الجامعة الوطنية
National University
Science & Technology للعلوم والتكنولوجيا
كلية عمان البحرية الدولية
International Maritime College Oman

Final Exam (Version-B)

TSQC: Statistical Quality Control

Spring 2025

Points of attention:

- For each question, the maximum earned points are specified in the question.
- Write clearly! Answers that are not readable are not marked and don't earn marks!
- All questions must be answered in the Excel workbook.
- **Download** the question data file from the **Final Exam 2025** folder on **Blackboard**.
- Save the Excel workbook with your ID and First Name e.g. **009999-24 Ahmad**
- Use the pencil only for diagrams and graphs.
- Show all the calculation steps in the respective sheet.
- When finished, submit the question paper by signing the cover page and handing it to the invigilator.
- **Upload** the workbook to the blackboard folder created for the exam, **Final Exam 2025**
- Any cheating/copying may result in an instant failing of the examination.

Exam Duration:	1 hour & 50 Minutes
Instructor's Name:	Muhammad Javed
Exam Date:	25/05/2025
Program:	PE

	40
	10

Student Information			
Name:		ID:	
Signature:			

Invigilator			
Initials:		☐ Student ID checked	
Time received:			

Question 1 **[10 Marks]**

Suppose you are a Process Engineer and responsible for evaluating the pressure drop performance in various segments of a newly installed fluid transport system at a petrochemical processing facility. Over the past month, the technical operations team has raised concerns about inconsistent pressure readings that may indicate blockages or inefficiencies in certain pipeline sections.

You instructed the team to measure pressure drop values (in kPa) across six key pipeline sections during regular operations under similar flow conditions. The acceptable pressure drop limit for these systems is under 35 kPa.

Inlet Filter	Shell-and-Tube Heat Exchanger	Vertical Separator	Reactor Inlet Pipe	Air Cooler	Surge Tank Outlet Valve
22	33	27	15	39	31
25	41	30	21	42	36
34	36	29	19	47	40
31	29	32	17	52	38
28	27	26	18	45	34
24	35	28	20	48	29
37	44	31	16	51	43
39	32	24	22	50	35
30	31	25	21	44	37
27	28	33	20	40	30
23	38	34	19	46	32
29	30	28	21	49	33
36	26	27	18	53	41
35	50	29	17	43	28
26	24	26	19	47	31

Tasks (Process Data Analysis using Excel):

1. Draw boxplots for each of the six components to visualize pressure drop distributions. (2 marks)
2. Compute the Five-Number Summary for each component. (2 marks)
3. Use the Interquartile Range (IQR) method to identify any outliers in pressure drop data. (2 marks)
4. Calculate the Pearson's Skewness Index to assess the symmetry of pressure drop distributions for each component. (2 marks)
5. Based on your analysis, provide engineering recommendations, such as checking for fouling, resizing components, or optimizing flow rates. (2 marks)

Question 2 **[10 Marks]**

Assume you are a Process Engineer at an oil refinery where a distillation column is used to separate hydrocarbons. One of the key operational performance indicators is the residence time of the feed mixture in the column before the desired separation is achieved.

Historical plant data suggests that the residence time (in minutes) follows a normal distribution with a mean of 42 minutes and a standard deviation of 5 minutes.

To improve operational planning and throughput analysis, you are tasked with applying statistical methods to evaluate the variability and reliability of the distillation process.

Tasks

1. What is the probability that a randomly selected feed batch completes distillation in less than 38 minutes? (2 marks)
2. What percentage of feed batches complete the process between 39 and 48 minutes? (2 marks)
3. What is the probability that a feed batch takes more than 50 minutes in the column? (2 marks)
4. Determine the maximum residence time within which the fastest 20% of batches complete the distillation process. (2 marks)
5. The plant manager wants to advertise that 70% of batches are completed within a certain time. What is the maximum residence time that should be stated in official documentation? (2 marks)

Question 3 **[5 marks]**

You are a Process Improvement Engineer at a natural gas processing plant. Over the past month, your operations team has tracked the number of unplanned process interruptions due to various mechanical and control-related equipment failures.

Your goal is to use the Pareto Principle (80/20 Rule) to pinpoint the few critical issues responsible for the majority of plant downtime, so you can prioritize preventive maintenance and root cause analysis efforts efficiently.

S. No.	Equipment Issue Type	Number of Interruptions
1	Gas Compressor Seal Failure	20
2	Instrument Air System Drop	13
3	Flare System Backpressure	7
4	Control Valve Stiction	18
5	Flow Transmitter Drift	9
6	Emergency Shutdown Trigger	5
7	Heat Exchanger Pressure Drop	11
8	Knock-Out Drum Overflow	6

Tasks (to be done using Microsoft Excel):

1. Construct a Pareto Chart that displays the number of interruptions by issue type, sorted in descending order. (2 marks)
2. Use the Pareto Principle (80/20 Rule) to identify which equipment issues contribute to approximately 80% of total process interruptions. (1 marks)
3. Calculate and display the cumulative percentage of interruptions for each issue on the chart. (1 marks)
4. Based on your analysis, provide engineering recommendations for process improvement or preventive maintenance actions. (1 marks)

Question 4 **[10 marks]**

You are a Process Quality Engineer at a specialty thin-film coating facility, where maintaining precise coating thickness uniformity is essential for the performance of advanced optical components.

To ensure consistent process output, you are monitoring the film thickness (in nanometers) produced by a plasma-enhanced chemical vapor deposition (PECVD) system. Your goal is to assess process stability using $\bar{X}$ (mean) and R (range) control charts.

You collected 25 subgroups, each consisting of 6 coated wafers, measured at hourly intervals. At the time of data collection, the process was believed to be operating in control.

Sample	Wafer 1	Wafer 2	Wafer 3	Wafer 4	Wafer 5	Wafer 6
1	108.49	106.59	108.94	111.57	106.30	106.30
2	111.74	109.30	105.59	108.63	105.61	105.60
3	107.73	101.26	101.83	105.31	103.96	107.94
4	104.28	102.76	111.40	106.32	107.20	102.73
5	105.37	107.33	103.55	108.13	105.20	106.12
6	105.19	112.56	106.96	103.83	109.47	103.34
7	107.63	101.12	103.02	107.59	109.22	107.51
8	106.65	106.10	102.56	104.84	105.62	110.17
9	108.03	101.71	107.97	105.84	104.97	108.84
10	110.09	109.79	104.48	106.07	107.99	109.93
11	105.56	106.44	103.68	103.41	109.44	111.07
12	106.78	110.01	108.08	105.06	108.08	111.61
13	106.89	111.69	99.14	109.47	107.26	106.10
14	107.28	101.04	106.34	108.07	111.43	105.45
15	104.57	105.49	109.75	107.99	105.41	108.54
16	107.29	109.91	104.89	106.02	105.82	102.61
17	107.89	107.78	107.02	106.30	102.75	105.74
18	105.97	104.59	106.52	108.21	112.66	107.52
19	107.77	106.78	101.24	106.92	107.18	114.39
20	106.42	107.90	106.90	103.49	110.43	109.26
21	109.37	104.27	111.21	102.79	108.76	113.57
22	104.03	105.30	107.30	105.49	102.35	107.21
23	103.81	108.42	104.24	111.65	104.65	106.03
24	109.44	103.31	107.68	110.92	102.18	107.55
25	107.78	109.35	103.29	103.04	108.57	107.89

Task 1:

Construct $\bar{X}$ (mean) and R (range) control charts using Microsoft Excel. (5 marks)

Task 2:

Analyze the control charts and address the following: (5 marks /1 mark each question)

a. Assess the chart for erratic fluctuations above or below the central line.

b. Identify any patterns or shifts (e.g. trends, runs) within the chart.

c. Highlight any notable deviations (e.g. out-of-control points).

d. Evaluate the chart for possible increased or decreased variation within the process.

e. Comment on whether over 68% of data falls within ±1 sigma of the centerline.

Question 5 **[5 marks]**

A Process Engineer is working in the quality and packaging division of a beverage manufacturing plant. The factory produces 500 mL electrolyte water bottles that are packaged into various bundle sizes for different market segments.

During a recent quality audit week, the following data was collected regarding the number of bottles in outgoing packages:

- 6 packs of 4 bottles
- 10 packs of 6 bottles
- 12 packs of 8 bottles
- 8 packs of 10 bottles
- 4 packs of 12 bottles

Tasks:

1. Construct a probability distribution for the variable x, using the actual number of good bottles per pack. (3 marks)
2. Draw a probability histogram for the distribution. (2 marks)

Rules for limits of Control Chart

1. $\mu \pm z\left(\frac{\sigma}{\sqrt{n}}\right)$
2. $\bar{p} \pm z\sigma_p$, where $\sigma_p = \sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$
3. $\bar{c} \pm z\sqrt{\bar{c}}$