X028/301

NATIONAL QUALIFICATIONS 2010

FRIDAY, 11 JUNE
1.00 PM – 4.00 PM

MECHATRONICS
HIGHER

100 marks are allocated to this paper.

Attempt **all** questions in Section A (50 marks).

Attempt any **two** questions from Section B (50 marks).

Use labelled diagrams and sketches to illustrate your answers where appropriate.

All calculations must be supported by working.

A PLC datasheet is included for questions 5 and 13.

A Flowchart symbol sheet is included for questions 6 and 11.

Worksheets are provided for questions 3, 4, 6, 8, 10 and 13.

PB X028/301 6/310

SECTION A

Marks

Attempt ALL questions in this Section (50 marks).

1. (*a*) State **one** type of flow sensor that could be used in a Mechatronic System. **1**

(*b*) With the aid of a simple sketch, briefly describe the basic operation of the sensor chosen in Q1(*a*). **2**

(*c*) State **two** appropriate applications for the sensor chosen in Q1(*a*). **2**

(5)

Marks

2. The diagram in Figure Q2 shows the basic architecture of a microcontroller. Some elements have been labelled with the letters A to C.

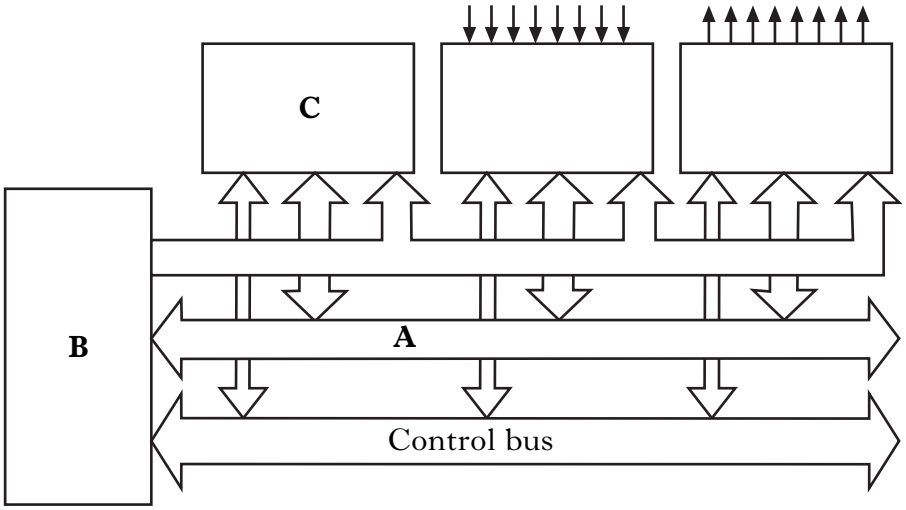


Figure Q2

(*a*) Which row in the Table Q2(*a*) correctly lists the names of the elements labelled A, B and C in Figure Q2.

Row	Element A is the ...	Element B is the ...	Element C is the ...
1	Data bus	Microprocessor Unit	Memory Unit
2	Data bus	Memory Unit	Microprocessor Unit
3	Address bus	Microprocessor Unit	Output Unit

2

Table Q2(*a*)

(*b*) Which **one** of the following three statements below correctly describes the nature of the data flow on the data bus in a microcontroller.

Statement 1: On a data bus, the data flow is uni-directional.

Statement 2: On a data bus, the data flow is bi-directional.

Statement 3: On a data bus, the data flow is omni-directional. **1**

(*c*) For a mechatronic control system within an industrial environment, state **two** advantages that a Programmable Logic Controller (PLC) based system has over an ASIC based system. **2**

(5)

[Turn over

Marks

3. Table Q3(*a*) shows a selection of codes used in Mechatronic Systems.

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

Table Q3(*a*)

(*a*) On **Worksheet Q3**, complete Table Q3(*a*) by:

(i) inserting each of the **two** missing code names; **2**

(ii) inserting each of the **four** missing code values. **2**

(*b*) An encoder disc has 1080 equally spaced slots and is rotated through 1·5 turns. On **Worksheet Q3**, determine the count that would be accumulated in a counter if the initial count was zero. **1**

(5)

Marks

4. (*a*) On **Worksheet Q4**, state the type of **each** robot in Figure Q4(*a*). **1**

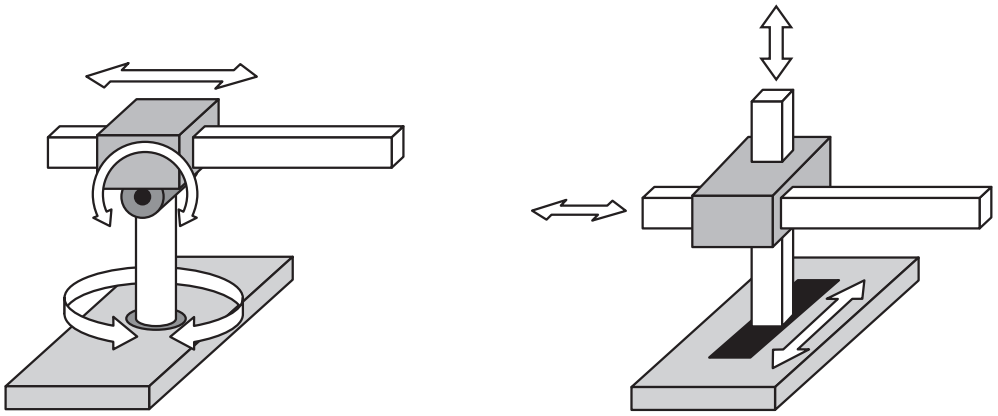


Figure Q4(*a*)

(*b*) On **Worksheet Q4**, for the cylindrical and SCARA robots shown in Figure Q4(*b*), sketch **each** work envelope. **2**

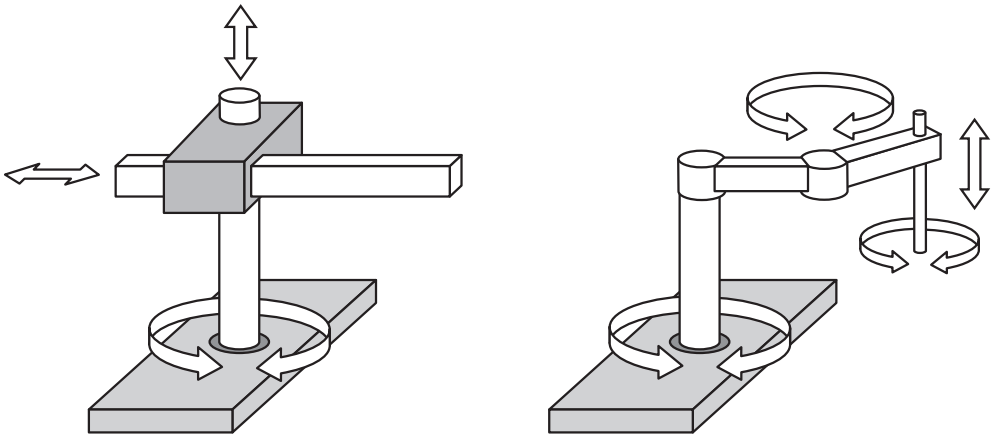


Figure Q4(*b*)

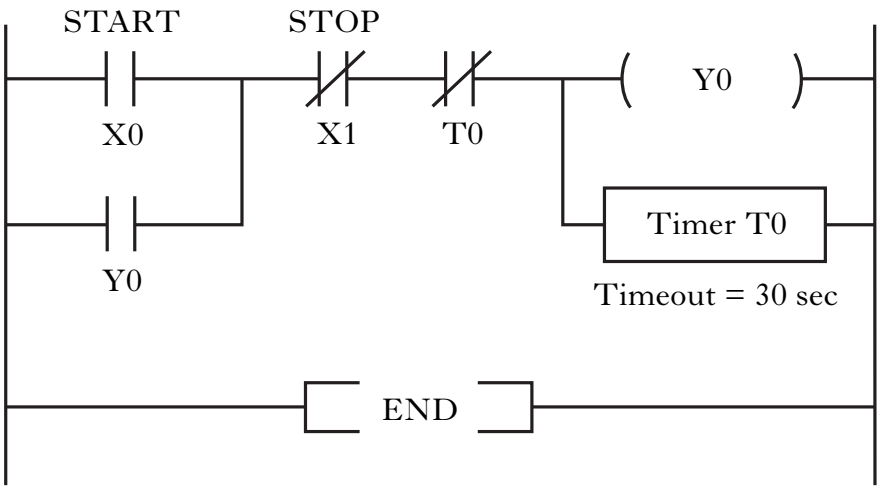
(*c*) On **Worksheet Q4**, briefly explain the differences between "lead-by-nose" and "point-to-point" methods of programming with specific reference to a robotic application. **2**

(5)

[Turn over

Marks

5. A mechatronic control system uses a Programmable Logic Controller (PLC). Ladder Diagram Q5 shows the PLC program.



Ladder Diagram Q5

Describe the operation of Ladder Diagram Q5 starting from the press (and release) of the START button, X0. **(5)**

Note: the inserted PLC Datasheet Q5/Q13 gives the PLC instruction set.

6. Figure Q6 illustrates an automated component sorting system. The system shows ARM2 activated. *Marks*

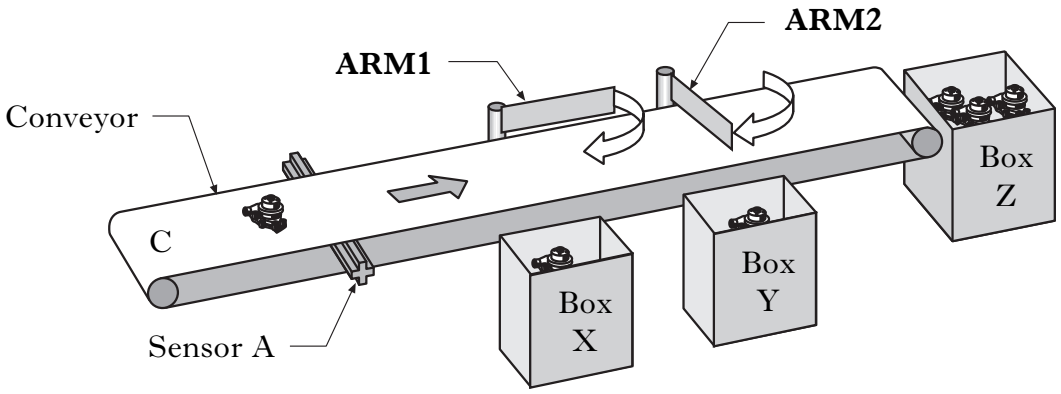


Figure Q6

The system operates as follows:

- each component is placed on the conveyor at point C;
- the component is weighed as it passes over Sensor A;
- **"overweight"** components are routed into Box X by ARM1;
- **"underweight"** components are routed into Box Y by ARM2;
- the **"correct weight"** components continue on the conveyor into Box Z;
- the conveyor runs continuously.

(*a*) On **Worksheet Q6**, complete the flowchart shown in Figure Q6(*a*) to show the operation of the automated sorting system. **3**

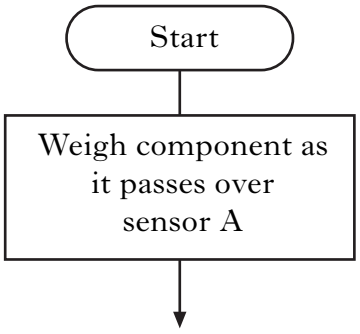


Figure Q6(*a*)

Note: the inserted Flowchart Symbol Sheet Q6/Q11 gives a suitable selection of Flowchart Symbols.

(*b*) The automated component sorting system is to be modified to count the **"correct weight"** components going into Box Z. This count has to be stored and displayed. On **Worksheet Q6**, describe the additional parts required for this modification and their basic operation. **2**

(5)

Marks

7. The graphs shown below in Figure Q7(*a*) and Figure Q7(*b*) represent the response to a step change for two different types of temperature control systems.

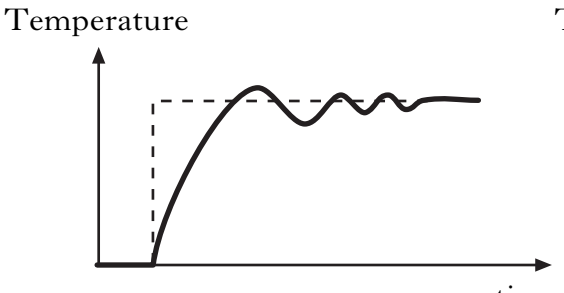


Figure Q7(*a*)

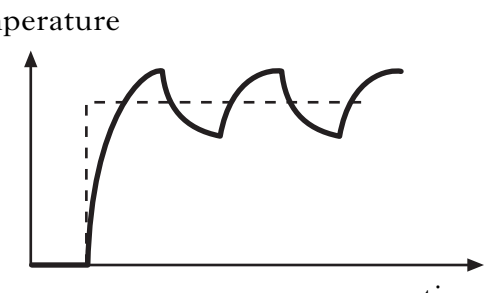


Figure Q7(*b*)

(*a*) With reference to the graphs in Figure Q7(*a*) and Figure Q7(*b*), state which row in the table below correctly describes the type of control response.

Row	**Figure Q7(*a*) represents ...**	**Figure Q7(*b*) represents ...**
1	an OPEN LOOP control system response	a PID control system response
2	a PID control system response	an ON/OFF control system response
3	an ON/OFF control system response	an OPEN LOOP control system response

2

(*b*) Briefly describe each of the following terms associated with the individual P, I and D elements within a PID control strategy.

- Error Signal
- Response Time
- Offset

3

(5)

Marks

8. Figure Q8 shows a directional motion sensor system. When a sensor is in line with a tooth on the wheel, a "logic 1" is the output. The wheel is shown rotating clockwise at a constant speed.

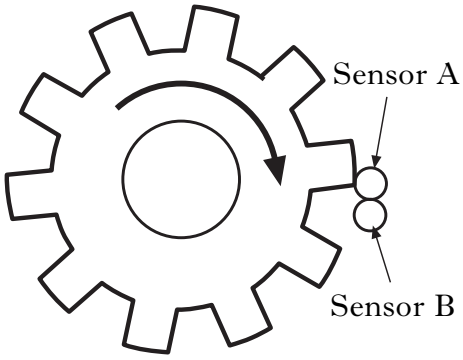
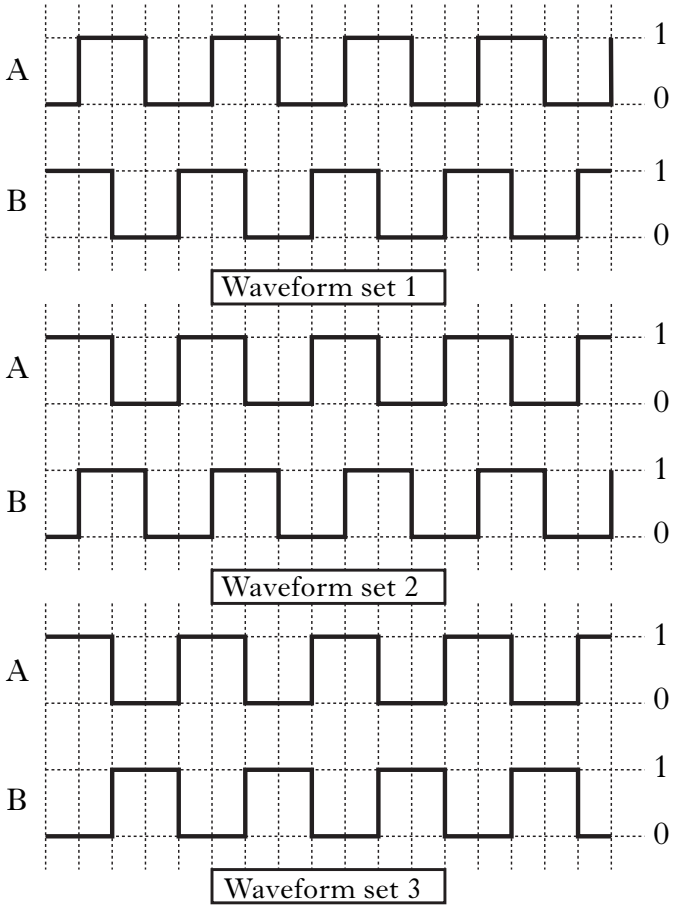


Figure Q8



(*a*) State which waveform set represents the output of sensors A and B for clockwise rotation. **2**

(*b*) On **Worksheet Q8(*b*)** draw the waveform set for anti-clockwise rotation of the toothed wheel. **2**

(*c*) In your **answer book**, state a suitable sensor for sensor A. **1**

(5)

[Turn over

Marks

9. Figure Q9 shows a schematic diagram of an automated liquid soap dispenser. When a hand is sensed in the sensor field, 5 ml of liquid soap is dispensed.

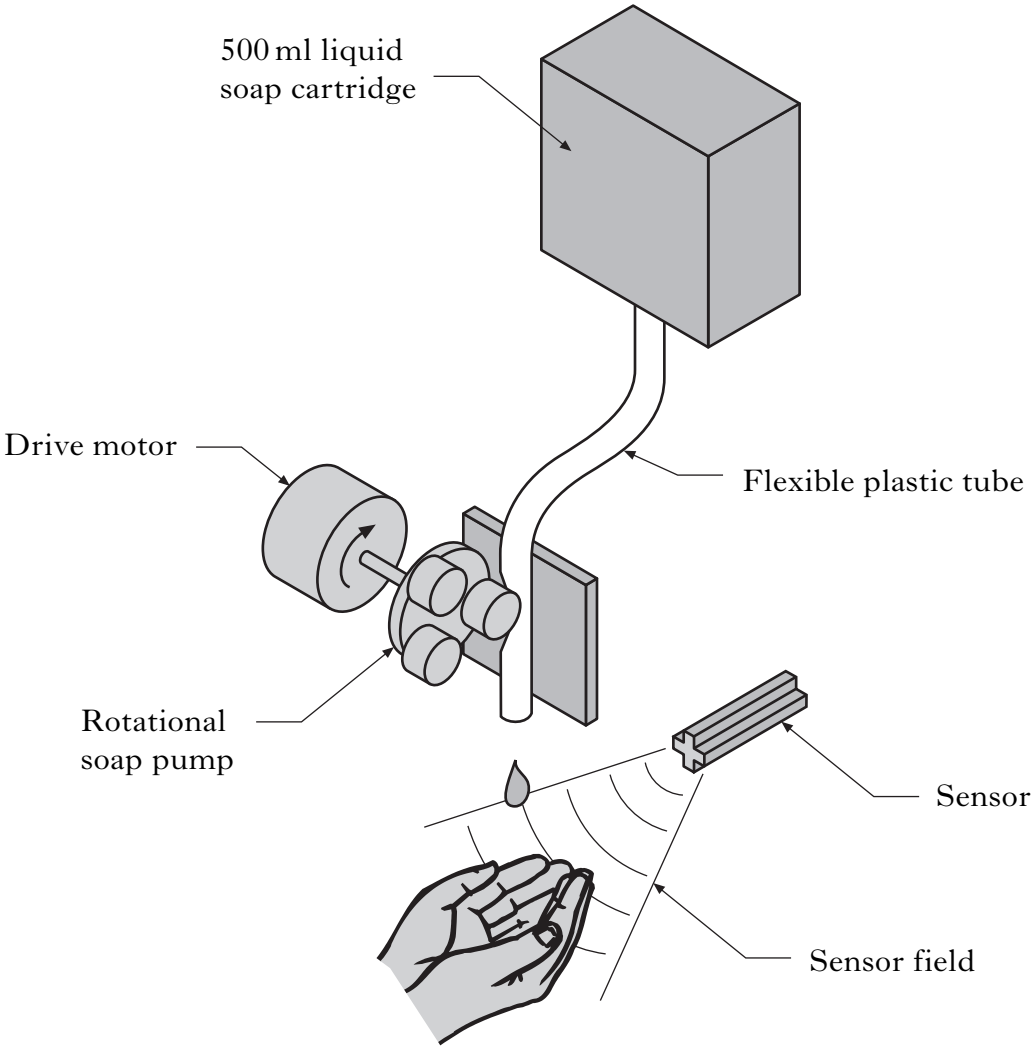


Figure Q9

(*a*) State a suitable sensor for the detection of a hand. **1**

(*b*) 5 ml of liquid soap is delivered by the rotational soap pump. Briefly describe a suitable system that would enable the number of rotations of the pump to be counted/controlled. **2**

(*c*) Briefly describe a suitable sensor/indication system that could be used to indicate when the automatic liquid soap dispenser requires the liquid soap cartridge to be replaced. **2**

(5)

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. *Marks*

(*a*) An example of a temperature sensor is

a a light emitting diode ☐
b an electric motor ☐
c a strain gauge ☐
d a micro switch ☐
e a thermocouple. ☐

(*b*) A float switch is a device used to sense

a force ☐
b pressure ☐
c level ☐
d temperature ☐
e flow. ☐

(*c*) A hydraulic actuator is used to

a count pulses ☐
b provide heat ☐
c measure level ☐
d detect pressure ☐
e provide motion. ☐

(*d*) A Programmable Logic Controller (PLC) is

a high maintenance ☐
b a pneumatic device ☐
c an electric motor ☐
d linear only ☐
e reprogrammable. ☐

(*e*) BCD is

a a sensor ☐
b a coding system ☐
c a control strategy ☐
d a mechatronic actuator ☐
e a type of electric motor. ☐

(5)

[*END OF SECTION A*]

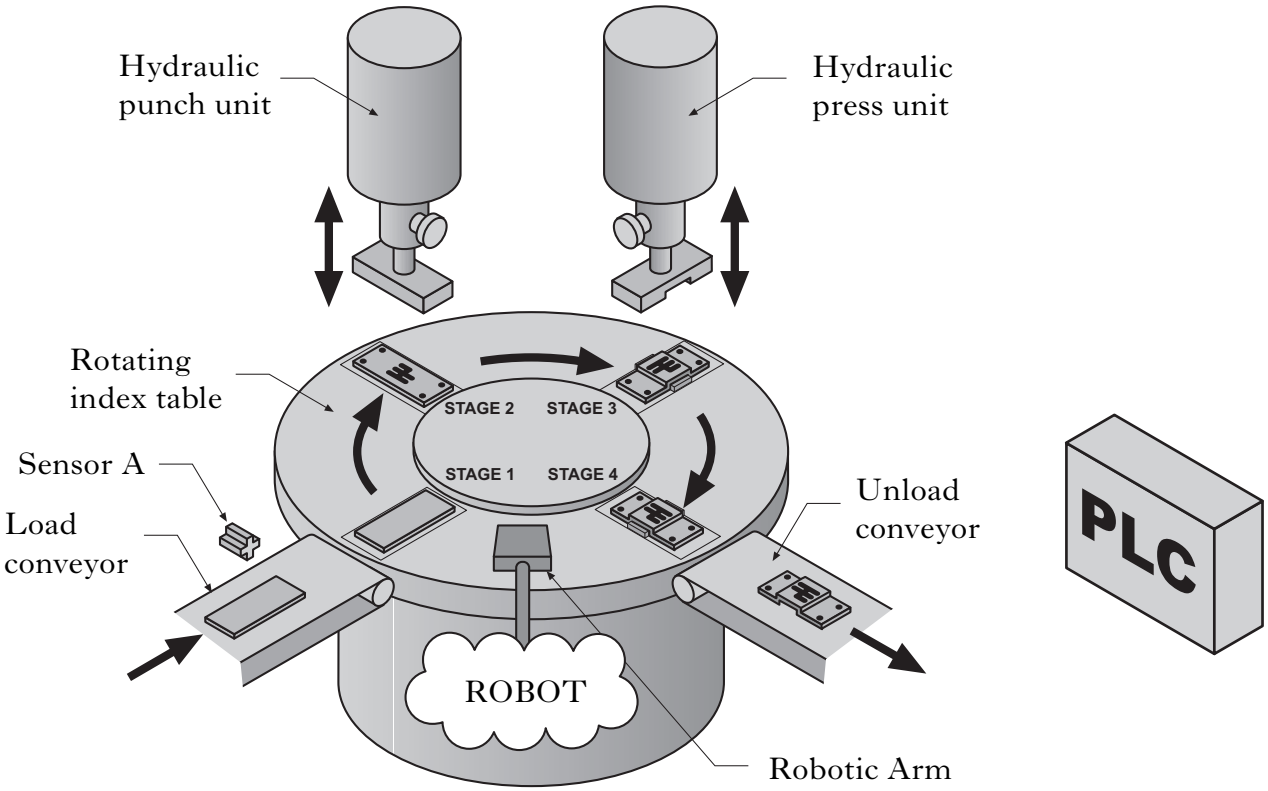
[Turn over for SECTION B on *Page twelve*

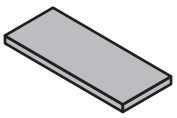
SECTION B

Attempt any TWO questions in this Section (50 marks).

Each question is worth 25 marks.

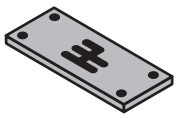
11. Figure Q11 shows a simplified schematic diagram of an automated workstation that produces sheet steel guide plates.





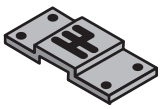
Stage 1

Blank Plate



Stage 2

Punched Plate



Stages 3 & 4

Punched & Pressed Plate

Figure Q11

The system comprises:

- Robotic arm to load/unload plates
- Load conveyor
- Sensor A
- Rotating index table
- Hydraulic punch unit
- Hydraulic press unit
- Unload conveyor
- Programmable Logic Controller (PLC).

11. (continued) *Marks*

The system operates in the following way for **each** blank plate.

Stage 1. The Robot loads a blank plate onto the rotating index table where it is magnetically clamped.

Stage 2. The blank plate is punched.

Stage 3. The punched plate is pressed into shape.

Stage 4. The punched and pressed plate is unloaded.

A signal from the PLC rotates the index table 90 degrees clockwise between each stage. The cycle continues while there are blank plates available.

The PLC sends a signal to the hydraulic punch unit to initiate the punching action. When the hydraulic punch unit has completed the punching action it returns a "punch completed" signal to the PLC.

The PLC sends a signal to the hydraulic press unit to initiate the pressing action. When the hydraulic press unit has completed the pressing action it returns a "press completed" signal to the PLC.

The system is designed in such a way that the load, punch, press and unload stages will not operate until the table has turned through the required angle. The PLC prevents the table from rotating while each stage is being carried out. The unload conveyor runs continuously.

(*a*) The load conveyor delivers blank plates. When a blank plate reaches Sensor A, the conveyor stops. When the robot removes the blank plate, the conveyor restarts and delivers the next blank plate. Suggest and describe a suitable sensor for Sensor A. **3**

(*b*) Sketch a flow chart of the system for one complete cycle of manufacture. **6**

Note: the inserted Flowchart Symbol Sheet Q6/Q11 gives a suitable selection of Flowchart Symbols.

(*c*) Give **one** advantage and **one** disadvantage of using a hydraulic power source for the hydraulic press unit. **2**

(*d*) Identify **two** safety issues with this system and state how **each** could be resolved. **4**

(*e*) Produce a labelled sketch of a suitable design for the robot gripper which would allow the loading/unloading tasks to be undertaken. **3**

(*f*) The table rotation must be 90 degrees with an error of plus or minus one tenth of a degree. Calculate how many bits would be required on a rotary encoder to achieve this resolution. **3**

(*g*) Identify:

(i) the input signals;

(ii) the output signals

which are required to interface the PLC unit with the physical hardware. **4**

(25)

12. Figure Q12 shows a schematic diagram of a crisp fryer unit used as part of a continuous manufacturing line.

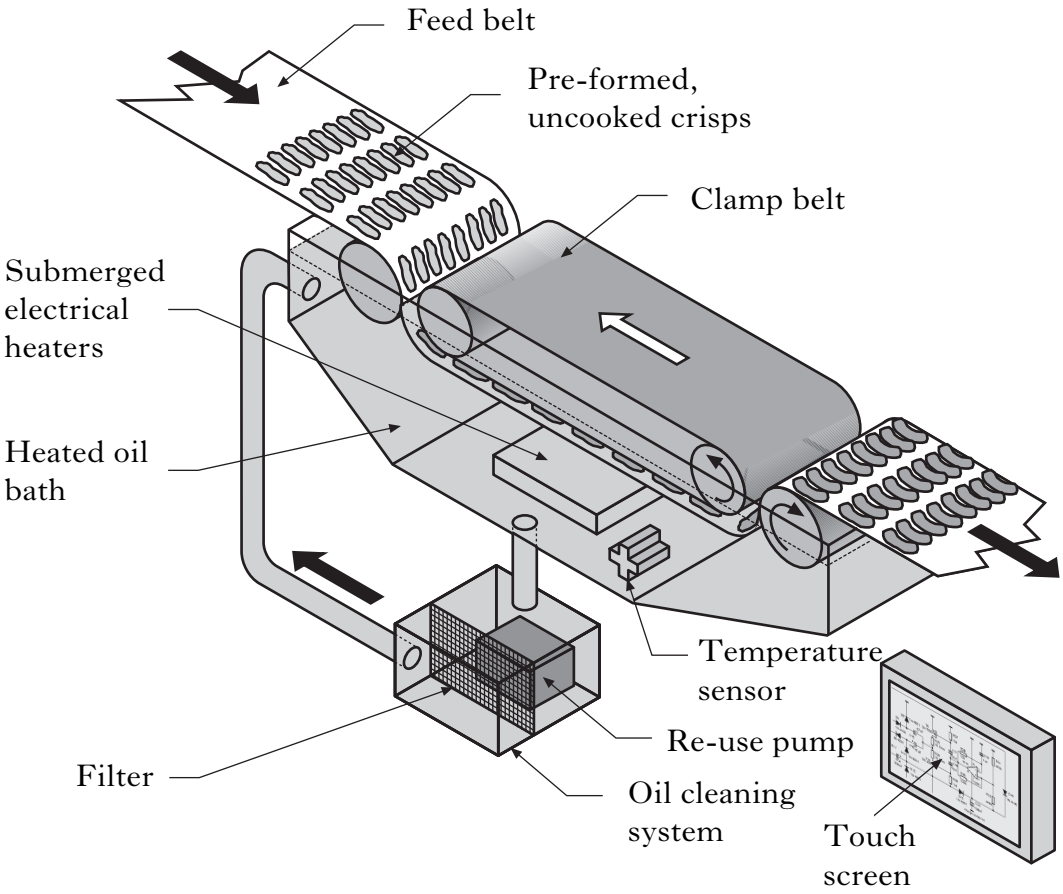


Figure Q12

The unit consists of a feed belt, clamp belt, heated oil bath, oil cleaning system with filter and re-use pump.

The pre-formed, uncooked crisps arrive on the feed belt and are held gently in place by the clamp belt whilst they travel through the heated oil bath and are cooked. The cooked crisps exit the fryer and then pass on for further processing.

The cooking oil temperature and belt speeds are computer controlled. The system is operated via a touch screen which displays a schematic diagram of the system showing the speed and temperature at strategic points.

The cooking oil is heated by submerged electrical heaters and the temperature controlled to the required value of 200 °C. The cooking oil is pumped from the bottom of the heated oil bath, passed through a filter to remove any crisp particles and is then returned into the heated oil bath.

Marks

12. (continued)

(*a*) Choose and briefly describe a suitable sensor which would allow the temperature of the cooking oil to be monitored/controlled. **2**

(*b*) The speed of the crisp fryer feed belt must be controlled accurately at 0·2m/s. Describe a suitable sensor system which would enable an accurate speed measurement to be obtained and interpreted by the computer control system. **4**

(*c*) Identify:

(i) the input signals;

(ii) the output signals

required for the computer to monitor/control the crisp fryer unit. **3**

(*d*) Sketch and briefly describe a suitable sensor system which would allow the condition of the oil cleaning system filter to be monitored. **3**

(*e*) It has been decided to add an automated oil top-up system to the existing crisp fryer unit. List the additional parts required and give a brief description of how your system would integrate and operate within the modified crisp fryer unit. **6**

(*f*) (i) Outline **two** safety hazards associated with the crisp fryer unit and how **each** may be addressed at the design stage. **4**

(ii) Briefly describe **two** practical issues, in addition to safety issues, which could arise when sensing and controlling within an environment containing very hot cooking oil. **3**

(25)

[Turn over

13. Figure Q13 shows a PLC controlled industrial shredder for paper recycling. Paper is loaded into the "paper cage". It then passes through the "shredding rollers" and the shredded paper falls into a skip.

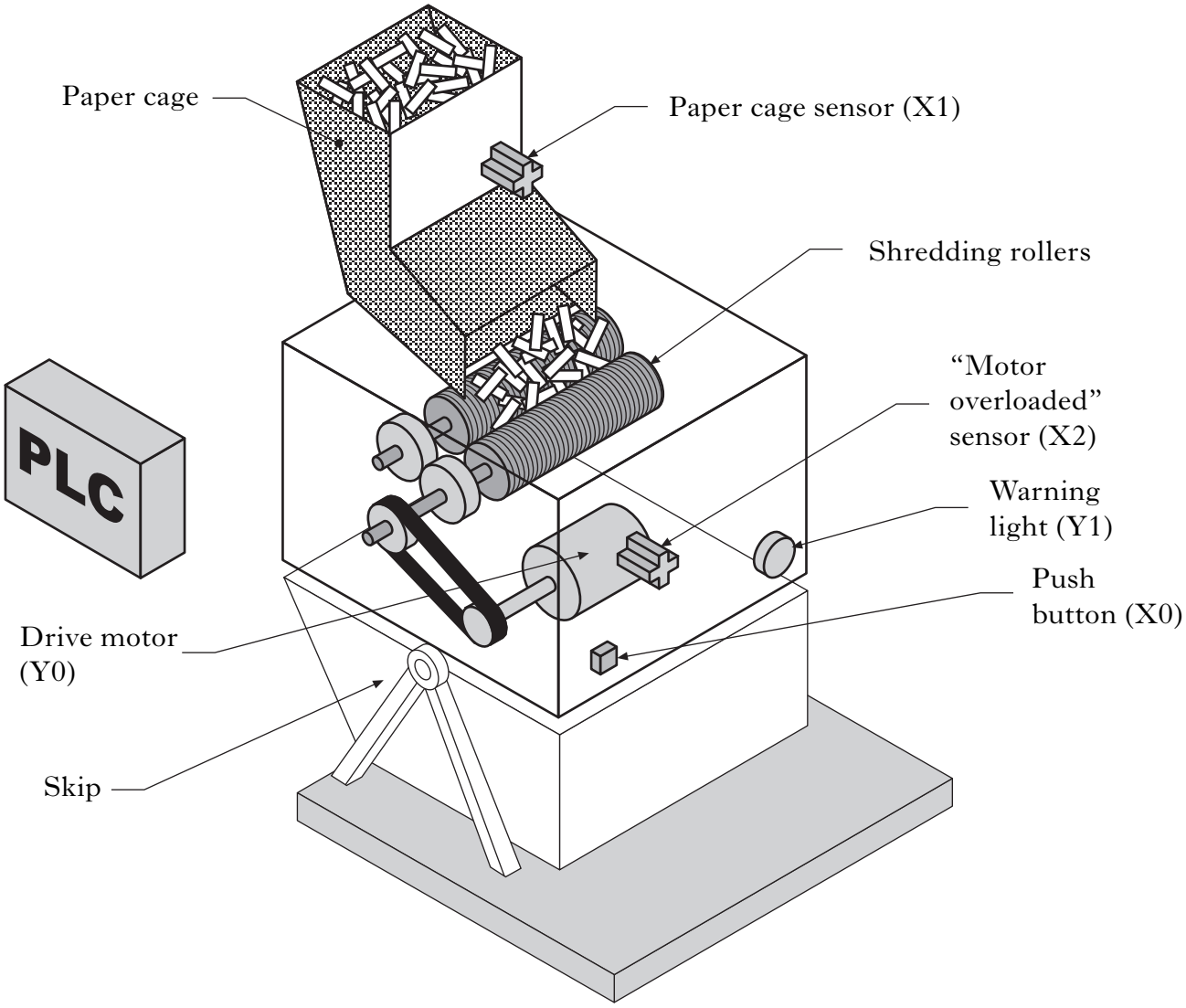


Figure Q13

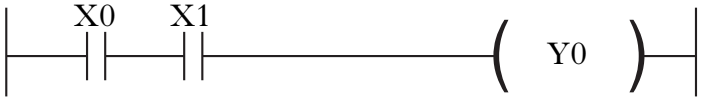
The shredder operates as follows:

- The "paper cage" sensor indicates that the paper cage is correctly positioned.
- One push button and a "paper cage" sensor are used to control the machine and are assigned to PLC inputs X0 and X1 respectively.
- The shredder should only shred paper if the push button is pressed **AND** the "paper cage" sensor is activated.
- The motor of the shredder is controlled by PLC output Y0.
- There is a "motor overloaded" sensor connected to PLC input X2 which is activated if the drive motor has overloaded.
- The "warning light" is controlled by PLC output Y1.

13. (continued) *Marks*

(*a*) A ladder diagram representing an initial PLC program controlling the shredder is shown in Ladder Diagram Q13(*a*). On **Worksheet Q13(*a*)** briefly explain the program action it represents and its effect on the operation of the shredder. **1**

Note: the inserted PLC Datasheet Q5/Q13 gives the PLC instruction set.



Ladder Diagram Q13(*a*)

(*b*) On **Worksheet Q13(*b*)**, sketch a modified ladder diagram that will ensure that the drive motor continues to run after **ONLY** the Push button (XO) is released. **2**

(*c*) Making reference to the diagram you modified in Q13(*b*), on **Worksheet Q13(*c*)**, briefly explain what would happen if the paper cage is removed and then put back while the shredder is in operation. **2**

(*d*) If the "motor overloaded" sensor (X2) detects an overload then it stops the drive motor and illuminates the "warning light" (Y1). On **Worksheet Q13(*d*)**, redraw your ladder diagram incorporating this feature. Explain the program operation with this addition in place. **6**

(*e*) As shredding progresses, the skip will become full. An addition is to be made to the system so that when this happens the shredder motor is stopped **and** a "skip full" light turned on.

(i) **On Worksheet Q13(*e*)**, state a suitable "skip full" sensor. **1**

(ii) **On Worksheet Q13(*e*)**, redraw your ladder diagram, adding the contact X3 of the "skip full" sensor to allow the program to stop the shredder motor **and** to turn on the "skip full" light on output Y2. **3**

(*f*) (i) The correct position of the paper cage is detected by a sensor. In your **answer book**, suggest a suitable sensor and briefly describe its operation. **2**

(ii) When the motor overloads it gets hot. Suggest **two** types of temperature sensor which could be used for this application and briefly describe the operation of **one** of your chosen sensors. **3**

(*g*) There is a risk that the shredder system "jams" and stops shredding material. Suggest a suitable system addition to detect this condition and briefly describe this with the aid of a sketch. **3**

(*h*) State **two** safety issues associated with this paper shredding system. **2**

(25)

[*END OF SECTION B*]

[*END OF QUESTION PAPER*]

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FOR OFFICIAL USE

Total Marks | | |

X028/302

NATIONAL QUALIFICATIONS 2010

FRIDAY, 11 JUNE
1.00 PM – 4.00 PM

MECHATRONICS
HIGHER
Worksheets for Q3, Q4, Q6, Q8, Q10 and Q13

Fill in these boxes and read what is printed below.

Full name of centre

Town

Forename(s)

Surname

Date of birth
Day Month Year

Scottish candidate number

Number of seat

To be inserted inside the front cover of the candidate's answer book and returned with it.

Worksheet Q3

(*a*) Complete Table Q3(*a*) by:

(i) inserting each of the **two** missing code names;

(ii) inserting each of the **four** missing code values.

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

Table Q3(*a*)

(*b*) An encoder disc has 1080 equally spaced slots and is rotated through 1·5 turns. Determine the count that would be accumulated in a counter if the initial count was zero.

Count = _____

Worksheet Q4

(*a*) State the type of **each** robot in Figure Q4(*a*).

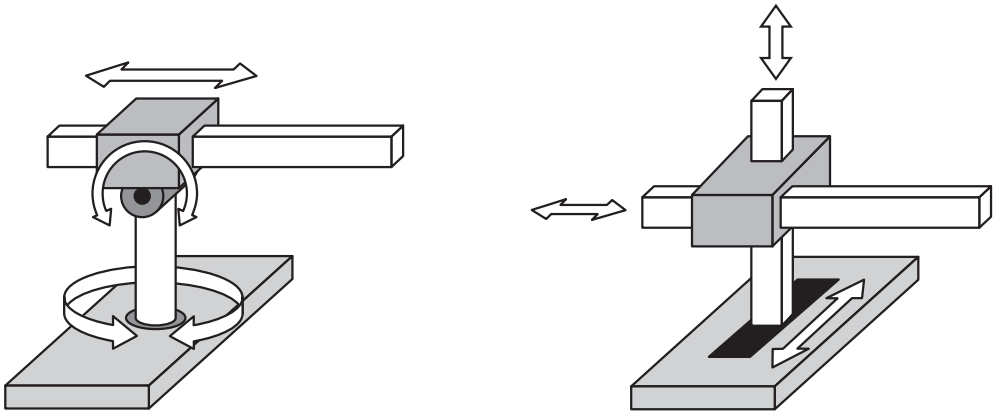


Figure Q4(*a*)

_____ _____

(*b*) For the cylindrical and SCARA robots shown in Figure Q4(*b*), sketch **each** work envelope.

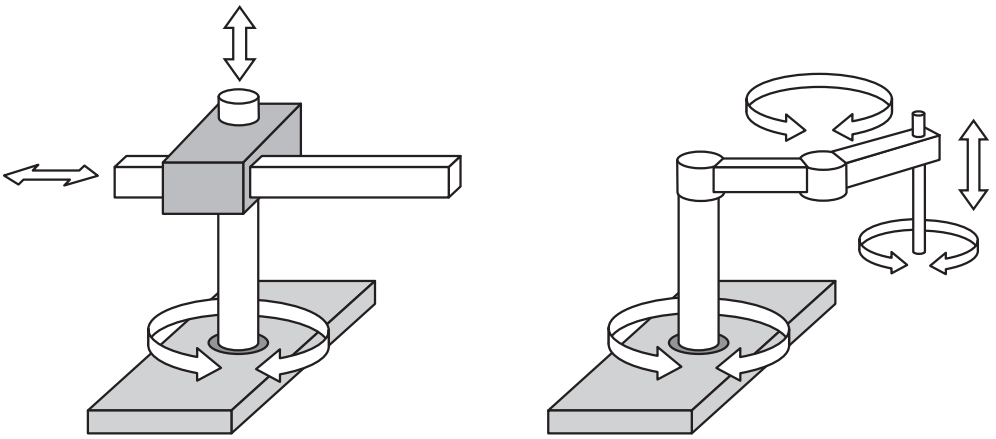


Figure Q4(*b*)

(*c*) Briefly explain the differences between "lead-by-nose" and "point-to-point" methods of programming with specific reference to a robotic application.

_____

_____

_____

_____

Worksheet Q6

(*a*) Complete the flowchart shown in Figure Q6(*a*) to show the operation of the automated sorting system.

Note: the inserted Flowchart Symbol Sheet Q6/Q11 gives a suitable selection of Flowchart Symbols.

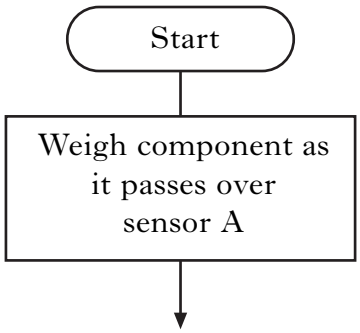
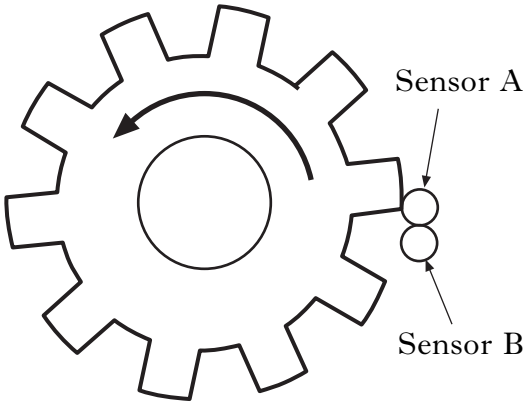


Figure Q6(*a*)

(*b*) The automated component sorting system is to be modified to count the **"correct weight"** components going into Box Z. This count has to be stored and displayed. Describe the additional parts required for this modification and their basic operation.

Worksheet Q8(*b*)

(*b*) Draw the waveform set for anti-clockwise rotation of the toothed wheel.



[Turn over

Worksheet Q10

10. This question consists of a series of multiple choice questions and answers for a number of mechatronic related themes. Answer the multiple choice question by putting a tick ☑ in the correct box.

(*a*) An example of a temperature sensor is

a	a light emitting diode	☐
b	an electric motor	☐
c	a strain gauge	☐
d	a micro switch	☐
e	a thermocouple.	☐

(*b*) A float switch is a device used to sense

a	force	☐
b	pressure	☐
c	level	☐
d	temperature	☐
e	flow.	☐

(*c*) A hydraulic actuator is used to

a	count pulses	☐
b	provide heat	☐
c	measure level	☐
d	detect pressure	☐
e	provide motion.	☐

(*d*) A Programmable Logic Controller (PLC) is

a	high maintenance	☐
b	a pneumatic device	☐
c	an electric motor	☐
d	linear only	☐
e	reprogrammable.	☐

(*e*) BCD is

a	a sensor	☐
b	a coding system	☐
c	a control strategy	☐
d	a mechatronic actuator	☐
e	a type of electric motor.	☐

Worksheet Q13

(*a*) A ladder diagram representing an initial PLC program controlling the shredder is shown in Ladder Diagram Q13(*a*). Briefly explain the program action it represents and its effect on the operation of the shredder.

Note: the inserted PLC Datasheet Q5/Q13 gives the PLC instruction set.

Ladder Diagram Q13(*a*)

_____

_____

_____

_____

(*b*) Sketch a modified ladder diagram that will ensure that the drive motor continues to run after **ONLY** the Push button (XO) is released.

Worksheet Q13 (continued)

(*c*) Making reference to the diagram you modified in Q13(*b*), briefly explain what would happen if the paper cage is removed and then put back while the shredder is in operation.

(*d*) If the "motor overloaded" sensor (X2) detects an overload, then it stops the drive motor and illuminates the "warning light" (Y1). Redraw your ladder diagram incorporating this feature. Explain the program operation with this addition in place.

Worksheet Q13 (continued)

(*e*) As shredding progresses, the skip will become full. An addition is to be made to the system so that when this happens the shredder motor is stopped **and** a "skip full" light turned on.

(i) State a suitable "skip full" sensor.

A suitable sensor is _____

(ii) Redraw your ladder diagram, adding the contact X3 of the "skip full" sensor to allow the program to stop the shredder motor **and** to turn on the "skip full" light on output Y2.

[*END OF WORKSHEETS*]

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