QUESTIONS:

1. **Identify all the statements below regarding control charts that are True:**

   A. A control chart is constructed based on acceptance sampling requirements
   B. If a process is in statistical control, it will never produce a unit outside of the control limits.
   C. The key concept of rational subgrouping is that the variability within a sample should be minimized resulting in a homogenous sample.
   D. Variable control charts work in pairs. One controls for the central tendency of the process while the other controls for the variation within the process

   - A, B
   - C, D
   - A, C
   - B, D

2. **Fill in the blank: A _____ is defined as a collection of units that are all produced under the same conditions.**
   - Rational Subgroup
   - Proper Sample Size
   - Heterogenous Sample
   - Acceptance Sample

3. **The Acme Brick company measures the weight of bricks coming off the production line. 15 bricks are measured per sub-group. Which of the following control charts is most appropriate?**
   - X-bar and R chart
   - X-bar and S Chart
   - P Chart
   - C Chart

4. **Using the following data points from these 5 sub-groups, calculate R-bar:**
   - 2
   - 3
   - 4
   - 5

Sub-group	Sample 1	Sample 2	Sample 3
1	12	15	16
2	14	12	13
3	10	13	13
4	14	16	16
5	14	12	16

5. **You're manufacturing a widget and using an X-bar and R chart to control the critical feature of the product. Your normal process has the following attributes: X-double bar is 225, R-bar is 12, n = 8.**
   Identify the upper control limits for the range chart:
   - 5.73
   - 18.23
   - 22.37
   - 24.17

6. **You're manufacturing a widget and using an X-bar and R chart to control the critical feature of the product. Your normal process has the following attributes: X-double bar is 225, R-bar is 12, n = 8.**
   Identify the lower control limits for the X-bar chart:
   - 220.52
   - 229.48
   - 233.14
   - 218.71

7. **You're manufacturing a widget and using an X-bar and R chart to control the critical feature of the product. Your normal process has the following attributes: X-double bar is 36, R-bar is 4, n = 5.**
   Identify the upper control limits for the X-bar chart:
   - 37.12
   - 38.31
   - 39.32
   - 40.58

8. **You manufacture a widget and use an x-bar and S chart to monitor your process, where you sample 5 units in each subgroup, and s-bar = 4.2. Estimate the population standard deviation for this process.**
   - 4.2
   - 2.1
   - 3.9
   - 4.5

9. **You manufacture a widget and use an x-bar and R chart to monitor your process, where you sample 3 units in each subgroup, and R-bar = 16.0. Estimate the population standard deviation for this process.**
   - 16.0
   - 9.5
   - 27.1
   - 13.2

10. You're manufacturing a widget and using an X-bar and S chart to control the critical feature of the product. Your normal process has the following attributes: X-double bar is 12.5, S-bar is 1.6, n = 10.
Identify the lower control limits for the X-bar chart:

- 9.65
- 10.94
- 11.26
- 14.06

11. You're manufacturing a widget and using an X-bar and S chart to control the critical feature of the product. Your normal process has the following attributes: X-double bar is 12.5, S-bar is 1.6, n = 10.
Identify the upper control limits for the S chart:

- 2.216
- 2.746
- 3.186
- 3.347

12. **You're manufacturing a widget and using an I-MR to control the critical feature of the product. You use 3 consecutive samples to measure the moving range, which you've assessed the average moving range to be 3.265. What is the upper control limit of the moving range chart?**

- 6.75
- 8.41
- 9.81
- 10.23

13. You're manufacturing a widget and using an I-MR where you measure 3 consecutive samples to control the critical feature of the product. Your process has the following attributes: $\bar{X} = 1.25, \overline{MR} = 0.55$
Identify the upper control limits for the I chart:

- 0.275
- 1.80
- 2.225
- 2.713

14. Pencil Makers Incorporated uses an x-bar and R chart of n=5 to monitor the length of pencils coming off the production line. The inspector takes two samples, measures the length and plots their values on the X-bar chart as both data points are outside of the upper control limit and decides to stop the process. What does this mean?

- Only the process range is out of statistical control
- Only the process average is out of statistical control
- Both the average and range are out of statistical control
- Nothing, the inspector is not executing the control chart appropriately

15. What factor determines which variable control chart should be used?

- Defects v. defectives
- The accuracy of the measurement system being used
- The acceptance sampling plan associated with your product
- The number of units sampled within each subgroup

SOLUTIONS:

1. **Identify all the statements below regarding control charts that are True:**
   A. A control chart is constructed based on acceptance sampling requirements – **False**
   B. If a process is in statistical control, it will never produce a unit outside of the control limits. – **False**
   C. The key concept of rational subgrouping is that the variability within a sample should be minimized resulting in a homogenous sample **- True**
   D. Variable control charts work in pairs. One controls for the central tendency of the process while the other controls for the variation within the process **– True**

- A, B
- **C, D**
- A, C
- B, D

2. **Fill in the blank: A _____ is defined as a collection of units that are all produced under the same conditions.**
   - **Rational Subgroup**
   - Proper Sample Size
   - Heterogenous Sample
   - Acceptance Sample

3. **The Acme Brick company measures the weight of bricks coming off the production line. 15 bricks are measured per sub-group. Which of the following control charts is most appropriate?**
   - X-bar and R chart
   - **X-bar and S Chart**
   - P Chart
   - C Chart

4. **Using the following data points from these 5 sub-groups, calculate R-bar:**
   - 2
   - **3**
   - 4
   - 5

First, we must solve for the Range value for each sub-group, shown in the far-right hand column.

Sub-group	Sample 1	Sample 2	Sample 3	Range
1	12	15	16	4
2	14	12	13	2
3	10	13	13	3
4	14	16	16	2
5	14	12	16	4
				3 R-Bar

Then we must take the average value of the 5 sub-group ranges to find the average range value of 3 (R-bar).

5. You're manufacturing a widget and using an X-bar and R chart to control the critical feature of the product. Your normal process has the following attributes: **X-double bar is 225, R-bar is 12, n = 8.**
Identify the upper control limits for the range chart:

- 5.73
- 18.23
- **22.37**
- 24.17

First, we must look up the constants required to calculate the control limits for the range chart using the sample size (n=8), and we find $D_3 = 0.136$ and $D_4 = 1.864$.

Now we can calculate the control limits for the Range control chart:

$$UCL_R = D_4 * \bar{R} = 1.864 * 12 = 22.37$$

X-Bar and R Chart				
Subgroup Sample Size	X-Bar Factor	Range Factors		Variance Factor
n	A_2	D_3	D_4	d_2
2	1.880	-	3.267	1.128
3	1.023	-	2.575	1.693
4	0.729	-	2.282	2.059
5	0.577	-	2.115	2.326
6	0.483	-	2.004	2.534
7	0.419	0.076	1.924	2.704
8	0.373	0.136	1.864	2.847
9	0.337	0.184	1.816	2.970
10	0.308	0.223	1.777	3.078
15	0.223	0.347	1.653	3.472
20	0.180	0.415	1.585	3.735
25	0.153	0.459	1.541	3.931

6. You're manufacturing a widget and using an X-bar and R chart to control the critical feature of the product. Your normal process has the following attributes: **X-double bar is 225, R-bar is 12, n = 8.**
Identify the lower control limits for the X-bar chart:

- **220.52**
- 229.48
- 233.14
- 218.71

$$\textbf{\textit{Lower Control Limit}}: \boldsymbol{LCL_{\bar{X}}} = \bar{\bar{X}} - A_2\bar{R}$$

The A2 constant for a subgroup sample size of 8 is 0.373.

$$\boldsymbol{LCL_{\bar{X}}} = \bar{\bar{X}} - A_2\bar{R} = 225 - 0.373 * 12 = \mathbf{220.52}$$

7. You're manufacturing a widget and using an X-bar and R chart to control the critical feature of the product. Your normal process has the following attributes: **X-double bar is 36, R-bar is 4, n = 5.**
Identify the upper control limits for the X-bar chart:

- 37.12
- **38.31**
- 39.32
- 40.58

$$\textbf{\textit{Upper Control Limit}}: \boldsymbol{LCL_{\bar{X}}} = \bar{\bar{X}} + A_2\bar{R}$$

The A2 constant for a subgroup sample size of 5 is 0.577

$$\boldsymbol{LCL_{\bar{X}}} = \bar{\bar{X}} - A_2\bar{R} = 36 + 0.577 * 4 = \mathbf{38.31}$$

8. **You manufacture a widget and use an x-bar and S chart to monitor your process, where you sample 5 units in each subgroup, and s-bar = 4.2. Estimate the population standard deviation for this process.**
   - 4.2
   - 2.1
   - 3.9
   - **4.5**

   We divide S-bar by the factor c_4, which is based on the n=5 sample size.

$$\textbf{Population Standard Deviation} = \hat{\sigma} = \frac{\bar{s}}{C_4} = \frac{4.2}{0.9400} = 4.5$$

9. **You manufacture a widget and use an x-bar and R chart to monitor your process, where you sample 3 units in each subgroup, and R-bar = 16.0. Estimate the population standard deviation for this process.**
   - 16.0
   - **9.5**
   - 27.1
   - 13.2

   We divide R-bar by the factor d_2, which is based on the n=3 sample size.

$$\textbf{Population Standard Deviation} = \hat{\sigma} = \frac{\bar{R}}{d_2} = \frac{16}{1.693} = 9.5$$

10. **You're manufacturing a widget and using an X-bar and S chart to control the critical feature of the product. Your normal process has the following attributes:** **X-double bar is 12.5, S-bar is 1.6, n = 10.**
    Identify the lower control limits for the X-bar chart:
    - 9.65
    - **10.94**
    - 11.26
    - 14.06

$$\boldsymbol{UCL_{\bar{X}}} = \bar{\bar{X}} - A_3\bar{s}$$
$$At\ a\ sample\ size\ of\ 10, the\ A_3\ factor = 0.975$$
$$\boldsymbol{UCL_{\bar{X}}} = 12.5 - 1.6 * 0.975 = \mathbf{10.94}$$

11. You're manufacturing a widget and using an X-bar and S chart to control the critical feature of the product. Your normal process has the following attributes: X-double bar is 12.5, S-bar is 1.6, n = 10.
Identify the upper control limits for the S chart:

- 2.216
- **2.746**
- 3.186
- 3.347

$$\boldsymbol{UCL_s} = B_4\bar{s}$$

$$At\ a\ sample\ size\ of\ 10, the\ B_4 = 1.716.$$

$$\boldsymbol{UCL_s} = 1.716 * 1.6 = \mathbf{2.746}$$

12. **You're manufacturing a widget and using an I-MR to control the critical feature of the product. You use 3 consecutive samples to measure the moving range, which you've assessed the average moving range to be 3.265. What is the upper control limit of the moving range chart?**

- 6.75
- **8.41**
- 9.81
- 10.23

$$UCL_{MR} = D_4\overline{MR}$$

$$When\ using\ three\ consecutive\ samples\ to\ measure\ the\ moving\ range, the\ D_4\ factor\ is\ 2.575.$$

$$UCL_{MR} = 2.575 * 3.265 = \mathbf{8.41}$$

13. You're manufacturing a widget and using an I-MR where you measure 3 consecutive samples to control the critical feature of the product. Your process has the following attributes: $\boldsymbol{\bar{X} = 1.25, \overline{MR} = 0.55}$
Identify the upper control limits for the I chart:

- 0.275
- 1.80
- **2.225**
- 2.713

$$UCL_I = \bar{X} + E_2\overline{MR}$$

$$When\ using\ three\ consecutive\ samples\ to\ measure\ the\ moving\ range, the\ E_2\ factor\ is\ 1.772$$

$$UCL_I = 1.25 + 1.772 * 0.55 = \mathbf{2.225}$$

14. Pencil Makers Incorporated uses an x-bar and R chart of n=5 to monitor the length of pencils coming off the production line. The inspector takes two samples, measures the length and plots their values on the X-bar chart as both data points are outside of the upper control limit and decides to stop the process. What does this mean?

- Only the process range is out of statistical control
- Only the process average is out of statistical control
- Both the average and range are out of statistical control
- **Nothing, the inspector is not executing the control chart appropriately**

The sub-group size for this control chart is five. The inspector stops the inspection after only 2 measurements, which is inappropriate.

The inspector should complete the entire sub-group measurement before making a conclusion about the process.

15. What factor determines which variable control chart should be used?

- Defects v. defectives
- The accuracy of the measurement system being used
- The acceptance sampling plan associated with your product
- **The number of units sampled within each subgroup**