UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 5 Examination in Engineering: May 2023

Module Number: ME5213 **Module Name: Industrial Automation**

[Three Hours]

[Answer **all questions**, each question carries **12** marks]

This paper contains **5 questions** in **8 pages**.
Clearly state any assumptions that you may make.
In order to get **full marks**, make sure to use standard notations and correct SI units.

Q1. (a) Briefly describe the difference between dynamic and static characteristics in the context of sensors using a suitable example.

[3.0 Marks]

(b) Briefly describe the measuring principle and operation of the following sensors with suitable sketches.

(i). Inductive proximity sensor
(ii). Capacitive proximity sensor
(iii). Photoelectric sensor
(iv). Digital optical encoder

[4.0 Marks]

(c) (i). Briefly explain the advantages of employing a soft starter or a VFD over the Direct On Line (DOL) method when starting an induction motor with a significant load.

(ii). Assume you are an industrial engineer responsible for installing a motor starter for a cooling fan. The operation of the fan is as follows:

- The cooling fan activates when the plant air temperature reaches a high-temperature setpoint.
- Once the low temperature setpoint is reached, the cooling fan's speed decreases to maintain the air temperature.
- If the temperature continues to rise and surpasses the high-temperature setpoint, the fan will need to operate at a faster speed.

Assume you have a soft starter and a VFD at the site. Suggest the most suitable device for this application and provide a brief explanation for your selection.

[5.0 Marks]

Q2. (a) Briefly describe the functionality of the main components in a pneumatic system and explain the importance of the compressed air preparation process.

[3.0 Marks]

(b) The positional sketch of a feeding device that transfers workpieces from a magazine to a macininig station is shown in **Figure Q2(b)**. The initial positions of the two cylinders 1A and 2A are detected by two magnetic reed switches 1B1 and 2B1.

The system starts when the operator presses the "START" pushbutton and continues operating until the "STOP" button is pressed. The sequence consists of these steps,

- Step 1: The piston rod of cylinder 1A advances, pushing the workpiece out from the magazine.
- Step 2: The piston rod of cylinder 2A advances, feeding the workpiece to the machine station.
- Step 3: The piston rod of cylinder 1A retracts.
- Step 4: The piston rod of cylinder 2A retracts.

(i). Suggest the type of proximity sensors (for B1 and B2) that would be suitable for detecting the presence of a workpiece at both magazine feeder and machining station locations.

(ii). Create an actuation chart that represents the operation of the feeding device.

(iii). Draw a displacement step diagram for the two cylinders, showing the relationship between the piston rod positions and the operational steps.

(iv). Design the complete Electro-Pneumatic circuit of the feeding device, including both Pneumatic and Electrical circuit diagrams, to ensure efficient and continuous operation until the "STOP" button is pressed.

[9.0 Marks]

Q3. An automated industrial system has been proposed for a plastic car roof box manufacturing plant to streamline the painting process. The overall system mainly consists of three (3) painting stations and a UV treatment point. The process layout of the proposed system is shown in **Figure Q3**.

Car roof boxes are transported through the production process via three conveyor segments, with each point performing specific operations as follows.

- **Incoming conveyor:** Car roof boxes enter the system through this conveyor, and at "Paint Station 1," the roof boxes receive their initial paint coat.
- **Intermediate conveyor:** Roof boxes with a single coat of paint receive a second coat at "Paint Station 2" before being forwarded to the outgoing conveyor.

- **Outgoing conveyor:** Roof boxes with two coats of paint undergo UV treatment and receive a protective layer before being transported to the packaging area.

The overall system is controlled by a programmable logic controller (PLC). Answer the following questions by considering the design process of the automated system.

(a) Analyze the system and identify the sequence of operations and steps under each operation.

[2.0 Marks]

(b) Develop a flow chart for the whole operation by considering inputs, outputs, and decision-making points.

[2.0 Marks]

(c) Suggest suitable sensor types for each step and sketch their placement in the diagram.
Mark the positions of the sensors on Figure Q3 and attach it to your answer script.

[2.0 Marks]

(d) Develop an input/ output table with relevant labels.

[2.0 Marks]

(e) Develop a PLC program as a ladder diagram for the automated process. All inputs and outputs should be labeled and indicated in a sketch of the relevant physical system.

[4.0 Marks]

Q4. A Supervisory Control and Data Acquisition (SCADA) system comprises both software and hardware components, enabling local and remote monitoring and control of facilities in real time.

(a) Sketch, indicate, and briefly describe the main components of a SCADA system.

[3.0 Marks]

(b) List the four key considerations in the design and implementation stages of a SCADA system.

[2.0 Marks]

(c) Explain the operation of a SCADA system by using an example application.

[3.0 Marks]

(d) There is often confusion between SCADA systems and human machine interfaces (HMIs) due to their similarity. Briefly explain the difference between SCADA and HMI.

[2.0 Marks]

(e) Assume that you are the maintenance manager in a manufacturing facility. Discuss the benefits and opportunities that your department can gain by implementing SCADA systems for the plant.

[2.0 Marks]

Q5. (a) Industrial automation has effects on people, society, the environment, energy and resources savings. Briefly explain the positive impacts of industrial automation and give four separate examples.

[4.0 Marks]

(b) Suppose that you are asked to automate a manual milk powder packaging plant that consists of filling, sealing, and printing of a barcode on the milk bag. There are five sizes of powder bags based on the weights 175g, 300g, 400g, 700g, and 1kg are required to package following all the above steps. Figure Q5 shows the manual filling station. Various operations perform in the present setup are as follows.

- The required size of an empty bag is placed manually by an operator to the hopper end filling starts and stops automatically
- Weight of the powder to be filled is adjusted by the machine based on the hoper powder level and the feeding time
- Once the filling is completed, the filled powder bag is sealed and placed on a conveyor
- Another operator applies the printed barcode on the sealed bag and arranges powder bags to a cartoon based on the weight.

Answer the following questions.

(i). Identify four drawbacks of the manual process and propose possible improvements that can be achieved by automating the above manual process.

(ii). List the main steps that you will follow in automating the above manual process.

(iii). Identify sensors and actuators required to automate the manual process. Name them and briefly explain the purpose of each of them.

(iv). Propose two solutions to improve the automated system further in terms of quality of the product and production process, and saving of resources.

[8.0 Marks]

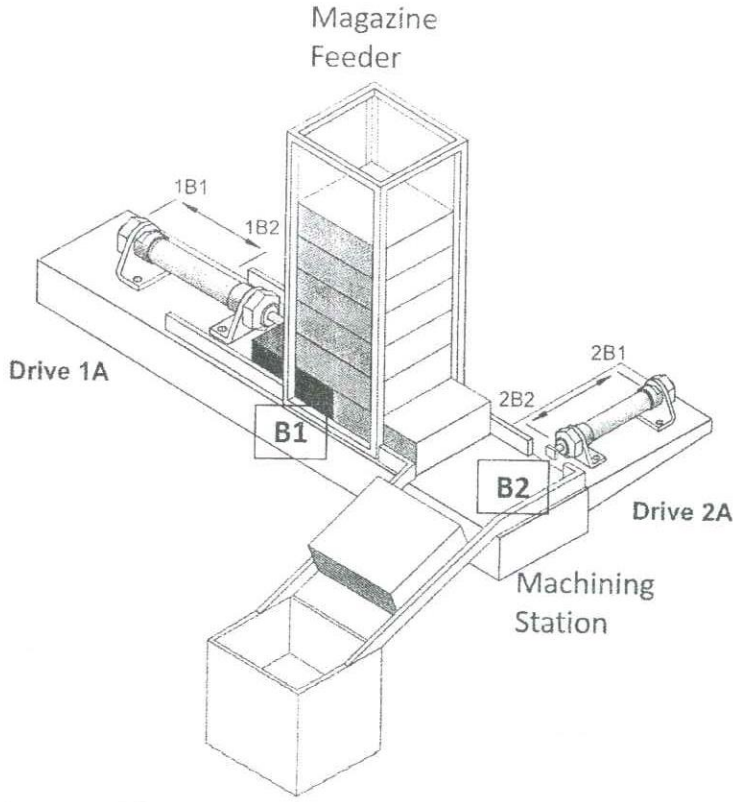


Figure Q2(b) - Positional layout of the feeding device

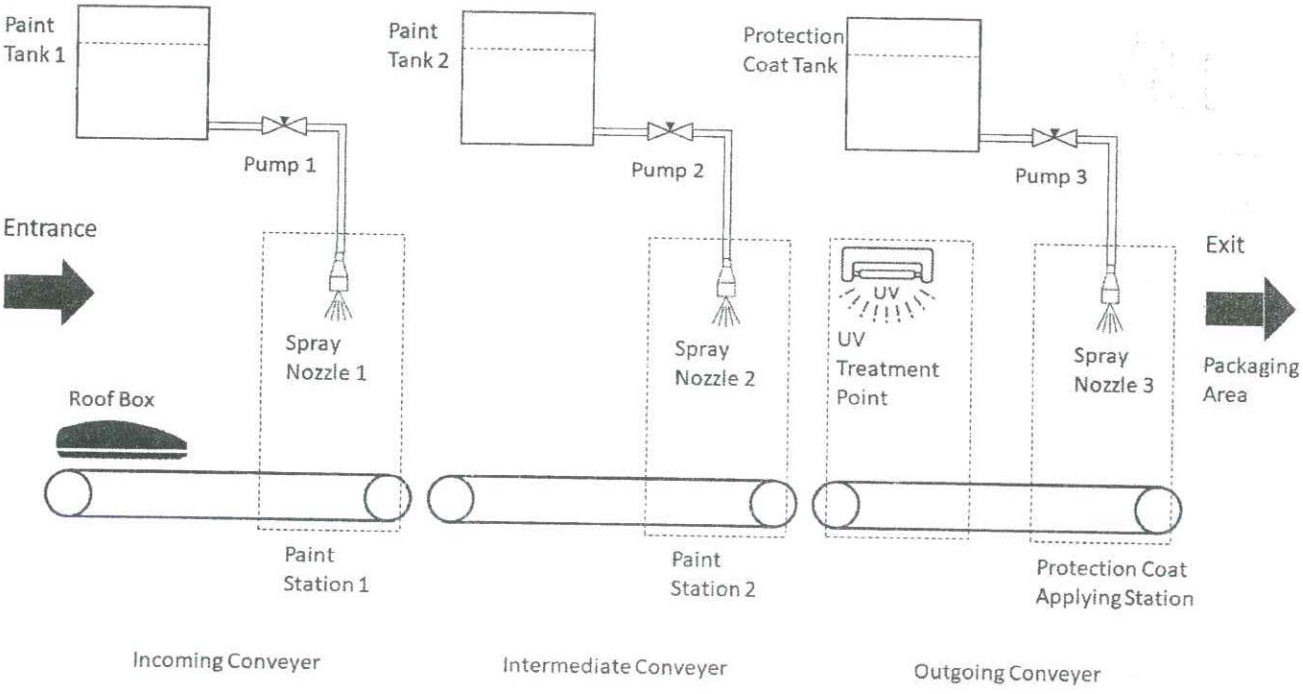
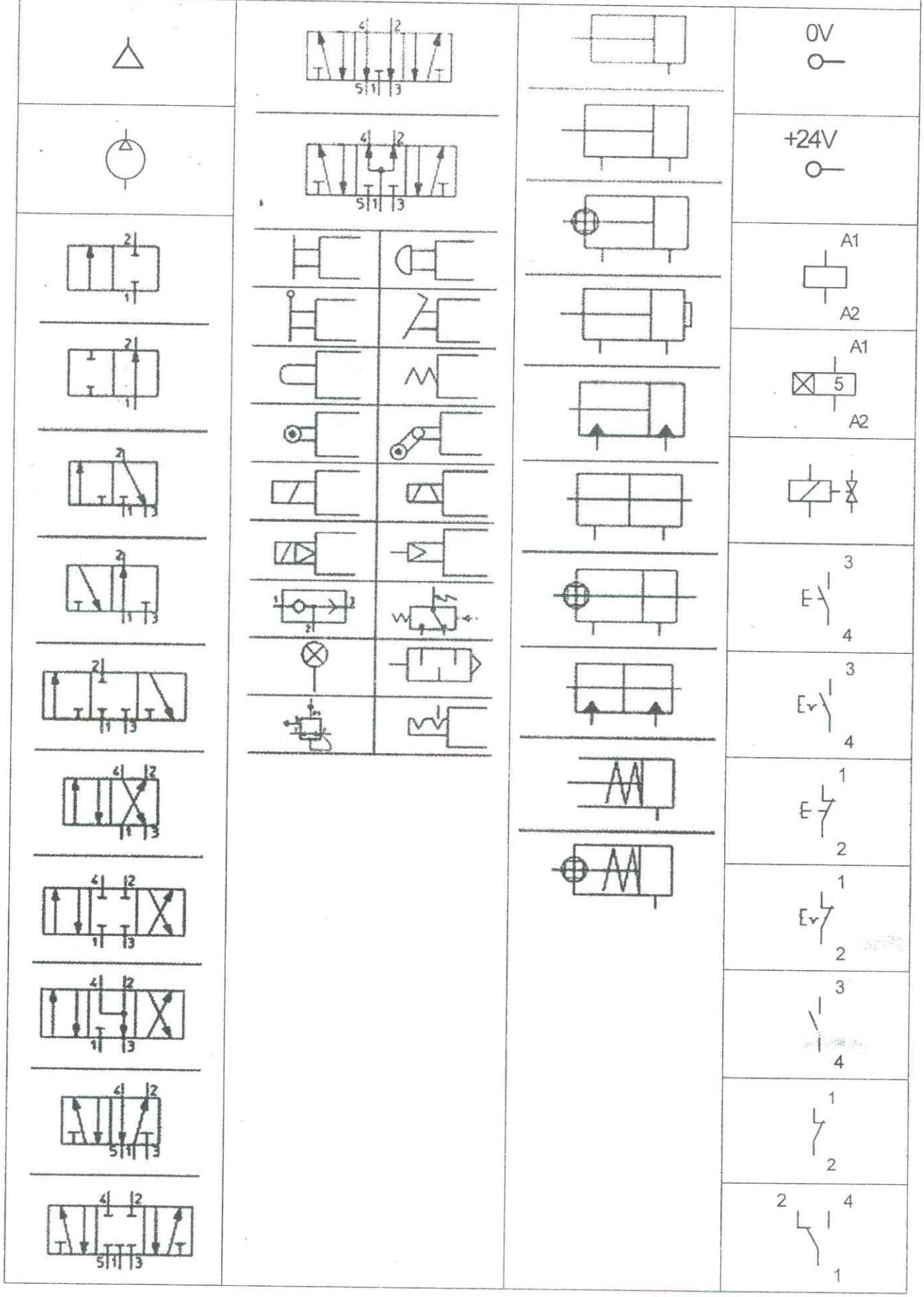
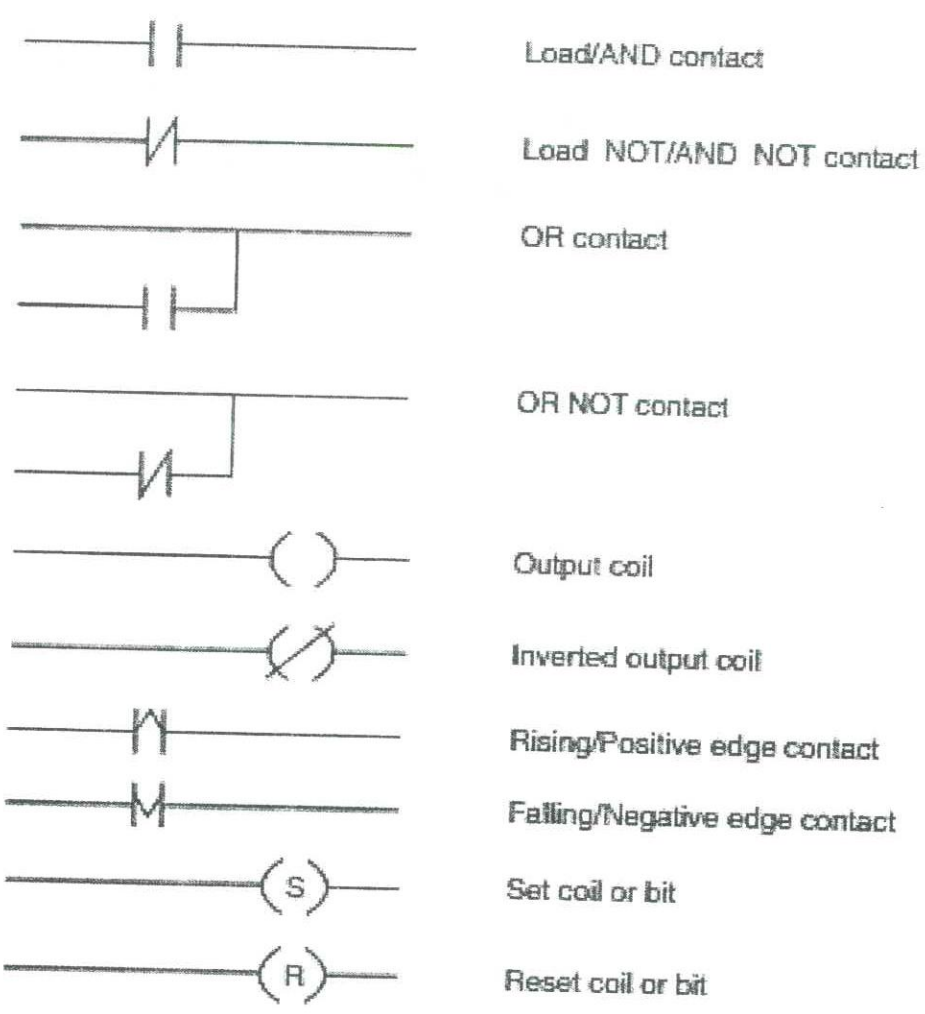


Figure Q3 - Layout of the proposed automatic painting system

Annex - A: Pneumatic and Electro-Pneumatic Symbols



Annex - B: PLC Ladder Logic Programming Symbols	
X	Input
Y	Output
M	Memory bit
S	Set
R	Reset
T	Timer
C	Counter



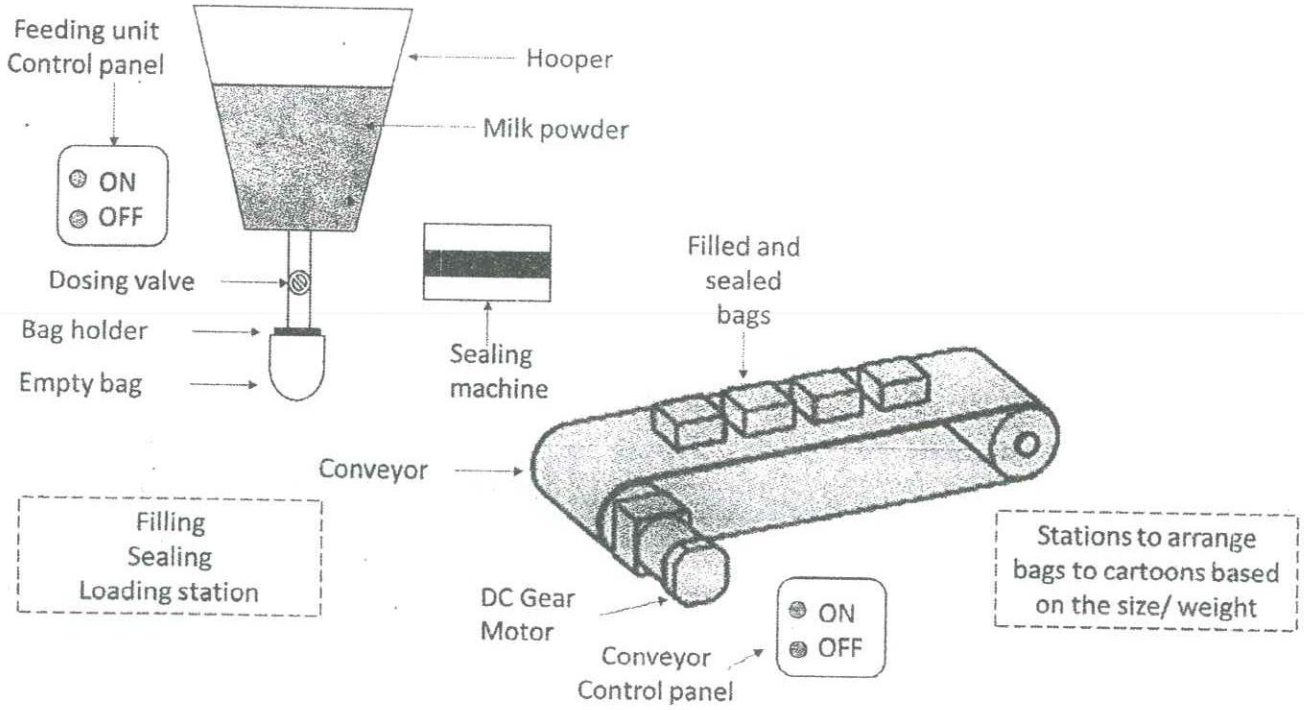


Figure Q5 - Milk Powder Packaging Station