, Warning lights during operation, Light curtains, Floor sensors, Safe operating procedures or other appropriate alternatives. **3**

[END OF MARKING INSTRUCTIONS]