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Lean Six Sigma Master Black Belt

Six Sigma LSSMBB

Version Demo

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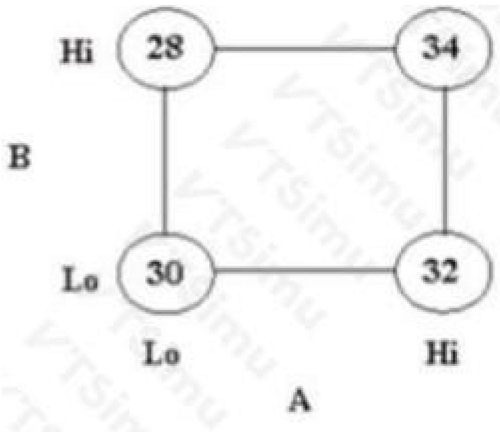
QUESTION NO: 1

What is the AB interaction effect of:



A. 4

B. 2

C. -2

D. 6

ANSWER: B

Explanation:

The correct interaction effect is **2**. In a two-factor, two-level factorial design, the AB interaction measures whether the effect of one factor changes when the other factor moves from its low level to its high level. It is calculated using the AB contrast: add the responses where the factor signs for A and B are alike (both low or both high), subtract the responses where their signs differ, and divide by 2 for a single replicate at each treatment combination. Equivalently, it is the difference between the two conditional effects of A across the levels of B. Applying this signed-contrast calculation to the treatment-combination responses shown in the figure gives an interaction contrast whose scaled effect is 2. A positive value means the combined behavior of A and B is greater than would be represented by additive main effects alone, in the coded-factor direction used for the experiment. This is the standard effect-estimation convention for a full 2^2 factorial experiment. See the NIST Engineering Statistics Handbook discussion of two-level full factorial designs and its guidance on estimating factorial effects.

QUESTION NO: 2

The English words used for the 5S's are __________ , _____________ , Shining, Standardizing and Sustaining. (Note: There are 2 correct answers).

A. Shaping

B. Sorting

C. Shifting

D. Straightening

ANSWER: B D

Explanation:

The correct terms are **Sorting** and **Straightening**. 5S is a workplace-organization and visual-management method derived from five Japanese terms: Seiri, Seiton, Seiso, Seiketsu, and Shitsuke. In a common English translation, these are expressed as Sort, Straighten, Shine, Standardize, and Sustain. “Sorting” is the first activity: separating necessary materials from unnecessary items and removing what is not needed from the work area. “Straightening” is the next activity: arranging the needed items so that they are clearly identified, easy to find, easy to use, and easy to return to their assigned locations. Together, these practices establish an orderly, efficient workplace before cleaning, standard work, and long-term discipline are reinforced through the remaining 5S activities. Terminology can vary slightly by organization—for example, “Set in Order” is frequently used in place of “Straighten”—but Sorting and Straightening accurately complete the stated English 5S sequence. The Lean Enterprise Institute’s 5S definition describes the five pillars and their purpose in creating a visual workplace. ASQ also summarizes 5S as a foundational method for organizing and maintaining an effective work environment: ASQ Five S Tutorial.

QUESTION NO: 3

Which practices are appropriate when planning a designed experiment? (Note: There are 4 correct answers).

A. Randomizing the run order

B. Replicating treatment combinations when resources permit

C. Blocking on known nuisance sources of variation

D. Defining response measurements and acceptance criteria before conducting runs

E. Changing factor levels after viewing early results without documenting a sequential plan

F. Running treatments in standard order to simplify execution

ANSWER: A B C D

Explanation:

Randomizing the run order is appropriate because it spreads uncontrolled time-related variation across treatment combinations. **Replicating treatment combinations when resources permit** provides an estimate of experimental error and improves precision. **Blocking on known nuisance sources of variation** is appropriate when a factor such as shift, material lot, or day is expected to affect the response but is not a factor of primary interest.

Defining response measurements and acceptance criteria before conducting runs is also appropriate. Clear operational definitions and an analysis plan reduce the risk of subjective or post hoc decisions. Changing factor levels after viewing early results is not an appropriate substitute for a planned sequential experiment, and running all treatments in standard order can confound factor effects with time trends. See NIST guidance on randomization, replication, and blocking.

QUESTION NO: 4

For the data shown here which statement(s) are true? (Note: There are 2 correct answers).

Grade A	Grade B	Grade C
0.917	1.1	0.63
0.68	0.173	4.17
1.74	0.24	0.6
0.3	0.67	0.84
0.33	6.94	0.22
4.13		

A. With 95% confidence, we cannot conclude if the samples are from three Normal Distributions

B. With greater than 95% confidence, we conclude the samples are from Non-normal Distributions

C. If we wanted to compare the Central Tendencies of these three samples we would use the one way ANOVA test

D. If we wanted to compare the Central Tendencies of these three samples we could use Mood's Median test

E. If we wanted to compare the Central Tendencies of all three samples we could use the Mann-Whitney test

ANSWER: B D

Explanation:

The displayed normality-test results provide statistically significant evidence at the 0.05 level that the samples do not follow normal distributions. Equivalently, this conclusion is supported with greater than 95% confidence. Normality testing assesses whether the observed departures from a normal distribution are larger than would reasonably be expected from sampling variation if the data were normal. When the relevant normality-test p-values are below 0.05, the normal-distribution assumption is rejected, making a rank- or median-based comparison appropriate for comparing the groups' locations.

Mood's Median test is suitable for comparing the central tendencies of three or more independent samples without requiring normal distributions. The method pools the observations, determines an overall median, and evaluates whether the groups have materially different proportions of observations above and below that median. Its inference therefore addresses whether the population medians—and, in this context, the groups' central locations—differ. This makes Mood's Median test an appropriate nonparametric procedure for the three samples shown. NIST's guidance on distributional tests is available at NIST Engineering Statistics Handbook, and Minitab documents the procedure at Minitab: Mood's Median Test overview.

QUESTION NO: 5

Following is a confounding pattern of a DOE:

A =BCD

B =ACD

C =ABD

D =ABC

AB=CD

AC=BD

AD = BC

Based on this structure, what is the resolution of the design:

A. III

B. IV

C. V

D. None, it is a full factorial

ANSWER: B

Explanation:

IV is correct because the alias structure implies the defining relation *I = ABCD*. For example, multiplying the alias A = BCD by A gives I = ABCD, since A multiplied by itself is I. The resolution of a regular fractional factorial design is the length of the shortest nonidentity word in its defining relation. Here, the shortest word is ABCD, which contains four letters; therefore, the design has resolution IV.

This structure also exhibits the characteristic behavior of a resolution-IV design: each main effect is aliased with a three-factor interaction, as shown by A = BCD, B = ACD, C = ABD, and D = ABC. Thus, under the common effect-hierarchy assumption that higher-order interactions are negligible, main effects can be estimated without confounding with two-factor interactions. The two-factor interactions are aliased with other two-factor interactions, such as AB = CD, which is consistent with resolution IV. Resolution is determined from the defining relation rather than by counting the displayed aliases alone. For further guidance on factorial-design resolution and alias structure, see the NIST Engineering Statistics Handbook discussion of fractional factorial designs and NIST's explanation of design resolution.

QUESTION NO: 6

Which statements regarding an Individuals and Moving Range (I-MR) control chart are correct? (Note: There are 3 correct answers).

A. It is appropriate when subgroup size is one

B. The Individuals chart monitors process location

C. The Moving Range chart monitors short-term variation

D. It requires each subgroup to contain at least 4 observations

E. It is used only for attribute data

ANSWER: A B C

Explanation:

An I-MR chart is used when measurements are collected one observation at a time rather than in rational subgroups of size two or more. The Individuals chart monitors the process level using each individual observation, while the Moving Range chart monitors short-term variation through the absolute difference between consecutive observations.

The moving range is normally calculated from successive observations, so the chart can estimate routine process variation even when subgrouping is not feasible. I-MR charts are commonly used for data such as daily transaction cycle time, monthly service results, or infrequently produced product characteristics. They should not be used as a substitute for rational subgrouping when multiple observations can be collected under comparable process conditions. See NIST guidance on Individuals control charts and Minitab guidance on selecting control charts.

QUESTION NO: 7

To properly analyze the variables impacting the output of a process we need to collect data that represents at least 80% of the variation in the process and assure ourselves we are collecting data from all three types of variation which are _______________.

A. Within, Between and Temporal

B. Within, Between and Temporary

C. Without, Above and Below

D. Induced, Natural and Unavoidable

ANSWER: A

Explanation:

Within, Between and Temporal is correct because a representative process-data collection plan must account for variation at multiple levels. Within variation describes differences observed inside a subgroup or unit, such as repeated measurements, locations, cavities, or features from the same production context. Between variation captures differences among meaningful groups, such as operators, machines, suppliers, shifts, lots, product families, or work cells. Temporal variation captures changes over time, including start-up effects, tool wear, environmental changes, maintenance cycles, and shifts in process conditions.

Considering all three sources helps a Six Sigma practitioner avoid drawing conclusions from data that reflect only a narrow slice of actual process behavior. Rational subgrouping and sampling across relevant strata and time periods make it more likely that the data describe the process's true variation and identify the factors that influence its output. This supports valid analysis in the Measure and Analyze phases, including estimating process capability and distinguishing stable routine variation from changes requiring investigation. The importance of examining variation over time and using rational subgroups is addressed in the NIST/SEMATECH e-Handbook discussion of control charts and in ASQ's overview of variation.

QUESTION NO: 8

Two of the key deliverables for the Measure Phase are a robust description of the process and its flow and an assessment of the Measurement System.

A. True

B. False

ANSWER: A

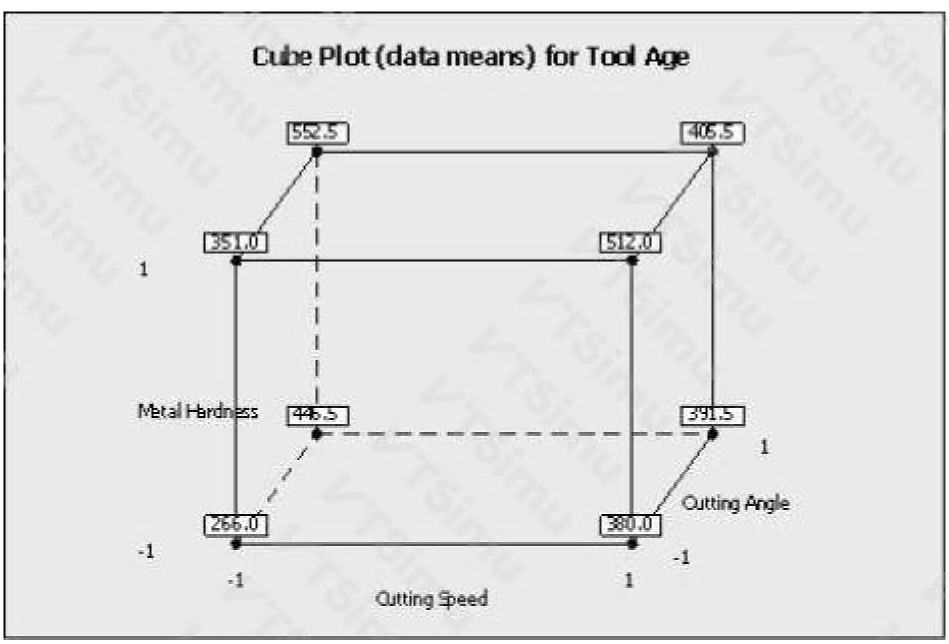
Explanation:

True is correct. In the Measure phase of DMAIC, the team establishes a reliable factual baseline for the problem before attempting to identify root causes or implement improvements. A robust process description—commonly documented through a SIPOC, process map, or value-stream map—makes the actual sequence of work, handoffs, inputs, outputs, and potential data-collection points visible. This shared understanding is essential for defining operational measures and ensuring the team studies the process as it is truly performed.

Measurement-system assessment is also a central Measure-phase deliverable because decisions are only as dependable as the data used to support them. The team verifies that measures are operationally defined and evaluates whether the system provides data with sufficient accuracy, precision, repeatability, reproducibility, and stability for the project. Measurement System Analysis, including gauge repeatability and reproducibility studies where applicable, helps establish that observed process variation is meaningful rather than primarily an artifact of the measurement method. With a clear process flow and validated measurement system, the project can produce a trustworthy baseline capability assessment and proceed into Analyze using credible evidence. See the ASQ DMAIC overview and NIST's Measurement System Analysis reference.

QUESTION NO: 9

Which statement(s) are correct about the Factorial Plot shown here? (Note: There are 3 correct answers).



A. When the cutting speed increased from low to high level, the tool age increases

B. The coefficient of the metal hardness is positively related to the output of tool age

C. The coded coefficient is lower for cutting speed than the cutting angle related to the output of tool age

D. These plots prove a statistically significance factor with 95% confidence

E. These plots are an example of interaction plots

ANSWER: A B C

Explanation:

The correct interpretations are that increasing cutting speed from its low setting to its high setting increases the plotted mean tool-age response; that metal hardness has a positive relationship with tool age; and that the coded coefficient for cutting speed is smaller than that for cutting angle. In a two-level factorial main-effects plot, the direction of the line between the low and high settings identifies the direction of the factor's estimated effect. An upward trend means the average response rises as the factor moves from low to high. Thus, the upward trends for cutting speed and metal hardness support the stated positive effects on tool age.

For factors expressed in coded units, the estimated coefficient represents the expected response change associated with the coded factor change, with its sign giving direction and its magnitude indicating relative effect size. The displayed main-effect slopes support the comparison that cutting angle has the larger coded effect relative to cutting speed. This is an appropriate visual interpretation of the factorial plot: it compares average responses at factor levels and provides an initial view of the direction and relative size of main effects. Formal statistical inference is ordinarily established from the fitted model, including its estimated effects and error term. See the NIST discussion of two-level factorial designs and the NIST guidance on factorial effect estimates.

QUESTION NO: 10

Assessing process proportion as opposed to evaluating a process with respect to a set target can be done using one or more of these. (Note: There are 2 correct answers).

A. Process proportion equals some desired value

B. Process proportion equals some value range

C. Target is current

D. When we deal with Attribute type data

E. Proportion of the tail is equal

ANSWER: A D

Explanation:

“Process proportion equals some desired value” is correct because a one-proportion hypothesis test assesses whether the population proportion associated with a process, such as the fraction defective, late, compliant, or successful, is consistent with a specified benchmark proportion. The analysis is based on a null hypothesis in the form $p = p_0$, where p is the true process proportion and p_0 is the desired or claimed value. The result provides an evidence-based assessment using the observed sample proportion rather than treating the target as automatically achieved.

“When we deal with Attribute type data” is correct because proportions arise from attribute data: each unit is classified into one of two categories, such as defective/nondefective or pass/fail. Lean Six Sigma practitioners use a one-proportion test when evaluating the rate or percentage in one category and comparing it with a required, historical, contractual, or improvement-goal proportion. The sampling plan should support independent observations, and the sample size should be sufficient for the selected method's assumptions or an exact binomial procedure should be used. See ASQ's overview of hypothesis testing and Minitab's guidance for the 1 Proportion test.

QUESTION NO: 11

Special Cause Variation falls into which two categories? (Note: There are 2 correct answers).

A. Natural

B. Short term

C. Assignable

D. Pattern

ANSWER: C D

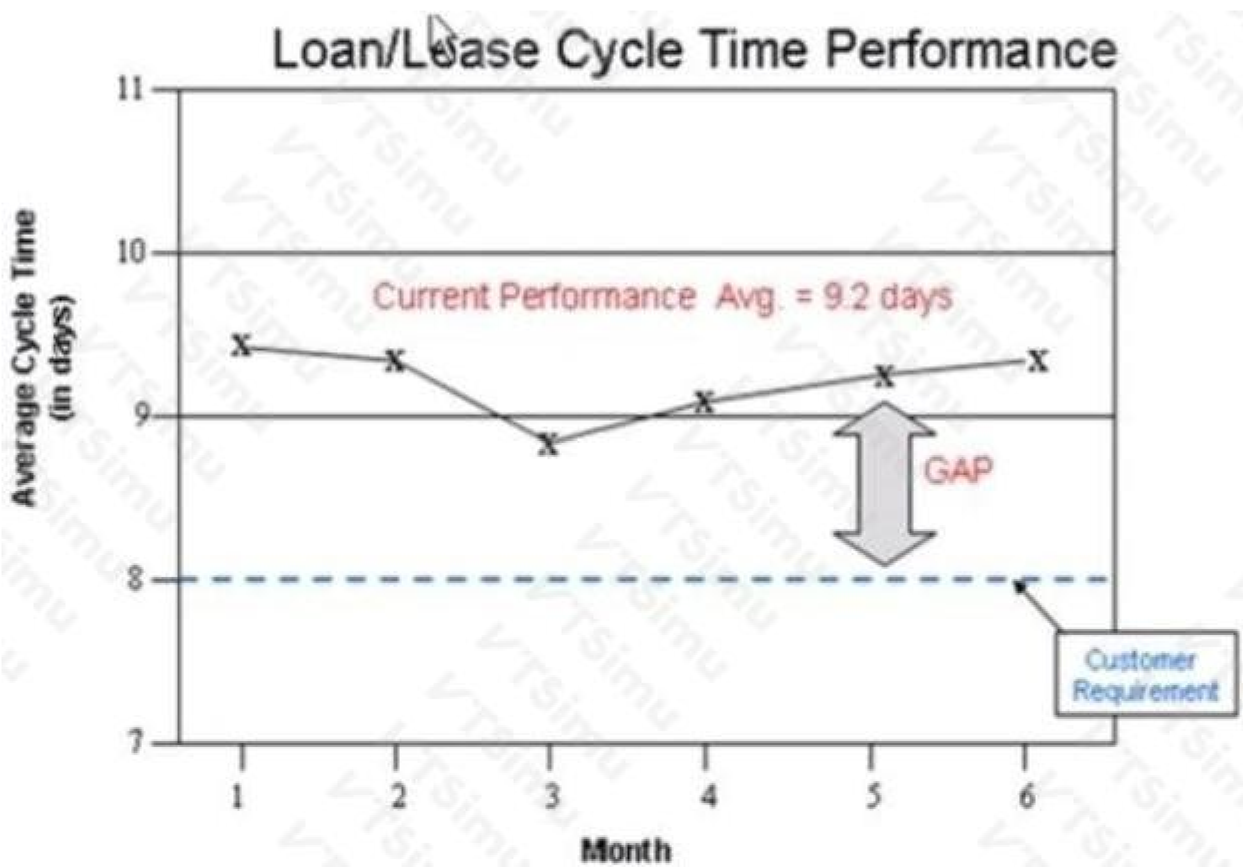
Explanation:

Special-cause variation is variation arising from a source outside the process's usual, stable operating system. It is commonly described as **assignable** because the organization should investigate the signal to identify a specific, actionable cause, such as a machine setting change, material issue, operator change, or measurement problem. Once identified, that source can be addressed through corrective action.

Special-cause variation can also be recognized through a **pattern** of nonrandom behavior on a control chart. A pattern may appear as a sustained run on one side of the center line, a trend, a cycle, or another statistically unlikely arrangement of plotted points. Such patterns indicate that the observed process behavior is not adequately explained by routine, inherent variation alone and warrants investigation. Control-chart analysis therefore uses both individual assignable signals and nonrandom patterns to distinguish unusual process behavior from the stable baseline. The NIST/SEMATECH e-Handbook on control charts describes special-cause detection using out-of-control points and nonrandom patterns. The ASQ control-chart resource also explains the role of control charts in identifying special causes for action.

QUESTION NO: 12

In the figure below, identify the Output Indicator.



A. Current performance

B. Customer requirement

C. Average cycle time

D. Month

ANSWER: C

Explanation:

Average cycle time is the output indicator because it expresses the measurable result produced by the process over time. In Lean Six Sigma, an output indicator is a performance measure for the process outcome—the dependent variable or “Y” that the team seeks to understand, control, and improve. Cycle time measures the elapsed time needed for a process to complete its work; therefore, an average cycle-time value summarizes actual process performance for the periods displayed in the figure. Tracking it by month makes variation, trends, and the effect of improvement actions visible. It can also be evaluated against a customer-driven requirement or target to determine whether the process is meeting the expected service level. This makes average cycle time an appropriate operational definition of the output, rather than merely a chart time scale, a target requirement, or a depiction of current status. ASQ describes cycle time as a commonly used process-performance metric and explains its relevance to process improvement: ASQ: Cycle Time. The relationship between customer requirements and measurable critical-to-quality outputs is also central to the Six Sigma approach: ASQ: Six Sigma.

QUESTION NO: 13

A Belt working in a supply chain environment has to make a decision to change suppliers of critical raw materials for a new product upgrade. The purchasing manager is depending on the Belt’s effort requiring that the average cost of an internal critical raw material component be less than or equal to $4,200 in order to stay within budget. Using a sample of 35 first article components, a Mean of the new product upgrade price of $4,060, and a Standard Deviation of $98 was estimated. The Alternative Hypothesis in the above example is?

A. The Standard Deviation is equal to $300.

B. The Mean is less than $4,320.

C. The Mean is equal to $4,060.

D. The Mean is less than $4,200.

E. The Mean is greater than $ 4,200.

ANSWER: D

Explanation:

The Mean is less than $4,200 is the appropriate alternative hypothesis because the business objective is to establish that the population mean cost of the critical component meets the maximum budgeted amount. In hypothesis-testing notation, this is expressed as H_a: $\mu < \$4,200$. The test is one-tailed (left-tailed), since evidence is sought only in the direction of costs being below the budget threshold. The sample mean of $4,060 and sample standard deviation of $98 are observed data used later to calculate a test statistic and assess the strength of evidence; they do not themselves define the hypothesis. For a one-sample mean test, the null hypothesis is conventionally framed to include equality and the unacceptable direction, such as H_0: $\mu \geq \$4,200$, while the alternative represents the claim that the improvement team needs evidence to support. This setup directly aligns the statistical decision with the purchasing manager’s requirement that average cost remain within budget. The NIST Engineering Statistics Handbook describes how alternative hypotheses specify the direction or difference being evaluated in a hypothesis test: NIST hypothesis-testing guidance. See also NIST guidance on one-sided tests.

QUESTION NO: 14

Which of the following are appropriate uses of a Pareto Chart in a Lean Six Sigma project? (Note: There are 3 correct answers).

A. Prioritizing defect categories by frequency or impact

B. Identifying the relatively few categories contributing most of the observed problem

C. Demonstrating that a suspected input causes a response

D. Communicating cumulative contribution across categories

E. Determining whether a process is statistically stable over time

ANSWER: A B D

Explanation:

A Pareto Chart is used to display categories in descending order of frequency, cost, or another meaningful measure. Therefore, **prioritizing defect categories by frequency or impact** is correct. It is also appropriate for **identifying the relatively few categories contributing most of the observed problem**, consistent with the practical prioritization concept often called the vital few.

Communicating cumulative contribution across categories is correct because Pareto charts commonly include a cumulative-percentage line that shows how much of the total is represented by the leading categories. A Pareto chart does not establish causation and is not a substitute for a control chart when the objective is to assess process stability over time. See [ASQ guidance on Pareto charts].

QUESTION NO: 15

Choose those characteristics of a Simple Linear Regression (SLR) Analysis that are applicable. (Note: There are 3 correct answers).

A. The Correlation Coefficient is always greater than the Regression Coefficient in a SLR

B. General Regression Analysis deals only with Continuous Data

C. Non-linear Regressions can explain curvature when with more statistical confidence than Linear Regressions

D. SLR can help quantify the significance of variation in X that influences the variation in Y via a mathematical equation

E. A Correlation does not explain causation but a Regression Analysis with a statistically valid mathematical equation does explain causation

F. SLR models the conditional mean of a response variable as a linear function of one predictor variable.

ANSWER: C D F

Explanation:

Simple linear regression models the mean response of a continuous outcome, Y, as a linear function of one predictor, X: $Y = \beta_0 + \beta_1 X + \varepsilon$. Therefore, “SLR can help quantify the significance of variation in X that influences the variation in Y via a mathematical equation” is applicable. The fitted slope estimates the direction and magnitude of the modeled X–Y association, while hypothesis tests and confidence intervals assess whether the estimated slope is distinguishable from zero under the model assumptions. This supports data-based process analysis and prediction.

“Non-linear Regressions can explain curvature when with more statistical confidence than Linear Regressions” is also applicable in the conditional sense expressed by “can.” When diagnostics and subject-matter knowledge indicate a curved functional relationship, an appropriately specified nonlinear or transformed regression model can represent that curvature and may provide better-supported inferences than forcing a straight-line relationship. Model adequacy should be established with residual analysis and suitable fit or comparison measures. Finally, “SLR models the conditional mean of a response variable as a linear function of one predictor variable” states the defining characteristic of SLR. See the [NIST regression overview] and [NIST discussion of nonlinear regression].

QUESTION NO: 16

Experimental error includes the ____________ in the experiment caused by uncontrolled and unknown nuisance factors. This is also called____________.

A. Noise/pure error

B. Noise/signal

C. Signal/noise

D. Pure error/signal

ANSWER: A

Explanation:

Noise/pure error is correct because experimental error is the random, unexplained variation in observed responses that remains after the effects of deliberately studied process inputs have been considered. In designed experiments, uncontrolled or unknown nuisance factors—such as small environmental fluctuations, measurement variation, unrecognized material differences, or other chance influences—create this background variation, commonly called *noise*. The term *pure error* refers to the experimental-error component estimated from replicated runs performed at identical factor settings. Since those replicates receive the same planned treatment, differences among their results provide a direct estimate of the inherent random variation affecting the experiment rather than variation due to intentional changes in factors.

This estimate is important in Six Sigma DOE because it supplies the denominator for assessing whether observed factor effects are distinguishable from ordinary experimental variation. Replication therefore helps quantify pure error, supports valid analysis of variance, and improves confidence in conclusions about critical inputs. NIST's Engineering Statistics Handbook describes experimental design concepts, including random error and replication, at NIST: Process or Product Performance Improvement and explains the role of replication in estimating experimental error at NIST: Replication.

QUESTION NO: 17

Suppose an X-bar / S Chart revealed that the variation of a process was consistent over time (consistent standard deviation, consistent mean) but a significant proportion of outcomes fell outside the customer requirements. Which of the following conclusions can best be made about the process?

A. The process is in control but has poor capability

B. The process variation is out of control

C. Special or assignable causes are affecting the process

D. The process mean needs to be reduced

ANSWER: A

Explanation:

The process is in control but has poor capability. An X-bar/S chart evaluates process stability over time: a consistent process mean and standard deviation, with no evidence of nonrandom variation, indicate that the process is statistically controlled (stable and predictable). Control limits on the chart are calculated from the process's observed behavior; they are not customer requirements. Customer specification limits, by contrast, define the range of outcomes that are acceptable to the customer.

If a substantial proportion of output falls beyond those specification limits despite the process being stable, the process's natural spread and/or its centering relative to specifications is inadequate. This is a capability problem. Capability measures such as Cp and Cpk compare the stable process distribution with the specification limits and help quantify whether the process can consistently meet requirements. Before capability is assessed or improved, stability must be established—precisely the condition described here. The appropriate next step is therefore to use capability analysis to determine whether reducing variation, recentering the process, or both are needed to meet customer requirements. See the NIST process capability analysis guidance and the NIST discussion of X-bar and S control charts.

QUESTION NO: 18

Control Charts were developed by Dr. Shewhart to track data over time. To detect Special Cause variation the Control Charts use which of these?

A. Data shift analysis

B. Outlier analysis methods

C. Center Line and Control Limits

D. None of the above

ANSWER: C

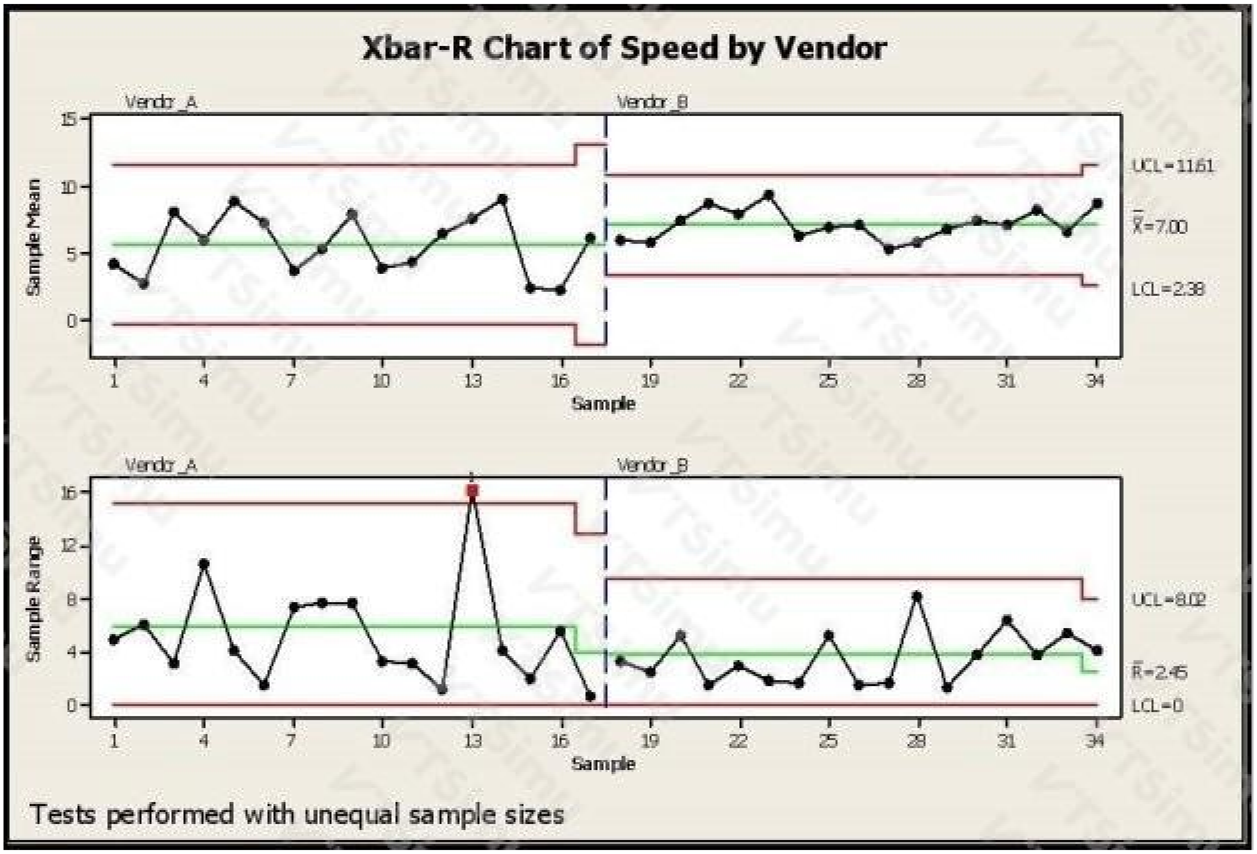
Explanation:

Control charts detect special-cause variation by plotting process data in time order against a center line and statistically derived control limits. The center line represents the expected process average (or another appropriate central value), while the upper and lower control limits define the range of variation expected from a stable process affected only by common causes. These limits are calculated from actual process variation and sampling characteristics; they are not simply customer specification limits or arbitrary thresholds.

A point outside a control limit is evidence that the process may have changed because of a special cause. Control charts can also apply established run-rule patterns to points within the limits, such as sustained shifts or trends, to identify nonrandom behavior. Thus, the center line and control limits provide the essential statistical framework that lets practitioners distinguish routine common-cause variation from signals requiring investigation. This approach originated with Walter A. Shewhart's statistical process-control work and remains a foundational Lean Six Sigma control-phase practice. See the NIST/SEMATECH e-Handbook discussion of control charts and the ASQ control-chart resource.

QUESTION NO: 19

SPC Charts are used extensively in different business and decision-making environments. In this example a vendor is being selected based on speed of delivery. Which of the conclusions would help you pick a vendor for your needs regarding leadtime of delivery from your vendors? (Note: There are 4 correct answers).



A. Vendor A with a much shorter lead time in delivery

B. Vendor B as it has a better consistency (lower variance) on lead time

C. Vendor B as Vendor A shows a situation out of control as shown in red

D. Vendor B as the Control Limits are much narrower than Vendor A

E. Vendor B with higher lead time, but a process with much narrower Control Limits

ANSWER: B C D E

Explanation:

For a delivery process, the preferred vendor is not determined solely by average lead time; predictable, stable performance is also essential for planning inventory, production schedules, and customer commitments. “Vendor B as it has a better consistency (lower variance) on lead time” is therefore a sound conclusion because lower common-cause variation makes future delivery performance more predictable. “Vendor B as Vendor A shows a situation out of control as shown in red” is also appropriate: an out-of-control signal indicates special-cause variation that should be investigated before the process can be treated as reliable for forecasting or supplier planning.

“Vendor B as the Control Limits are much narrower than Vendor A” and “Vendor B with higher lead time, but a process with much narrower Control Limits” both identify the same important operational advantage: when charts are constructed on comparable data and subgrouping, narrower control limits indicate less observed process variation. A stable process with a known, narrow delivery-time spread supports dependable replenishment decisions and allows the organization to plan around a consistent lead time. Control charts distinguish stable common-cause behavior from special-cause signals and provide a practical basis for supplier-performance decisions. See NIST’s control-chart guidance and ASQ’s control chart overview.

QUESTION NO: 20

If an experiment has 5 factors and no replicates for a 2-level Experimental Design with 16 experimental runs which statement is incorrect?

A. The Experimental Design is half-fractional

B. The Main Effects are confounded with only 4-way interactions

C. The Main Effects for the 5 factors are not aliased or confounded but the 2-way interactions are confounded with the 3-way interactions

D. The experiment has 8 experimental runs with the first factor at the high level

E. None of the statements is incorrect; all are true for a regular 16-run, 5-factor half-fractional factorial design.

ANSWER: E

Explanation:

None of the listed statements is incorrect, assuming the conventional regular one-half fractional factorial design, denoted 2^{5-1}. A full two-level factorial for five factors requires $2^5 = 32$ runs; therefore, 16 runs constitute a one-half fraction. The usual defining relation for a resolution-V half fraction can be written as I = ABCDE. Multiplying this defining word by any main-effect letter shows that each main effect is aliased with a four-factor interaction, such as A with BCDE. Multiplying it by a two-factor interaction shows that each two-factor interaction is aliased with its complementary three-factor interaction, such as AB with CDE. This preserves clear estimation of main effects with respect to lower-order interactions under the standard hierarchy assumption. In addition, every factor column in a balanced 16-run two-level regular fraction contains eight high-level settings and eight low-level settings. Thus, all four supplied descriptions are consistent with the standard design, so the only valid response to a question asking for an incorrect statement is that no supplied statement is incorrect. See the [NIST discussion of fractional factorial designs]() and the [NIST explanation of design resolution and aliasing]().

QUESTION NO: 21

What type of knowledge is gained by doing an MSA?

A. Determine the size of the measurement variability

B. Determine if the measurement system is stable over time

C. Determine if the measurement system is capable of making the required measurements

D. All of the above

ANSWER: D

Explanation:

All of the above is correct because a Measurement System Analysis (MSA) evaluates whether measurement data are dependable enough for process-control, improvement, and decision-making purposes. A core MSA result is quantification of measurement variation, including repeatability (variation when the same appraiser measures the same item repeatedly) and reproducibility (variation among appraisers). These results establish the size of measurement-system variability relative to the process or specification tolerance.

MSA also assesses stability: a stable measurement system produces consistent results over time when measuring a stable reference. Stability is commonly evaluated with repeated measurements and control-chart concepts, helping reveal drift, shifts, or other time-related changes. Finally, MSA establishes whether the system is capable for its intended use. This judgment considers the measurement variation relative to the tolerance or process variation, as well as practical attributes such as resolution, bias, and linearity where relevant. Therefore, an MSA provides knowledge of variability, time stability, and fitness for the required measurement task. See the [ASQ Measurement System Analysis overview]() and NIST's [measurement process characterization guidance]().

QUESTION NO: 22

Which of the following are appropriate elements of an effective Control Plan following implementation of a process improvement? (Note: There are 4 correct answers).

A. Critical characteristics to be monitored

B. Method of measurement or monitoring

C. Sampling frequency or monitoring timing

D. Reaction plan for a nonconforming condition

E. A list of all project brainstorming ideas

F. Only the original project charter benefits statement

ANSWER: A B C D

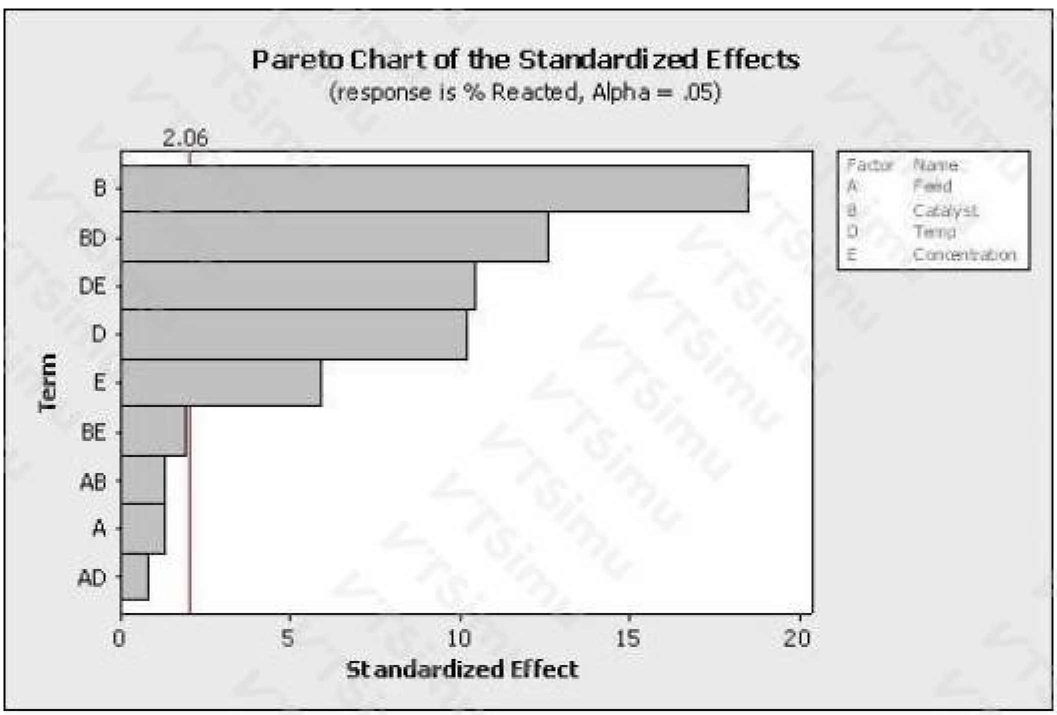
Explanation:

An effective Control Plan specifies the critical process or product characteristics to be monitored, the measurement or monitoring method, the sampling frequency or timing, and a reaction plan for out-of-control or nonconforming conditions. It also identifies responsible roles so that the controls are actually performed and the process owner has clear accountability.

The Control Plan translates the project solution into routine operating management. It should be aligned with work instructions, training, visual controls, error-proofing, and the selected control-chart or audit method as applicable. The plan is not merely a list of project ideas; it must define how process performance will be sustained and how the organization will respond when requirements are not met. See [ASQ control plan resources] and [AIAG Control Plan resources].

QUESTION NO: 23

Which statement(s) are correct about the Pareto Chart shown here for the DOE analysis? (Note: There are 2 correct answers).



A. It is unknown from this graph how many factors were in the Experimental Design

B. The factors to keep in the mathematical model are E, D, DE, BD and B with an alpha risk equal to 2.06

C. The effects to keep in the mathematical model are E, D, DE, BD and B with an alpha risk equal to 0.05

D. The factors to keep in the mathematical model with a 5% alpha risk are BE, AB, A and AD

ANSWER: A C

Explanation:

It is unknown from this graph how many factors were in the Experimental Design because a Pareto chart of standardized effects displays the estimated terms selected or evaluated in the fitted DOE analysis, rather than providing a complete specification of the original design. Although terms such as E, D, DE, BD, and B identify factor labels and interactions represented on the chart, the chart alone does not establish the total factor count, design resolution, number of runs, or whether other factors were omitted from the displayed model.

The effects to keep in the mathematical model are E, D, DE, BD and B with an alpha risk equal to 0.05 because these effects exceed the chart's reference line for statistical significance. In a DOE Pareto chart of standardized effects, the bars are ordered by absolute standardized effect, and the reference line is calculated using the selected significance level. With a 5% alpha risk, terms crossing that line have evidence of an effect at the corresponding confidence level and are appropriate candidates for retention in the hierarchical regression model, subject to engineering knowledge and model hierarchy. The displayed value near the line is the critical standardized-effect threshold, not the alpha value itself. See Minitab's guidance on Pareto charts of standardized effects and NIST's discussion of factorial-design analysis.

QUESTION NO: 24

The English words used for the 5S's are Sorting, Straightening, _____________ , __________ and Sustaining. (Note: There are 2 correct answers).

A. Shaping

B. Shining

C. Standardizing

D. Signing

ANSWER: B C

Explanation:

The missing 5S terms are **Shining** and **Standardizing**. In the commonly used English translation of the workplace-organization method, the five steps are Sort, Set in Order (often expressed as Straighten), Shine, Standardize, and Sustain. "Shining" means cleaning the workplace and equipment while also inspecting for abnormalities such as leaks, wear, unsafe conditions, or sources of contamination. It establishes a clean, visible environment in which problems can be detected promptly. "Standardizing" creates consistent methods, visual controls, schedules, and responsibilities so that the first three practices—Sorting, Straightening, and Shining—are applied reliably across people, shifts, and work areas. Together, these practices provide the repeatable operating conditions needed before the organization can sustain the gains through discipline, auditing, and continual improvement. The English terminology is widely used in Lean and Six Sigma implementations, although "Set in Order" may be used instead of "Straightening" in some references. See the U.S. EPA overview of 5S and Lean Enterprise Institute's 5S definition.

QUESTION NO: 25

Which statement(s) are incorrect for the Regression Analysis shown here? (Note: There are 2 correct answers).

Regression Analysis: Turbine Output versus Air-Fuel Ratio, % steam, ...

The Regression Equation is
TurbineOutput = 16.5 + 3.21 Air-Fuel Ratio + 0.386 % methane
+ 0.0166 SteamExitTemp

Predictor	Coef	SE Coef	T	P
Constant	16.488	2.918	5.65	0.000
Air-Fuel Ratio	3.2148	0.2377	13.52	0.000
% methane	0.38637	0.07278	5.31	0.000
SteamExitTemp	0.016576	0.004273	3.88	0.004

S = 0.508616   R-Sq = 98.6%   R-Sq(adj) = 98.2%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	170.003	56.668	219.06	0.000
Residual Error	9	2.328	0.259		
Total	12	172.331			

Source	DF	Seq SS
Air-Fuel Ratio	1	159.048
% methane	1	7.062
SteamExitTemp	1	3.892

A. The air-fuel ratio explains most of the TurbineOutput variation

B. The Regression explains over 98% of the process variation

C. This Multiple Linear Regression has three statistically significant independent variables

D. If the air-fuel ratio increases by 1, the TurbineOutput more than triples

E. The SteamExitTemp explains the most variation of the TurbineOutput

ANSWER: D E

Explanation:

The incorrect statements are *"If the air-fuel ratio increases by 1, the TurbineOutput more than triples"* and *"The SteamExitTemp explains the most variation of the TurbineOutput"*. In a multiple linear regression, a coefficient represents the estimated additive change in the response for a one-unit increase in that predictor, with the other predictors held constant. It does not imply that the response is multiplied or tripled unless the model and variables have specifically been transformed into a logarithmic form that supports such a multiplicative interpretation. Therefore, the air-fuel-ratio coefficient must be interpreted in TurbineOutput units, not as a claim that output more than triples.

The regression output indicates that air-fuel ratio, rather than SteamExitTemp, has the strongest relative association with TurbineOutput among the listed predictors. Relative predictor importance should be assessed from the appropriate comparable evidence in the fitted model, such as standardized coefficients or the reported analysis used to compare predictor effects; raw coefficients alone can be distorted by differing measurement units. This distinction is important when interpreting multiple regression, because each predictor's estimated effect is conditional on the others. See NIST's Multiple Linear Regression guidance and the regression coefficient interpretation discussion.

QUESTION NO: 26

A service organization wants to determine whether the distribution of customer satisfaction ratings differs among four geographic regions. Ratings are recorded as Poor, Fair, Good, or Excellent.

Which statistical test is most appropriate?

A. Chi-Square test of independence

B. One-way ANOVA

C. Paired T-test

D. 1 Proportion test

ANSWER: A

Explanation:

A **Chi-Square test of independence** is appropriate because the response and explanatory variables are categorical. The customer satisfaction ratings can be summarized in a contingency table by region, and the test compares the observed category counts with counts expected if satisfaction rating and region were independent.

ANOVA and t-tests compare means of continuous responses, while a one-proportion test evaluates one binary proportion against a benchmark. The team should ensure that observations are independent and that expected cell counts are sufficiently large for the selected chi-square approximation; otherwise, an exact or combined-category approach may be needed. See NIST guidance on chi-square contingency-table tests.

QUESTION NO: 27

An engineer is trying to increase a product characteristic mean from the current production 850Å to above 855Å. The standard deviation of the current process and the proposed process are assumed to be the same, σCurrent = 7.7. The engineer wants to verify that the average difference of his new process as compared to the old process is statistically significant and is greater than 5Å. What are the correct statistical hypotheses for this engineering problem?

A. Ho: μ New - μ Old ≤ 5, Ha: μ New - μ Old > 5

B. Ho: μ New - μ Old=5, Ha: μ New - μ Old ≠ 5

C. Ho: μ New = 850, Ha: μ New > 850

D. Ho: σ New ≤ 7.7, Ha: σ New > 7.7

ANSWER: A

Explanation:

The appropriate hypotheses are H_0: $\mu_{New} - \mu_{Old} \le 5$ versus H_a: $\mu_{New} - \mu_{Old} > 5$. The engineering requirement is not merely that the new process mean increase relative to the old process; it is that the true mean increase exceed the practically meaningful threshold of 5 Å. Because the claimed improvement is directional and specifies an amount that must be surpassed, this requires a one-sided, upper-tailed test of the difference in population means. The null hypothesis represents the status in which the improvement is no more than 5 Å, including no improvement or an improvement exactly equal to 5 Å. Sufficient sample evidence is needed to reject that status and support an increase greater than 5 Å. The stated common-process-standard-deviation assumption is relevant to selecting and calculating an appropriate two-sample mean test statistic, but it does not change the parameter or threshold being tested. This formulation directly connects statistical significance to the process-performance objective. The NIST/SEMATECH handbook discusses hypothesis-test construction and one-sided alternatives at NIST Hypothesis Testing; its discussion of comparing two means is available at NIST Comparison of Two Means.

QUESTION NO: 28

The Lean toolbox includes all of these items except ________________.

A. Mistake Proofing

B. Visual Factory

C. Design of Experiments

D. Inventory Management

ANSWER: C

Explanation:

Design of Experiments is the correct exception because it is principally a statistical, data-driven method for planning controlled experiments and determining how input factors, including their interactions, affect an output response. It is most closely associated with the analytical and optimization work performed in Six Sigma, particularly during the Analyze and Improve phases of DMAIC or during Design for Six Sigma activities. A designed experiment deliberately varies factors according to a structured experimental plan, then uses statistical analysis to identify significant effects and select settings that improve performance.

Lean's core toolkit instead emphasizes improving flow, eliminating waste, making work visible, building quality into the process, and operating pull-based systems. While Lean practitioners may participate in projects where experimental methods are useful, Design of Experiments is not ordinarily categorized as a foundational Lean tool. The American Society for Quality describes DOE as a structured method for determining the relationship between factors affecting a process and that process's output, which reflects its statistical problem-solving purpose. NIST also provides detailed guidance on experimental design and analysis in its engineering statistics handbook. See ASQ's Design of Experiments overview and the NIST/SEMATECH Engineering Statistics Handbook section on process improvement.

QUESTION NO: 29

Which of the following are purposes of conducting a Measurement System Analysis before using data for a process-improvement decision? (Note: There are 3 correct answers).

A. Quantifying measurement variation

B. Determining whether appraisers obtain consistent results

C. Establishing customer specification limits

D. Assessing whether the measurement system can distinguish part-to-part variation

E. Demonstrating that the process is statistically stable

ANSWER: A B D

Explanation:

Measurement System Analysis evaluates whether the data collection process is adequate for its intended use. **Quantifying measurement variation** is correct because a measurement system contributes variation in addition to actual part-to-part or process variation. The team needs to understand whether the observed differences in data represent real process differences or measurement noise.

Determining whether appraisers obtain consistent results is also correct. For a measurement system involving people, reproducibility evaluates the extent to which different appraisers obtain comparable results when measuring the same parts. **Assessing whether the measurement system can distinguish part-to-part variation** is correct because a system that cannot distinguish meaningful differences among units is not suitable for monitoring or capability work. MSA does not establish specification limits, nor does it eliminate the need to validate process stability. See AIAG Measurement Systems Analysis resources and NIST measurement process characterization guidance.

QUESTION NO: 30

When variation is removed from the output of a process then the process customer can have more confidence in the experience that results from the process.

A. True

B. False

ANSWER: A

Explanation:

True is correct. A central Lean Six Sigma objective is to reduce variation in process outputs so that results are consistent, predictable, and reliably meet customer requirements. When output variation is reduced, customers are less likely to receive a product or service that differs materially from what they expect, whether that expectation concerns dimensions, performance, delivery time, accuracy, or service quality. This consistency increases confidence because the customer experience is no longer dependent on random fluctuation or unstable process conditions.

Variation reduction is closely associated with process capability and statistical control. A stable process has predictable common-cause variation, while capability assesses whether that predictable output fits within customer specification limits. Improving both allows an organization to deliver conforming outcomes more consistently. In Six Sigma practice, teams use data to identify sources of variation, control critical input variables, standardize work, and sustain the improved process through a control plan. The result is a more dependable customer experience and stronger trust in the process output. See the ASQ overview of Six Sigma and NIST guidance on process capability.

QUESTION NO: 31

How many experimental runs exist in a Full Factorial and fully randomized design for 5 factors with 2 replicates for the Corner Points and no Center Points? The factors in the experiment are only at 2-levels.

A. 10

B. 128

C. 256

D. 64

ANSWER: D

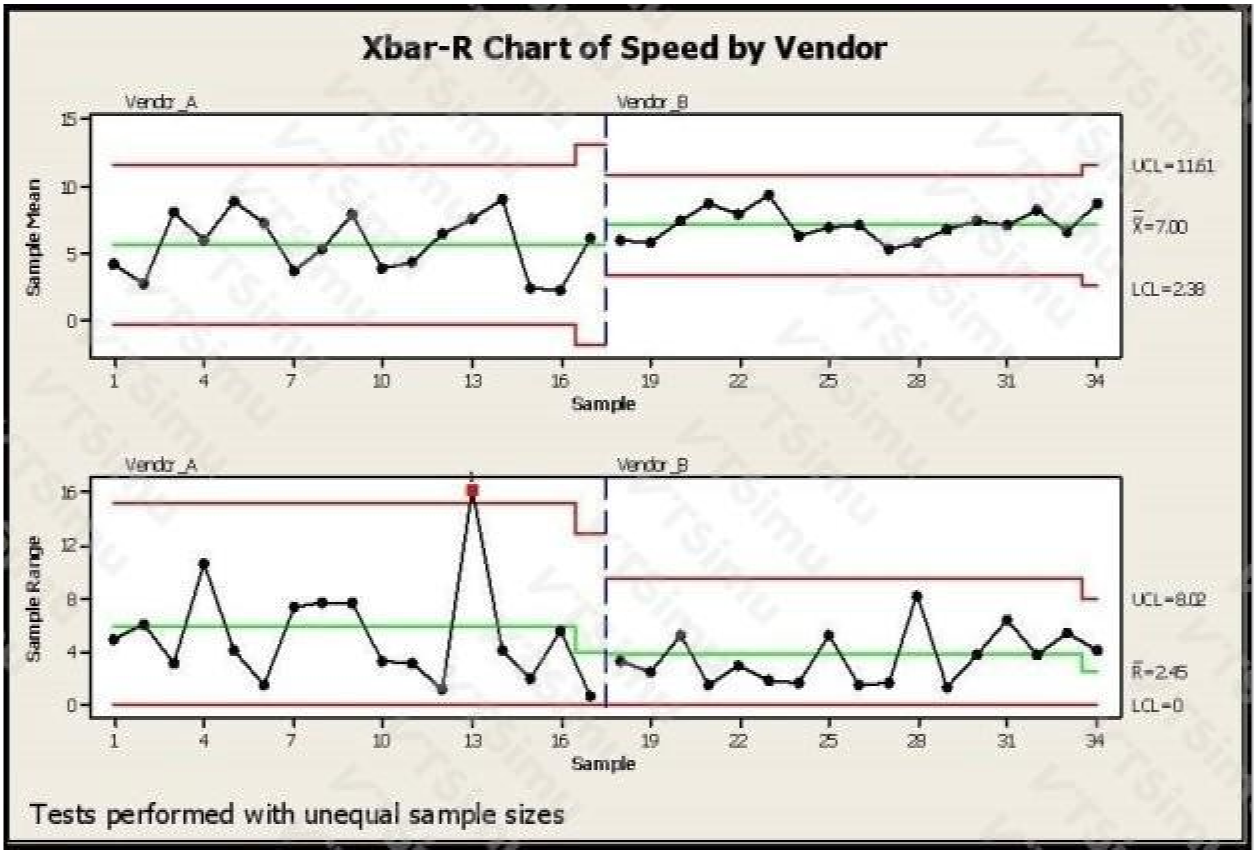
Explanation:

64 is correct. A full two-level factorial design includes every possible combination of the low and high settings for each factor. With five factors, the number of unique corner-point treatment combinations is calculated as 2^5, which equals 32. “Corner points” refers to those combinations at the extremes of the experimental region; because every factor has only two levels, all factorial treatment combinations are corner points.

The design specifies two replicates for the corner points. Replication means conducting the complete set of 32 treatment combinations twice, rather than merely taking two measurements from one run. Therefore, the total number of experimental runs is 32 multiplied by 2, or 64. Full randomization affects the order in which these 64 runs are performed, helping protect the experiment from time-related, environmental, and other nuisance-variable effects; it does not change the number of runs. No center points are included, so no additional runs are added to the replicated factorial total. This follows the standard factorial-design run-count relationship: number of treatment combinations equals the number of levels raised to the number of factors, with replication multiplying that count. See NIST/SEMATECH on full factorial designs and NIST/SEMATECH on two-level factorial designs.

QUESTION NO: 32

SPC Charts are used extensively in different business and decision-making environments. In this example a vendor is being selected based on speed of delivery. Which of the conclusions would help you pick a vendor for your needs regarding leadtime of delivery from your vendors? (Note: There are 4 correct answers).



A. Vendor A with a much shorter lead time in delivery

B. Vendor B as it has a better consistency (lower variance) on lead time

C. Vendor B since Vendor A shows a situation out of control as shown in red

D. Vendor B since the Control Limits are much narrower than Vendor A

E. Vendor B has higher lead time, but a process with much narrower Control Limits

ANSWER: B C D E

Explanation:

For a vendor decision where dependable delivery performance matters, the evidence favoring Vendor B is its more consistent lead-time process. Lower process variation means delivery dates are more predictable, which supports planning, inventory control, production scheduling, and customer commitments. The narrower control limits displayed for Vendor B are consistent with a smaller level of routine, common-cause variation when the charts use comparable measures and charting conditions. Vendor A also displays a red, out-of-control signal, indicating special-cause variation that should be investigated before the process can be considered stable and predictable. A process must first be statistically stable before its historical performance can be used confidently for forecasting or supplier decisions. Although Vendor B has a higher typical lead time, its narrow and stable process spread can make it the stronger choice when the operational need is reliable, consistent delivery rather than simply the shortest average lead time. The appropriate selection can therefore weigh the trade-off between central lead time and predictability, while recognizing that an unstable process creates greater delivery risk. See the ASQ control-chart overview and the NIST guidance on control charts.

QUESTION NO: 33

The Mann-Whitney test is a powerful test and is unique to situations from which of the choices listed? (Note: There are 2 correct answers).

A. Testing the identity of two populations

B. Focuses on equality of the Median of the two populations

C. Less powerful than the traditional “t-test”

D. More widely applicable than the traditional “t-test”

ANSWER: B D

Explanation:

The Mann-Whitney test is a nonparametric, rank-based procedure for comparing two independent populations. “Focuses on equality of the Median of the two populations” is correct in the common Lean Six Sigma interpretation: when the population distributions have a similar shape and spread, a difference in their rank locations is interpreted as a difference in central location, commonly expressed as a difference in medians. This makes the test especially useful when continuous data do not satisfy the normality assumptions needed for a two-sample t-test, or when the data are ordinal.

“More widely applicable than the traditional “t-test”” is also correct because the Mann-Whitney procedure does not require normally distributed source populations and operates on ranks rather than the original measurement values. It can therefore support valid comparisons in many practical process-improvement settings involving skewed data, outliers, or ordered categorical ratings, provided the samples are independent and the measurement scale permits ranking. NIST describes the Mann-Whitney test as a nonparametric alternative for comparing two populations, and notes its use when normal-distribution assumptions are unsuitable. See the NIST Engineering Statistics Handbook and Penn State’s Mann-Whitney test overview.

QUESTION NO: 34

Using this partial Z Table, how many units from a month’s production run are expected to not satisfy customer requirements for the following process?

Upper specification limit: 8.4 Lower specification limit: 4.7 Mean of the process: 6.2 Standard Deviation: 2.2 Monthly production: 360 units

A. 8

B. 13

C. 28

D. 57

E. 146

ANSWER: E

Explanation:

The expected number of units not satisfying requirements is **146 units**, calculated from the combined probability of observations below the lower specification limit and above the upper specification limit. Standardize each specification limit using $z = (x - mean) / standard\ deviation$. For the upper specification limit, $z = (8.4 - 6.2) / 2.2 = 1.00$, giving an upper-tail probability of approximately 0.1587. For the lower specification limit, $z = (4.7 - 6.2) / 2.2 = -0.68$, whose lower-tail probability is approximately 0.2483 (using a Z table; minor variation results from rounding the z value). Because a unit fails customer requirements when it falls in either non-overlapping tail, the total nonconforming proportion is approximately $0.1587 + 0.2483 = 0.4070$. Multiplying by the monthly production volume gives $360 \times 0.4070 = 146.52$ expected units. Since units are counted as whole items and Z-table values are rounded, this is reported as approximately 146 units. This application follows the normal-distribution tail-area method used in process-capability analysis; see the NIST normal-distribution reference and the NIST process-capability guidance.