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

Final Exam (Version-A)
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]**

You are a **Process Engineer** responsible for monitoring and maintaining operational safety at a chemical processing plant. Recently, plant personnel reported concerns about elevated temperatures in several key equipment units. You instructed the maintenance team to collect **temperature readings (in °C)** from six critical equipment units over different times of the day and week. It is important to note that safe operating temperature limit is 85°C.

Distillation Column	Heat Exchanger	Centrifugal Pump	Boiler	Compressor	Storage Tank
50	78	65	30	84	73
45	91	72	55	88	90
68	83	79	48	102	95
75	59	87	43	111	80
62	71	68	51	95	89
57	66	74	44	108	76
81	88	60	53	99	124
93	79	67	61	120	92
85	72	83	47	115	98
78	69	75	50	91	85
64	65	81	49	87	74
73	77	73	54	96	79
90	74	77	45	110	99
88	68	76	52	92	70
66	63	69	46	101	82

Tasks

1. Draw boxplots for each of the six equipment units using Excel Sheet. (2 marks)
2. For each unit, compute the Five-Number Summary. (2 marks)
3. Identify any outliers using the Inter Quartile Range method. (2 marks)
4. Determine the skewness of the temperature distribution for each unit, using Pearson index. (2 marks)
5. Based on your analysis, make specific recommendations. (2 marks)

Question 2 **[10 Marks]**

You are a Process Engineer at a chemical plant where a continuous reactor is used to produce a specialty polymer. The reaction completion time (in minutes) is known to follow a normal distribution with a mean of 96 minutes and a standard deviation of 8 minutes based on historical production data.

To optimize plant operations and resource planning, you are tasked with analyzing the reaction time data using statistical tools.

Tasks

1. What is the probability that a randomly selected batch completes in less than 90 minutes? (2 marks)
2. What percentage of batches are completed between 88 and 104 minutes? (2 marks)
3. What is the probability that a batch will take more than 108 minutes to complete? (2 marks)
4. Determine the maximum completion time within which the fastest 10% of batches are completed. (2 marks)
5. The engineering team wants to advertise that 90% of batches complete on time. What should be the maximum completion time promised in plant documentation? (2 marks)

Question 3 **[5 marks]**

You are a **Process Improvement Engineer** at a chemical processing facility. Over the past month, your team recorded the number of production stoppages due to various equipment-related issues. You want to use the **Pareto Principle (80/20 Rule)** to identify the few key problems that are causing the majority of downtime, so that maintenance resources can be focused effectively.

The table below shows the number of stoppages caused by different types of equipment issues:

S.No.	Issue Type	Number of Stoppages
1	Pump Failure	18
2	Valve Malfunction	12
3	Sensor Error	9
4	Compressor Overload	22
5	Power Supply Issues	5
6	Control System Crash	14
7	Heat Exchanger Fouling	8
8	Leak in Piping	6

Tasks

1. Using Excel, construct a Pareto Chart based on the number of stoppages. (2 marks)
2. Apply the Pareto Principle (80/20 Rule) to identify the top issues that contribute to approximately 80% of the total stoppages. (2 marks)
3. Calculate the cumulative percentage of stoppages for each issue in accordance with the chart. (1 marks)
4. Based on your findings, provide recommendations for process improvement or preventive maintenance planning. (1 marks)

Question 4 **[10 marks]**

In semiconductor manufacturing, the hard-bake process works hand in hand with photolithography. Our aim is to achieve precise control over the flow width of the resist within this process by employing **x-bar** and **R** charts. We've conducted twenty-five sets of measurements, with each set comprising five wafers, to gauge the flow width when we believe the process is operating within acceptable bounds. These measurements were taken at hourly intervals between each sample or subgroup. Below is the data table containing the flow width measurements in microns:

Sample Number	1	2	3	4	5
1	169.14	145.73	167.44	132.35	141.28
2	161.09	146.66	160.75	143.14	135.92
3	156.74	143.24	149.32	142.84	148.71
4	155.07	128.31	138.41	150.28	163.52
5	164.41	143.63	152.65	156.04	127.35
6	141.98	132.81	135.74	159.55	154.51
7	151.44	141.77	183.66	162.74	150.64
8	155.19	160.67	166.37	141.9	143.03
9	136.88	151.76	153.55	138.84	172.77
10	152.2	146.27	150.89	140.39	166.97
11	141.81	159.28	142.78	141.58	176.67
12	175.59	139.08	157.77	158.21	133.55
13	119.28	163.98	144.47	128.56	141.06
14	149.69	164.58	158.93	149.51	140.36
15	154.71	124.97	159.96	135.89	128.63
16	186.62	118.39	151.71	157.47	153.01
17	144.49	150.14	139.57	136.8	172.69
18	155.73	162.1	130.57	141.63	138.64
19	172.47	151.16	165.41	157.96	141.85
20	176.01	138.2	123.61	171.06	144.12

Task-1: Construct X-bar and R control charts. (5 marks)

Task-2: Identify special causes in the charts and respond to the following actions: (5 marks)

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

b. Identify any patterns or shifts discernible within the chart.

c. Highlight any notable deviations that stand out prominently.

d. Evaluate the chart for possible variations within the process.

e. Comment on the chart if over 68% of the data falls within the 1-sigma range.

Question 5 **[5 marks]**

A factory packages 330 milliliters of water bottles for retail sale. The bottles are sold in 3-pack, 6-pack, 9-pack, and 12-pack formats. During one week, the factory ships out 7 three-packs, 12 six-packs, 9 nine-packs and 4 twelve-packs.

Let the random variable $\boldsymbol{x}$ represent the number of bottles in a randomly selected package.

Tasks:

1. Construct a probability distribution for the variable $\boldsymbol{x}$. (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. $\bar{c} \pm z\sqrt{\bar{c}}$