

PRACTICE EXAM 3: ASQ CQE SIMULATION

(175 QUESTIONS)

1. A quality engineer discovers that a process has $C_{pk} = 1.45$ for a critical dimension. The production manager asks whether 100% inspection can be eliminated. Which response best reflects sound quality engineering practice?

- A. Yes, because any C_{pk} above 1.0 guarantees zero defects and makes inspection unnecessary
- B. The high C_{pk} supports reducing inspection intensity, but ongoing SPC monitoring must continue to verify the process remains stable and capable
- C. No, because process capability cannot predict individual part conformance under any circumstances
- D. Yes, but only if the measurement system has been recently recalibrated within the last 30 days

2. A manufacturing company identifies that 72% of its total Cost of Quality consists of internal and external failure costs. Which strategic action best aligns with the classical COQ optimization model?

- A. Increase investment in prevention activities, which should produce a disproportionately larger decrease in failure costs
- B. Reduce appraisal activities to offset the high failure costs and minimize total spending
- C. Accept the current distribution as typical for the industry and focus on revenue growth instead
- D. Shift from internal failure detection to external failure response to reduce internal costs

3. A quality engineer needs to determine whether a new cleaning solvent removes contaminants more effectively than the current solvent. Each of 15 test coupons is cleaned with both solvents, and residual contamination is measured after each cleaning. Which statistical test is most appropriate?

- A. Twosample ttest for independent groups with equal variances assumed
- B. Oneway ANOVA comparing the two solvent groups as independent treatments
- C. Chisquare test of independence for categorical contamination classifications
- D. Paired ttest because the same coupons are measured under both conditions

4. In the context of lean manufacturing, a production line has a takt time of 2 minutes but the cycle time for the bottleneck workstation is 2.8 minutes. What is the immediate consequence of this imbalance?

- A. The line will overproduce inventory at downstream stations because work arrives faster than demand
- B. The bottleneck station will produce at exactly takt time through operator overtime and increased effort
- C. The line cannot meet customer demand because the bottleneck constrains throughput below the required rate
- D. The takt time calculation is incorrect and must be recalculated using the bottleneck cycle time

5. An organization implements a document control system for its quality management system. Six months later, an internal audit reveals that three departments are using locally stored copies of procedures that were superseded two revisions ago. This finding most directly indicates a failure in which aspect of document control?

- A. Document approval procedures requiring multiple levels of management signoff
- B. Distribution and withdrawal controls that should ensure obsolete documents are removed from all points of use
- C. The naming convention used for document identification numbers and titles
- D. The frequency of procedure revisions, which is occurring too rapidly for users to track

6. A quality engineer is conducting a risk assessment and identifies a failure mode where the probability is rated as "remote" but the severity is rated as "catastrophic — potential loss of life." Under risk management principles for safetycritical applications, how should this risk be prioritized?

- A. Low priority because the remote probability makes the expected loss negligible
- B. Medium priority to be addressed after all higherprobability risks are resolved
- C. Deferred until additional historical data confirms whether the failure has ever occurred
- D. High priority because catastrophic severity demands robust risk reduction regardless of probability

7. A quality engineer is analyzing a set of process measurements and finds that the mean is 50.2, the median is 48.6, and the mode is 47.0. What does the relationship among these three measures indicate about the distribution?

- A. The distribution is rightskewed (positively skewed) with a tail extending toward higher values
- B. The distribution is perfectly normal with all three measures converging at the center
- C. The distribution is leftskewed (negatively skewed) with a tail extending toward lower values
- D. The distribution is bimodal with two peaks at 47.0 and 50.2 respectively

8. During a supplier audit, the auditor discovers that the supplier performs incoming inspection on all purchased materials but has no system for evaluating or monitoring supplier performance over time. Which quality system element is the supplier lacking?

- A. Firstarticle inspection procedures for new product introductions
- B. Document control for incoming material specifications and drawings
- C. A supplier performance monitoring system with defined metrics such as quality, delivery, and cost
- D. An MRB process for dispositioning nonconforming incoming material

9. In a designed experiment, a quality engineer identifies an interaction between cutting speed (Factor A) and feed rate (Factor B) that is nearly as large as the main effect of cutting speed alone. When optimizing the process, the engineer should take which approach?

- A. Optimize cutting speed and feed rate jointly, considering their interaction, rather than setting each factor independently
- B. Ignore the interaction because main effects are always more important than interactions
- C. Set both factors to their high levels since both main effects are positive
- D. Eliminate the interaction by adding a third factor to the experimental design

10. A quality engineer is implementing SPC on a plating process that applies a coating thickness to metal substrates. The process produces one batch per day, and the engineer takes a single thickness measurement from each batch. Which control chart is most appropriate?

- A. Xbar and R chart with subgroups of 5 measurements per batch
- B. pchart monitoring the proportion of batches with outofspecification thickness
- C. cchart counting the number of coating defects per substrate surface
- D. Individuals and Moving Range (IMR) chart plotting single daily measurements

11. A quality engineer discovers that operators on a production line are making process adjustments after every measurement, even when the control chart shows the process is in statistical control. The engineer recognizes this as tampering. What is the expected effect of this behavior on process variation?

- A. Process variation will decrease because operators are keeping the process closer to target
- B. Total process variation will increase because each unnecessary adjustment adds variation on top of the inherent common cause variation
- C. Process variation will remain unchanged because the adjustments cancel each other out over time
- D. Process variation will initially increase but then stabilize at a lower level as operators improve

12. In the context of ISO 9001:2015, which clause specifically addresses the requirement for the organization to ensure that externally provided processes, products, and services conform to requirements?

- A. Clause 5.3 — Organizational roles, responsibilities, and authorities
- B. Clause 7.5 — Documented information control and maintenance
- C. Clause 8.4 — Control of externally provided processes, products, and services
- D. Clause 10.1 — General requirements for improvement activities

13. A Gage R&R study produces the following results: repeatability contributes 18% of total variation and reproducibility contributes 15% of total variation. The total Gage R&R is approximately 23.4% of total variation. Which improvement strategy should be pursued first?

- A. Address both repeatability and reproducibility simultaneously since they contribute similar amounts, through instrument upgrade and operator training
- B. Focus exclusively on repeatability by replacing the instrument, since it is the largest single contributor
- C. Focus exclusively on reproducibility by standardizing the measurement procedure across operators
- D. Accept the measurement system since the total %GRR is below 30%

14. A quality engineer is conducting a hypothesis test and the calculated pvalue is 0.001. The significance level was set at $\alpha = 0.05$. Which statement most accurately describes the practical interpretation of this result?

- A. The result confirms that the observed difference has no practical significance
- B. The sample size was too large, artificially inflating the significance of a trivial effect
- C. The null hypothesis must be retested with a larger significance level for confirmation

D. There is very strong statistical evidence against the null hypothesis, but the quality engineer should also evaluate the practical significance and magnitude of the observed effect

15. An organization's corrective action log reveals that 85% of corrective actions are closed within the required 30day timeline, but recurring nonconformities account for 40% of all new corrective action requests. What does this data pattern most likely indicate?

A. The 30day timeline is too short for implementing effective corrective actions

B. Corrective actions are being closed on time but are not effectively addressing root causes, leading to recurrence

C. The corrective action system is performing well since most actions are closed promptly

D. The root causes are too complex to be resolved through the corrective action process

16. In a 2^{5-2} fractional factorial design, how many experimental runs are required?

A. 32 runs representing the full factorial for five factors

B. 16 runs representing a halffraction of the full factorial

C. 8 runs representing a quarterfraction of the full factorial

D. 4 runs representing oneeighth of the full factorial

17. A quality engineer notices that two control charts are being maintained for the same characteristic on the same process — one by the day shift and one by the night shift, using different baseline data to calculate control limits. Why is this practice problematic?

- A. Maintaining two charts doubles the inspection cost without providing additional quality information
- B. Using different baselines means the two charts may signal differently for the same process condition, creating inconsistent decisions about when to investigate
- C. Control charts should only be maintained by the quality department, not by production shifts
- D. The day shift chart should always be used because day shift data is more reliable

18. A quality engineer is analyzing warranty return data and discovers that 60% of field failures are caused by a single component — a capacitor that degrades under hightemperature operating conditions the design team did not anticipate. This failure is most accurately classified as which type of design deficiency?

- A. A process validation failure related to manufacturing parameter control
- B. A supplier quality failure from substandard capacitor material composition
- C. An incoming inspection failure for not detecting weak capacitors before assembly
- D. A design input failure — the actual operating environment was not adequately identified in the design requirements

19. In the context of quality system auditing, which type of audit involves a customer evaluating a potential supplier's quality management system and manufacturing capabilities before placing orders?

- A. Secondparty audit conducted by the customer on the prospective supplier
- B. Firstparty audit conducted by the supplier's own internal audit team
- C. Thirdparty audit conducted by an independent certification body
- D. Regulatory audit conducted by a government enforcement agency

20. A quality engineer is constructing an acceptance sampling plan and needs to minimize both producer's risk and consumer's risk simultaneously. The most effective way to achieve this is to take which action?

- A. Increase the AQL value to make the plan more lenient for the producer
- B. Decrease the LTPD value to make the plan less demanding for the consumer
- C. Increase the sample size, which steepens the OC curve and improves discrimination between good and bad lots
- D. Use tightened inspection permanently regardless of quality history

21. A process control plan requires a reaction plan for each monitored characteristic. An operator detects an outofcontrol signal on the Xbar chart at 2:15 PM. The reaction plan states: "Stop process, segregate material, notify quality." The operator stops the process and notifies quality but does not segregate any material. Why is this response incomplete?

- A. The operator should have continued production while waiting for the quality engineer to arrive
- B. Notifying quality should have been the first action before stopping the process
- C. The control chart signal was likely a false alarm and no action was actually required
- D. Material produced since the last known good subgroup must be segregated because it was produced under potentially outofcontrol conditions and may be nonconforming

22. A quality engineer is implementing a kanban system and needs to determine the number of kanban cards required. The calculation depends on which primary factors?

- A. The number of employees on each shift and the overhead cost per unit produced
- B. Daily demand, lead time for replenishment, safety stock factor, and container size
- C. The number of inspection stations and the defect rate per station

D. Equipment utilization rates and preventive maintenance schedules

23. A quality engineer calculates a 90% confidence interval for a process mean as (24.8, 25.4). If the engineer recalculates using the same data but at a 95% confidence level, which change will occur?

- A. The interval will become wider than (24.8, 25.4) because higher confidence requires more width
- B. The interval will become narrower because 95% is a more precise estimate than 90%
- C. The interval will shift to the right because a higher confidence level increases the mean estimate
- D. The interval will remain exactly the same because it is calculated from the same data

24. In the context of the Kano Model, a hotel guest expects a clean room with functioning plumbing and electricity. These expectations represent which type of requirement?

- A. Excitement requirements that differentiate the hotel from competitors
- B. Performance requirements with satisfaction proportional to quality level
- C. Reverse requirements that decrease satisfaction when present
- D. Basic requirements whose absence causes strong dissatisfaction but whose presence achieves only neutral satisfaction

25. A quality engineer is tasked with evaluating whether four different furnace temperatures produce significantly different mean hardness values in heat-treated steel. Eight specimens are tested at each temperature. Which statistical method is most appropriate?

- A. Four separate one-sample t-tests comparing each temperature group to a reference value

- B. Paired ttest comparing the highest and lowest temperature groups only
- C. Twoproportion Ztest comparing defect rates across the four temperature settings
- D. Oneway ANOVA comparing the means of four independent groups simultaneously

26. In the Six Sigma DMAIC methodology, the primary purpose of the Define phase is to accomplish which of the following?

- A. Establish the project scope, objectives, business case, and team composition through a formal project charter
- B. Collect baseline data and validate the measurement system through Gage R&R analysis
- C. Identify the root causes of the problem using statistical tools such as regression and ANOVA
- D. Implement and verify solutions that address the confirmed root causes of the quality problem

27. A quality engineer is analyzing process data using a histogram and observes that the distribution has a long tail extending to the right while the bulk of the data is concentrated on the left. Which probability distribution might best model this data?

- A. Normal distribution with equal tails on both sides of the mean
- B. Uniform distribution with equal probability across the entire range
- C. Lognormal distribution, which naturally produces rightskewed shapes bounded at zero
- D. Binomial distribution with a small number of trials and moderate probability

28. During a process FMEA, the team identifies that a critical assembly step relies entirely on the operator visually verifying correct component orientation before inserting it. No physical barrier

prevents incorrect insertion. The team rates Severity = 8, Occurrence = 5, Detection = 8. What is the most effective recommended action to reduce this risk?

- A. Increase the severity rating to 9 to better reflect the criticality of the failure
- B. Implement errorproofing (pokayoke) such as an asymmetric fixture that prevents incorrect insertion
- C. Add a final inspection checkpoint to catch incorrectly oriented components after assembly
- D. Retrain all operators on the correct visual verification technique with updated work instructions

29. A quality engineer is analyzing control chart data and discovers that the process standard deviation estimated from the R chart ($\hat{\sigma} = \bar{R}/d_2$) is 0.10, while the process standard deviation estimated from all individual data points (s_{overall}) is 0.10. What does the equality of these two estimates indicate?

- A. The measurement system has zero variation and does not contribute to the observed data
- B. The control chart constants were incorrectly applied for the subgroup size used
- C. The sample size is too small to detect any difference between the two estimates
- D. The process has been in statistical control — no significant between-subgroup variation from special causes exists

30. A quality engineer is reviewing an organization's risk management program and discovers that the risk register has not been updated in 18 months, even though two new product lines were launched and a major supplier was changed during that period. What is the primary concern?

- A. The risk register may no longer reflect the organization's actual risk profile because significant changes have occurred that could introduce new risks or alter existing ones
- B. The risk register format may be outdated and should be converted to a newer software platform
- C. The 18-month gap exactly matches the ISO 31000 recommended review interval and is acceptable
- D. Risk registers are static documents that only need updating during external audit preparation

31. In GD&T, a position tolerance of 0.50 mm diameter at MMC is applied to a hole pattern with datum references A, B, and C. The term "0.50 mm diameter" defines which geometric concept?

- A. The maximum diameter of each hole in the pattern
- B. The minimum wall thickness between adjacent holes
- C. A cylindrical tolerance zone within which the axis of each hole must lie
- D. The maximum permissible center-to-center distance between holes

32. A quality engineer is using a cause-and-effect diagram to investigate a soldering defect. After the team identifies 35 potential causes across the 6M categories, which tool should be used next to narrow the investigation?

- A. An activity network diagram to schedule the corrective action implementation
- B. A process decision program chart to anticipate problems during the investigation
- C. A tree diagram to decompose each potential cause into more granular subcauses
- D. Data collection targeting the most likely causes, followed by Pareto analysis to prioritize based on evidence

33. A quality engineer is evaluating a supplier's process capability data and notices that the supplier calculated C_p and C_{pk} using only 25 data points collected over a single two-hour production run. Why might this data be insufficient for a reliable capability assessment?

- A. The short collection period may not capture the full range of process variation from shift-to-shift, lot-to-lot, and environmental sources that affect long-term performance
- B. Twenty-five data points always exceeds the minimum required for capability studies
- C. Capability indices can only be calculated from attributes data, not variables measurements
- D. The two-hour window is the standard recommended duration for all capability studies

34. In the context of quality training, a company discovers that employees who attended SPC training six months ago are not maintaining control charts correctly on the production floor. According to Kirkpatrick's model, which evaluation level failure does this represent?

- A. Level 4 — Results, because organizational quality metrics have not improved
- B. Level 3 — Behavior, because trained skills are not being transferred to the workplace
- C. Level 1 — Reaction, because participants were dissatisfied with the training
- D. Level 2 — Learning, because participants did not acquire the knowledge during training

35. A reliability analysis of a safety system reveals a single point of failure — one component whose failure alone causes the entire system to fail. Which design modification most directly addresses this vulnerability?

- A. Increasing the inspection frequency for the single component to detect degradation earlier
- B. Adding a preventive maintenance schedule with shorter replacement intervals
- C. Replacing the component with a higher reliability alternative from a different manufacturer
- D. Adding a redundant (parallel) component so that both must fail for the system to fail

36. A quality engineer is comparing the output of five production machines using oneway ANOVA. The ANOVA yields a significant Ftest ($p = 0.01$), indicating that at least one machine differs. However, the engineer needs to determine which specific machines differ from which others. Which followup analysis is appropriate?

- A. Repeat the ANOVA with each pair of machines excluded to isolate the effect
- B. Conduct a chisquare test of independence for each pair of machines
- C. Perform a multiple comparison procedure such as Tukey's HSD test
- D. Calculate the coefficient of variation for each machine independently

37. An organization is implementing ISO 9001:2015 and must address Clause 6.1, which requires actions to address risks and opportunities. The quality manager asks whether a formal risk management methodology like FMEA is required. What is the correct answer?

- A. ISO 9001:2015 requires riskbased thinking but does not prescribe a specific risk management methodology — the organization may use any approach appropriate to its context
- B. FMEA is the only acceptable method for ISO 9001 compliance
- C. ISO 9001:2015 does not address risk in any clause and the requirement is voluntary
- D. Only organizations with more than 500 employees are required to implement formal risk management

38. A quality engineer needs to determine whether a process improvement has reduced the defect rate from the historical level of 5%. A sample of 300 units from the improved process yields 9 defective units (3.0%). Which hypothesis test is most appropriate?

- A. Ftest for equality of variances between the old and new process
- B. Oneproportion Ztest comparing the sample proportion to the historical proportion
- C. Paired ttest comparing individual unit measurements before and after the improvement
- D. Chisquare goodnessoffit test for the distribution of defects across categories

39. In the cost of quality framework, a quality engineer classifies the cost of conducting incoming material inspection. Under which COQ category does this activity fall?

- A. Prevention costs because inspection prevents defective material from entering production
- B. Internal failure costs because inspection occurs before the product reaches the customer
- C. Appraisal costs because the activity is designed to detect nonconformances through examination
- D. External failure costs because the material was received from an external source

40. A quality engineer observes a cyclical pattern on a control chart — the plotted values oscillate regularly above and below the center line with a period of approximately 8 subgroups. Which category of root cause is most likely responsible?

- A. A random shift in the process mean caused by a single discrete event
- B. Gradual tool wear that progressively increases the measured dimension
- C. Measurement system drift that produces a consistent upward bias over time
- D. A periodic disturbance such as temperature cycling, batch rotation, or scheduled equipment maintenance

41. A quality engineer is evaluating a designed experiment and discovers that the experiment was conducted without randomization — all treatments were run in the order listed in the design matrix. What is the primary risk introduced by this lack of randomization?

- A. Factor effects may be confounded with time-dependent lurking variables, making it impossible to determine whether observed differences are due to the factors or to the time-related changes
- B. The statistical analysis cannot be performed without randomization because ANOVA requires random run order
- C. The experimental results will automatically be statistically insignificant without randomization
- D. Randomization only matters for experiments with more than four factors

42. In the context of acceptance sampling, a lot of 1,000 items is inspected using a sampling plan with $n = 80$ and $c = 2$. The sample yields 3 defective items. What is the disposition decision for this lot?

- A. Accept the lot because 3 defectives out of 1,000 represents only 0.3%
- B. Reject the lot because the number of defectives (3) exceeds the acceptance number ($c = 2$)
- C. Accept the lot because the percentage defective in the sample is below the AQL

D. Place the lot on hold pending additional sampling to confirm the initial results

43. A quality engineer is implementing a 5S program in a production area. During the Set in Order phase, the team labels storage locations, installs shadow boards for tools, and applies floor markings for material staging areas. What is the primary purpose of these visual controls?

A. To document the 5S implementation for the ISO 9001 certification audit

B. To reduce the cost of maintaining the workplace organization system over time

C. To prepare the workspace for automated material handling equipment installation

D. To make the standard condition immediately visible so that missing items, misplaced materials, and deviations from the standard are instantly apparent

44. A quality engineer discovers that a critical process parameter drifted out of its validated range for approximately 4 hours before being detected and corrected. Which immediate action is most important?

A. Document the deviation and include it in the next scheduled management review meeting

B. Recalibrate the instrument that monitors the process parameter to prevent future drift

C. Retrain the operator responsible for monitoring the process parameter during that shift

D. Identify and segregate all product manufactured during the 4hour period for evaluation and disposition

45. In a multiple regression analysis, the quality engineer includes five predictor variables. The R^2 is 0.89, but the adjusted R^2 is only 0.71. What does the large gap between R^2 and adjusted R^2 suggest?

- A. One or more predictor variables are not contributing meaningfully and are overfitting the model, inflating R^2 without genuine explanatory power
- B. The model is highly significant and all five predictors are important contributors
- C. The sample size is too large, causing artificial inflation of the adjusted R^2 value
- D. The residuals are normally distributed, confirming that all model assumptions are met

46. A quality engineer needs to select a nondestructive testing method for detecting internal voids and porosity in aluminum castings. The castings have complex geometries that make access from all sides difficult. Which NDT method is most appropriate?

- A. Liquid penetrant testing for surfacebreaking discontinuity detection
- B. Radiographic testing, which can detect internal volumetric defects regardless of access limitations
- C. Magnetic particle testing for subsurface discontinuities in the casting
- D. Visual inspection with fiber optic borescope for internal surface examination

47. A process produces output with a normal distribution, a mean of 100.0 mm, and a standard deviation of 0.5 mm. The specification limits are 99.0 mm and 101.0 mm. Approximately what percentage of output falls outside the specification limits?

- A. 0.27% based on the $\pm 3\sigma$ coverage of the normal distribution
- B. 4.56% based on the $\pm 2\sigma$ coverage leaving approximately 4.56% in the tails combined
- C. 31.73% based on the $\pm 1\sigma$ coverage of the normal distribution
- D. The percentage cannot be calculated without knowing the sample size

48. A quality engineer is reviewing a Material Review Board disposition and finds that the board approved a "repair" disposition for a batch of nonconforming parts. The repair involves machining the parts to a dimension that does not meet the original drawing specification but that engineering analysis confirms is functionally acceptable. What distinguishes this repair from rework?

- A. Repair is less expensive than rework and is therefore preferred by the organization
- B. After repair, the parts meet a revised acceptance criterion rather than the original drawing specification, whereas rework restores full conformance to the original specification
- C. Repair requires customer approval while rework does not under any circumstances
- D. Repair applies only to incoming purchased material while rework applies to internally manufactured parts

49. In a screening experiment using a 2^{7-4} fractional factorial design, the engineer identifies three factors as statistically significant. The next step in the sequential experimentation strategy is to perform which type of followup experiment?

- A. Repeat the same 2^{7-4} screening design with double the replication to confirm results
- B. Conduct a onefactoratatime study on each of the three significant factors independently
- C. Conduct a higherresolution design (such as a 2^3 full factorial) with only the three significant factors to characterize main effects and interactions cleanly
- D. Immediately implement the factor settings identified in the screening experiment into production

50. A quality engineer is evaluating a supplier's measurement capability for a critical dimension. The supplier's Gage R&R study shows %GRR = 35% of tolerance and $ndc = 3$. Based on AIAG MSA guidelines, what is the assessment?

- A. The system is unacceptable for making quality decisions because %GRR exceeds 30% and ndc is below 5

- B. The system is fully acceptable because the %GRR is within the conditionally acceptable range
- C. The system is conditionally acceptable and can be used with management approval
- D. The ndc value alone determines acceptability, and 3 is sufficient for most applications

51. A quality engineer is analyzing timeseries data from a chemical process and discovers that the autocorrelation at lag 1 is statistically significant ($r_1 = 0.78$). Standard Xbar and R charts are being used to monitor the process. What is the primary concern?

- A. The chemical process is out of control and requires immediate corrective action
- B. The autocorrelation has no effect on control chart performance for chemical processes
- C. The data should be transformed using a BoxCox transformation before plotting on control charts
- D. Standard control charts assume independent observations, and significant autocorrelation will produce excessive false alarms because the chart interprets correlated patterns as special causes

52. Deming argued that the vast majority of quality problems — approximately 8594% — are caused by the system rather than by individual workers. This perspective most directly supports which management action?

- A. Focusing improvement efforts on changing the system (processes, equipment, materials, methods) rather than blaming individual workers for systemcaused problems
- B. Eliminating all performance evaluations and accountability measures for workers
- C. Reducing the quality department headcount since workers are rarely the cause of problems
- D. Outsourcing all quality improvement activities to external consulting firms

53. A quality engineer needs to verify that the output of a filling machine follows a normal distribution before calculating process capability indices. Which graphical tool provides the most direct visual assessment of normality?

- A. Histogram with specification limits overlaid for visual comparison
- B. Run chart plotting individual measurements in time order
- C. Normal probability plot where normally distributed data falls on a straight line
- D. Box plot showing the median, quartiles, and potential outliers

54. In the context of the ASQ Code of Ethics, a quality engineer is asked by a client to certify that a product meets a specification when the engineer's own test results show it does not. The client argues that the nonconformance is trivial and will not affect safety. What is the engineer's ethical obligation?

- A. Certify the product since the client takes responsibility for the decision
- B. The engineer must not certify a product that does not meet specifications, regardless of the client's assessment of significance
- C. Certify the product with a footnote describing the nonconformance in small print
- D. Defer the decision to the client's quality department for their independent judgment

55. A quality engineer is constructing a pchart for a production process. The average proportion nonconforming is $\bar{p} = 0.03$, and the standard sample size is $n = 200$. What are the center line and upper control limit?

- A. CL = 0.03, UCL = 0.030
- B. CL = 6.0, UCL = 13.35
- C. CL = 0.03, UCL = 0.066
- D. CL = 0.03, UCL = 0.066

56. A reliability engineer needs to determine the probability that a component with a constant failure rate of $\lambda = 0.002$ failures per hour will survive for 500 hours of operation. Using the exponential reliability function $R(t) = e^{-(\lambda t)}$, what is the reliability?

- A. $R(500) = e^{-(0.002 \times 500)} = e^{-1.0} \approx 0.368$
- B. $R(500) = 1 - 0.002 \times 500 = 0.000$, indicating certain failure
- C. $R(500) = 0.002 / 500 = 0.000004$, a negligible probability of survival
- D. $R(500) = e^{-(0.002/500)} = e^{-0.000004} \approx 1.000$

57. In the context of lean manufacturing, the concept of "pull" production means which of the following?

- A. Production is triggered by forecasted demand, with finished goods stored in anticipation of customer orders
- B. Equipment operators pull materials from the warehouse based on their own judgment of production needs
- C. Production is scheduled by a central planning system that pushes work orders to each workstation
- D. Each process step produces only what is consumed by the downstream process, triggered by actual demand signals

58. A quality engineer is reviewing the results of a twoway ANOVA with factors Machine (A, B, C) and Material (X, Y). The interaction term is not statistically significant ($p = 0.62$), but both main effects are significant. What does the nonsignificant interaction mean for interpretation?

- A. The analysis is invalid and should be reconducted with different factor levels
- B. Machine and material should be analyzed together as a single combined factor

C. The nonsignificant interaction confirms that the effect of each factor is consistent across the levels of the other factor, and the main effects can be interpreted independently

D. The main effects are also nonsignificant because interaction must be significant before main effects are meaningful

59. A quality engineer is implementing errorproofing on a packaging line where operators occasionally place the wrong product label on boxes. Which pokayoke approach is most effective?

A. Adding a warning sign at the workstation reminding operators to verify the label before application

B. A barcode scanner that reads both the product and the label and prevents the packaging machine from sealing unless they match

C. A daily audit of packaged products to detect labeling errors before shipment

D. A checklist requiring operators to initial after verifying each label application

60. A quality engineer calculates the following from an Xbar and R chart with 25 subgroups of size 5: grand average $\bar{\bar{x}} = 75.0$, average range $\bar{R} = 5.8$, $A_2 = 0.577$, $D_3 = 0$, $D_4 = 2.114$. What is the lower control limit for the R chart?

A. Zero, because $D_3 = 0$ for subgroup sizes of 5 or less

B. 2.90, calculated as $\bar{R} \times D_3/2$ for balanced control limits

C. 5.80, the same as the center line since the R chart cannot have an LCL

D. 3.35, calculated as $\bar{R} - A_2 \times \bar{R}$ using the Xbar chart constant

61. A quality engineer is analyzing the costeffectiveness of a preventive maintenance program. The program costs \$120,000 annually to operate but has reduced unplanned equipment failures from 48 per

year to 8 per year. Each unplanned failure costs an average of \$5,000 in repairs, scrap, and lost production. What is the annual net benefit of the preventive maintenance program?

- A. The program costs more than the savings and should be discontinued
- B. The net cost is \$120,000 because the failure cost savings do not offset the program cost
- C. The annual net benefit is \$80,000 — the \$200,000 in failure cost reduction minus the \$120,000 program cost
- D. The annual net benefit is \$200,000 because only the failure cost reduction should be considered

62. In the context of measurement system analysis, "stability" refers to which property of a measurement system?

- A. The variation in measurements when the same operator measures the same part repeatedly under identical conditions
- B. The difference between the average of the measurement system's readings and the true value of the characteristic
- C. The consistency of bias across the full operating range of the measurement instrument
- D. The consistency of the measurement system's performance over an extended period of time

63. A quality engineer needs to determine the appropriate sample size for a hypothesis test comparing two population means. The engineer wants to detect a difference of 2 units with 80% power at $\alpha = 0.05$. The estimated population standard deviation is 4 units. If the engineer increases the desired power to 95%, what happens to the required sample size?

- A. The required sample size decreases because higher power requires fewer observations
- B. The required sample size increases because higher power demands more data to maintain the same probability of detecting the true difference

- C. The required sample size remains the same because power does not affect sample size calculations
- D. The effect on sample size depends entirely on whether the test is onesided or twosided

64. A quality engineer is reviewing an organization's internal audit program and discovers that auditors are assigned to audit their own departments. Which fundamental audit principle is being violated?

- A. Independence — auditors must not audit their own work to ensure objectivity and credibility of findings
- B. Competence — auditors should only audit areas where they have subject matter expertise
- C. Confidentiality — audit findings should only be shared with the auditee's direct manager
- D. Systematic approach — audits should follow a standardized checklist regardless of the area being audited

65. A quality engineer is implementing a quality information system (QIS) and must determine which data to collect. Which principle should guide the selection of data elements?

- A. Collect every possible data point to ensure no information is missed regardless of storage cost
- B. Collect only the data that customers specifically request in their purchase orders
- C. Collect data that is relevant to quality decisionmaking, actionable, and costeffective to obtain
- D. Collect the minimum data required by ISO 9001 and nothing more

66. A quality engineer is analyzing a regression model and discovers that the pvalue for the slope coefficient is 0.24 at $\alpha = 0.05$. The r^2 value is 0.08. What should the engineer conclude about the relationship between the predictor and response variables?

- A. The relationship is strong but requires a larger sample size to achieve statistical significance
- B. The predictor has a strong effect on the response but the data is too variable to detect it
- C. A highly significant linear relationship exists between the predictor and response variables
- D. There is no statistically significant linear relationship — the predictor does not meaningfully explain variation in the response

67. In the context of ISO 14971 (Risk management for medical devices), which phase of the product lifecycle requires active risk management activities?

- A. The entire product lifecycle from initial concept through postmarket surveillance and decommissioning
- B. Only the design and development phase before the product enters production
- C. Only the manufacturing phase when the product is being produced
- D. Only the postmarket phase after the product has been released to customers

68. A quality engineer observes that an R chart for a machining process shows a single point above the upper control limit on subgroup 15, while all other points are in control. The Xbar chart shows no outofcontrol signals. What is the most appropriate action?

- A. Take no action because the Xbar chart confirms the process mean is stable
- B. Investigate the special cause of increased variability at subgroup 15 — possible causes include a loose fixture, worn tooling, material change, or measurement error
- C. Recalculate the R chart control limits excluding subgroup 15 to see if the chart normalizes
- D. Increase the subgroup size to reduce the sensitivity of the R chart

69. A quality engineer is reviewing the FMEA for a new product and notices that every failure mode has been assigned a Detection rating of 1 (nearcertain detection). Which concern should the engineer raise about this pattern?

- A. Detection ratings of 1 are standard for products with final inspection programs in place
- B. The Detection ratings may not accurately reflect the real likelihood of detecting each failure mode, suggesting the ratings were assigned without careful evaluation of the actual detection capability of each control
- C. A Detection rating of 1 means no detection exists and all ratings should be changed to 10
- D. The low Detection ratings will artificially inflate the RPN values above acceptable thresholds

70. A quality engineer is evaluating whether the variance of a critical dimension has changed after installing new tooling. Twenty measurements before the change yield $s_1^2 = 0.036$ and twenty measurements after yield $s_2^2 = 0.015$. The Fstatistic is calculated as $F = 0.036/0.015 = 2.40$ with 19 and 19 degrees of freedom. The critical Fvalue at $\alpha = 0.05$ (twotailed) is 2.168. What is the conclusion?

- A. The variance has not changed significantly because the Fstatistic is close to the critical value
- B. The test is invalid because variance tests require sample sizes of at least 30
- C. The variance has increased significantly after the tooling change
- D. The variance has changed significantly because the Fstatistic (2.40) exceeds the critical value (2.168), providing evidence that the new tooling has altered process variability

71. A quality engineer is tasked with creating a process control plan for a new automotive component. The PFMEA identifies a critical weld joint as the highestrisk feature. Which element is most essential to include in the control plan for this feature?

- A. The specific control method (SPC, 100% inspection, or errorproofing), measurement technique, sample size and frequency, and a detailed reaction plan for outofspecification conditions

- B. The historical defect rate from similar products manufactured at other facilities
- C. The cost of implementing the selected control method compared to alternative methods
- D. The name of the quality engineer who developed the PFMEA and the date of completion

72. In acceptance sampling using ANSI/ASQ Z1.4, a quality engineer is currently on tightened inspection after a lot rejection. Under the switching rules, what triggers discontinuation of inspection?

- A. Five consecutive lots are accepted under tightened inspection
- B. Five consecutive lots are rejected (or fewer if specified by the standard) under tightened inspection, requiring that the source of supply take corrective action before inspection is resumed
- C. The customer requests a return to normal inspection based on production schedule needs
- D. The supplier achieves ISO 9001 certification from an accredited registrar

73. A designed experiment using a 2^3 full factorial yields the following effect estimates: $A = +15.2$, $B = +3.1$, $C = 1.8$, $AB = +12.7$, $AC = 0.5$, $BC = +2.0$, $ABC = 0.3$. A normal probability plot identifies A and AB as the only significant effects. What is the practical implication?

- A. Factor B can be set to any level without affecting the response since its main effect is small
- B. All three factors should be set to their high levels to maximize the response
- C. The large interaction AB is a mathematical artifact and can be safely ignored
- D. Factors A and B must be optimized jointly because the significant AB interaction means the best level of A depends on the level of B

74. A quality engineer discovers that a control chart has been maintained for 18 months without ever being updated to reflect process improvements that have reduced the process mean and standard deviation. The original control limits are still being used. What is the primary problem with this situation?

- A. The original limits are still valid because they were calculated from a statistically adequate baseline period
- B. Using outdated wider control limits makes the chart insensitive to current process changes, failing to detect shifts that would be visible with updated limits
- C. The chart should have been replaced with an attributes chart after the process improvement
- D. Control limits should never be revised because doing so introduces bias into the monitoring system

75. In the context of supplier management, a quality engineer develops a supplier risk assessment that evaluates each supplier based on singlesource status, geographic concentration, financial stability, and quality system maturity. A supplier scores "high risk" on singlesource status and "medium risk" on all other factors. What is the most appropriate risk mitigation strategy?

- A. Qualify an alternate supplier for the same component to eliminate singlesource dependency
- B. Increase incoming inspection frequency on all shipments from this supplier
- C. Require the supplier to achieve ISO 9001 certification within six months
- D. Reduce order quantities to minimize financial exposure to a supply interruption

76. A quality engineer is conducting a process capability analysis on a characteristic with only a lower specification limit of 500 psi (minimum tensile strength). There is no upper specification limit. Which capability index should be calculated?

- A. $CPL = (\mu - LSL) / 3\sigma$, measuring capability relative to the lower specification limit only
- B. $Cp = (USL - LSL) / 6\sigma$ using zero as the implied upper specification limit

- C. $C_{pk} = \min(C_{PU}, C_{PL})$ using the range of the data as a proxy for the upper limit
- D. P_p using overall standard deviation with assumed bilateral specifications

77. A quality engineer is reviewing the results of a Gage R&R study and finds that the reproducibility component is four times larger than the repeatability component. This result suggests that the primary source of measurement variation is related to which factor?

- A. The inherent precision and mechanical condition of the measurement instrument
- B. Environmental conditions such as temperature and humidity affecting the measurement
- C. The part-to-part variation in the characteristics being measured
- D. Differences in measurement technique, interpretation, or approach among operators

78. In the context of designed experiments, which statement best describes the "sparsity of effects" principle?

- A. Most industrial processes are affected by a large number of factors that all contribute equally to the response variation
- B. In most industrial processes, the response is dominated by a small number of main effects and lower-order interactions, while higher-order interactions are typically negligible
- C. Fractional factorial designs always provide the same information as full factorial designs
- D. The number of significant effects in an experiment equals the number of factors studied

79. A quality engineer discovers that a documented work instruction for a critical assembly process contains an error — one step lists an incorrect torque specification that is 30% below the validated

value. Several operators have been following this incorrect specification. What is the most critical immediate action?

- A. Issue a document revision request through the normal document control process
- B. Schedule a meeting with the operators to discuss the correct torque specification
- C. Stop production on the affected process, segregate all potentially affected product, and issue an immediate correction to the work instruction
- D. Add a note to the work instruction clarifying that the torque value is approximate

80. In the context of the PDCA improvement cycle, which specific failure causes many improvement initiatives to lose momentum and revert to previous practices?

- A. Conducting the Plan phase too thoroughly, resulting in analysis paralysis
- B. Skipping or inadequately performing the Act phase — failing to standardize successful changes, update procedures, and train personnel to sustain the improvement
- C. Collecting too much data during the Check phase, overwhelming the team with information
- D. Implementing the Do phase too quickly, not allowing sufficient time for the change to take effect

81. A quality engineer calculates a chisquare test statistic of 18.7 for a contingency table with 6 rows and 4 columns at $\alpha = 0.05$. The degrees of freedom for this test are calculated as which of the following?

- A. 24, calculated as rows \times columns
- B. 9, calculated as (6-1) + (4-1)
- C. 23, calculated as (rows \times columns) - 1
- D. 15, calculated as (rows - 1) \times (columns - 1)

82. A quality engineer is implementing SPC on a process and needs to decide between an Xbar/R chart and an Xbar/S chart. The subgroup size is 15. Which chart pair should be selected and why?

- A. Xbar and R chart because it is always the default choice regardless of subgroup size
- B. Xbar and S chart because the standard deviation provides a more efficient estimate of variability than the range for subgroup sizes greater than 10
- C. Either chart pair is equally appropriate for a subgroup size of 15
- D. Neither chart is appropriate — an IMR chart should be used for subgroups of this size

83. An organization is evaluating whether to pursue Malcolm Baldrige National Quality Award recognition or ISO 9001 certification. The CEO wants a framework that evaluates business results including financial performance, market outcomes, and customer satisfaction trends. Which framework better serves this need?

- A. ISO 9001 because its certification process evaluates business results as part of the conformance assessment
- B. Neither framework evaluates business results — both focus exclusively on process conformance
- C. The Baldrige framework because it allocates 450 of 1,000 points to Results, explicitly evaluating business outcomes
- D. ISO 9001 and Baldrige evaluate identical criteria and produce equivalent assessments

84. In acceptance sampling, the Average Outgoing Quality Limit (AOQL) represents which concept?

- A. The minimum acceptable incoming quality level that the supplier must maintain
- B. The worstcase average quality of outgoing product after inspection, assuming rejected lots are 100% screened and defectives replaced
- C. The maximum number of defective units permitted in any single accepted lot

D. The quality level at which the probability of lot acceptance equals exactly 50%

85. A quality engineer is analyzing process data and notices that the control chart shows a pattern where points alternate — high, low, high, low, high, low — in a systematic zigzag. This pattern is called which of the following, and what does it typically indicate?

A. Stratification, indicating that the data comes from two distinct process streams combined into one chart

B. A trend, indicating gradual tool wear or process degradation over time

C. A run, indicating a sustained shift in the process mean to one side of the center line

D. A mixture or systematic pattern, often caused by overadjustment of the process, alternation between two machines, or rotation between two operators or setups

86. A quality engineer is preparing a justification for investing in errorproofing devices on an assembly line. The current annual cost of the targeted defect is \$180,000 (including scrap, rework, warranty, and complaint handling). The errorproofing investment is \$45,000. Using a simple payback calculation, what is the payback period?

A. 3 months, assuming the devices eliminate 100% of the targeted defect

B. 12 months based on a standard oneyear payback assumption for capital investments

C. 6 months based on eliminating half the defect cost in the first year

D. The payback period cannot be calculated without knowing the device's maintenance cost

87. In the context of process validation, which type of process requires validation because its output cannot be fully verified by subsequent inspection and testing?

- A. A CNC machining process where all dimensions can be measured after processing
- B. A painting process where color and thickness are verified by standardized instruments
- C. A special process such as welding, sterilization, or heat treatment where internal quality depends on parameters controlled during the process
- D. A manual assembly process where each step can be visually verified by the operator

88. A quality engineer discovers that a newly hired operator has been working on a critical production process for two weeks without completing the required training and competence evaluation. Under ISO 9001:2015, this situation violates which specific requirement?

- A. Clause 9.2 requiring internal audits at planned intervals to verify system conformance
- B. Clause 7.2 requiring the organization to ensure that persons performing quality affecting work are competent based on appropriate education, training, or experience
- C. Clause 5.2 requiring top management to establish and communicate the quality policy
- D. Clause 10.2 requiring the organization to maintain a corrective action procedure

89. A quality engineer uses exponential smoothing with $\alpha = 0.3$ to forecast quality metric values. The previous forecast was 85.0 and the actual observed value was 91.0. What is the new forecast?

- A. 86.8, calculated as $85.0 + 0.3 \times (91.0 - 85.0)$
- B. 91.0 because the most recent observation should replace the forecast entirely
- C. 88.0 calculated as the simple average of 85.0 and 91.0
- D. 83.2 calculated by subtracting the smoothing constant adjustment

90. A quality engineer discovers that a process has been running with a Cpk of 0.65 for three months. During this time, approximately 7% of production has been nonconforming, requiring sorting, rework, and scrap. Management asks whether the process should continue running while improvements are planned. What is the most appropriate recommendation?

- A. Continue running the process as is since the 7% defect rate is economically acceptable
- B. Stop all production immediately until the process achieves a Cpk of 1.33 or higher
- C. Continue production but reduce the inspection frequency to save costs while the process is improved
- D. Continue production with 100% inspection or increased SPC monitoring to contain nonconforming output while implementing process improvements to increase capability

91. A quality engineer is constructing a fishbone diagram for a surface finish problem and organizes causes under the 6M categories. Which set of categories correctly represents the 6M framework?

- A. Market, Money, Morale, Methods, Machinery, Materials
- B. Measurement, Machine, Man, Method, Material, Environment are five of six — the sixth is sometimes Money
- C. Man, Machine, Material, Method, Measurement, and Mother Nature (Environment)
- D. Management, Mission, Metrics, Methods, Machines, Manpower

92. A quality engineer is evaluating the OC curve for an acceptance sampling plan and finds that at an incoming quality level of 2% nonconforming, the probability of lot acceptance is 0.95. At an incoming quality level of 8% nonconforming, the probability of acceptance is 0.10. What do these two points represent?

- A. The 2% point is the AQL and the 8% point is the LTPD, corresponding to producer's risk of 0.05 and consumer's risk of 0.10
- B. The 2% point is the AOQL and the 8% point is the rejection quality level

- C. Both points are arbitrary reference levels with no specific statistical meaning
- D. The 2% point represents the consumer's risk and the 8% point represents the producer's risk

93. A quality engineer is reviewing a calibration program and notices that a particular instrument has been found within tolerance at every scheduled calibration for the past five years — a total of 20 consecutive calibrations. The current calibration interval is 6 months. What adjustment to the calibration interval is most appropriate?

- A. Extending the interval based on the consistent calibration history, since the instrument has demonstrated longterm stability
- B. Maintaining the 6month interval indefinitely regardless of calibration history
- C. Shortening the interval because older instruments become less reliable over time
- D. Eliminating calibration entirely since the instrument has proven it stays within tolerance

94. A quality engineer needs to compare the proportion of nonconforming items from two independent production processes. Process 1 produces 18 nonconforming items out of 450, and Process 2 produces 32 nonconforming items out of 500. Which statistical test should be used?

- A. Paired ttest for comparing matched observations between the two processes
- B. Ftest for comparing the variances of the two process outputs
- C. Oneway ANOVA for comparing the means of more than two groups simultaneously
- D. Twoproportion Ztest for comparing independent proportions from two populations

95. In lean manufacturing, value stream mapping reveals that a production process has 12 individual process steps, but only 4 of those steps physically transform the product. The remaining 8 steps involve

inspection, transport, staging, and administrative activities. What lean principle does this observation illustrate?

- A. Most process steps in manufacturing do not add value from the customer's perspective and represent opportunities for waste elimination
- B. All 12 process steps are necessary and should be optimized individually for maximum efficiency
- C. Inspection and transport activities add value because they ensure quality and move product forward
- D. The four transforming steps should be eliminated because they consume the most resources

96. A quality engineer is implementing a risk management system and establishes risk acceptance criteria that define thresholds for acceptable, tolerable, and unacceptable risk levels. These criteria should be established during which step of the ISO 31000 risk management process?

- A. Risk identification, when potential risks are first discovered and catalogued
- B. Risk analysis, when probability and severity ratings are assigned to each risk
- C. Establishing the context, when the scope, objectives, and criteria for risk management are defined
- D. Risk treatment, when specific actions are selected to modify unacceptable risks

97. A quality engineer is conducting a two-sample ttest and obtains a pvalue of 0.048 at $\alpha = 0.05$. The observed difference between the two sample means is 0.02 mm. The process specification tolerance is ± 1.0 mm. What should the engineer conclude?

- A. The result is both statistically and practically significant because the pvalue is below α
- B. The result is statistically significant but may not be practically significant — the 0.02 mm difference, while statistically real, may be too small to matter relative to the 2.0 mm tolerance
- C. The result is not statistically significant because the pvalue is very close to α
- D. The practical significance cannot be evaluated without performing additional statistical tests

98. A quality engineer discovers that an Xbar chart has been constructed using specification limits rather than statistically calculated control limits. Why is this practice incorrect?

- A. Specification limits and control limits serve different purposes — specification limits define product requirements while control limits define the expected range of process variation due to common causes
- B. Specification limits are always wider than control limits, making the chart less sensitive
- C. Using specification limits requires approval from the customer before implementation
- D. Specification limits can only be used on individual measurement charts, not on Xbar charts

99. A quality engineer is analyzing a scatter diagram and observes that the data points form a clear Ushaped pattern — the response decreases as the predictor increases up to a midpoint, then increases as the predictor continues to increase. What does this pattern indicate?

- A. No relationship exists between the variables because the overall linear correlation would be near zero
- B. The data contains measurement errors that should be removed before further analysis
- C. A nonlinear (quadratic) relationship exists that a linear correlation coefficient would not adequately capture
- D. The scatter diagram was plotted incorrectly and the axes should be reversed

100. A quality engineer is reviewing an organization's management review process and notices that the inputs include audit results, customer feedback, process performance, and corrective action status, but the review does not consider changes in external context such as new regulations or market conditions. Which management review input is missing?

- A. The names and qualifications of all audit team members who conducted recent audits
- B. Changes in external and internal issues relevant to the QMS, as required by ISO 9001:2015 Clause 9.3.2

- C. Daily production reports from each manufacturing department for the entire review period
- D. Individual employee performance evaluations for all quality department personnel

101. A quality engineer is monitoring a process using an Xbar and R chart with subgroups of size 4. The R chart has been in control for 30 subgroups, but the Xbar chart shows a sudden upward shift — the last 9 consecutive points all fall above the center line, though none exceed the UCL. Based on the Western Electric rules, what is the status of this process?

- A. In control because no points have exceeded the upper or lower control limits
- B. The shift is not yet statistically significant and requires 12 consecutive points to confirm
- C. The R chart outofcontrol condition is masking the Xbar chart shift and must be resolved first
- D. Out of control because 9 consecutive points on one side of the center line violates the run rule for 8 or more consecutive points

102. A quality engineer needs to estimate the reliability of an electronic assembly at 1,000 hours of operation. The assembly has a constant failure rate of $\lambda = 0.0005$ failures per hour. Using the exponential reliability model, what is the reliability at 1,000 hours?

- A. $R(1000) = e^{(0.5)} \approx 0.607$
- B. $R(1000) = 1 - 0.0005 \times 1000 = 0.50$
- C. $R(1000) = 0.0005 \times 1000 = 0.50$
- D. $R(1000) = e^{(0.0005)} \approx 0.9995$

103. During a lean kaizen event, the team maps a production process and discovers that parts travel a total distance of 1,200 feet between 8 workstations arranged in different buildings. The team proposes rearranging workstations into a cellular layout. Which lean waste category is primarily being addressed?

- A. Overprocessing by performing unnecessary operations on the product
- B. Transportation — the excessive and unnecessary movement of materials between distant workstations
- C. Overproduction by manufacturing more units than customer demand requires
- D. Defects caused by handling damage during the long transport distances

104. A quality engineer is planning a designed experiment with 6 factors, each at 2 levels. The full factorial would require 64 runs, which exceeds the budget. The engineer selects a 2^{6-2} design requiring 16 runs. What is the resolution of this design if the defining relations are $I = ABCE$ and $I = BCDF$?

- A. Resolution III because main effects are aliased with twofactor interactions
- B. Resolution V because all main effects and twofactor interactions are estimable
- C. Resolution IV because main effects are clear but some twofactor interactions are aliased with each other
- D. Resolution II because main effects are aliased with other main effects

105. In the context of ISO 9001:2015, Clause 8.5.6 requires the organization to identify and control changes in production to maintain conformity. A process engineer changes a machine parameter setting without documenting the change or evaluating its impact on product quality. This situation violates which quality system principle?

- A. The requirement for management review at planned intervals
- B. The requirement for internal audits to verify system conformance
- C. The requirement for customer communication regarding product changes
- D. Change control — the requirement to identify, review, and control changes that could affect conformity

106. A quality engineer is conducting a chisquare test of independence on a 3×4 contingency table and calculates a chisquare statistic of 22.4. The degrees of freedom for this test are $(3-1)(4-1) = 6$. The critical value at $\alpha = 0.05$ with 6 degrees of freedom is 12.59. What is the correct conclusion?

- A. There is a statistically significant association between the two categorical variables because the test statistic (22.4) exceeds the critical value (12.59)
- B. There is no significant relationship because the test statistic must exceed 25.0 for significance
- C. The test is invalid because the degrees of freedom were calculated incorrectly
- D. The result is inconclusive and requires a larger sample size for determination

107. A supplier provides a Certificate of Analysis showing that material hardness test results range from 5862 HRC against a specification of 5565 HRC. The quality engineer wants to assess the supplier's process capability but only has the certificate data, not the raw measurements. Why is this data insufficient for capability analysis?

- A. Certificate of Analysis data is never valid for any quality engineering calculations
- B. The specification limits should be tighter than 5565 HRC for a valid capability study
- C. Capability indices require the process mean and standard deviation, which cannot be determined from only the range of reported values without the individual measurements
- D. The hardness values must be converted to tensile strength before capability can be calculated

108. A quality engineer is implementing a calibration program and must decide between calibrating a micrometer inhouse versus sending it to an external calibration laboratory. Which factor is most important in making this decision?

- A. The age of the micrometer and its remaining expected service life
- B. Whether the organization has traceable reference standards and qualified personnel to perform the calibration to the required accuracy

- C. The color coding system used for calibration status identification labels
- D. Whether the external laboratory offers a faster turnaround time than inhouse capability

109. A quality engineer is evaluating a process that has been in statistical control for 6 months. The $C_p = 2.10$ and $C_{pk} = 0.92$. The difference between C_p and C_{pk} is unusually large. What is the most effective single action to improve quality performance?

- A. Recenter the process mean toward the midpoint of the specification limits, which would bring C_{pk} closer to the C_p value without reducing variation
- B. Reduce the process standard deviation through equipment upgrades and tighter material specifications
- C. Widen the specification limits to accommodate the current offcenter process location
- D. Implement 100% inspection to sort nonconforming product from the output stream

110. In the FMEA methodology, the Action Priority (AP) method from the AIAG/VDA FMEA Handbook was introduced to address a key limitation of the traditional RPN method. What is that limitation?

- A. The RPN formula is too complex for most quality engineers to calculate correctly
- B. The RPN method requires computer software that is not available to small manufacturers
- C. The RPN can produce identical scores for very different risk profiles, potentially masking highseverity failure modes behind moderate occurrence and detection ratings
- D. The RPN method does not include a Detection rating and therefore ignores detection capability

111. A quality engineer is analyzing a scatter diagram of two process variables and calculates a Pearson correlation coefficient of $r = 0.12$. The sample size is $n = 150$. At $\alpha = 0.05$, the correlation is found to be statistically significant. How should this result be interpreted?

- A. The correlation has both statistical and practical significance given the large sample size
- B. The large sample size has inflated a trivially weak correlation to statistical significance
- C. With a large sample, even a very weak linear relationship ($r = 0.12$, $r^2 = 0.014$) can be statistically significant, but it explains less than 2% of the variation and has little practical value
- D. The result indicates a strong relationship that warrants immediate process adjustment

112. A quality engineer discovers that internal audit findings consistently identify the same types of nonconformities year after year — document control issues and training record gaps — without any apparent improvement. What does this recurring pattern most likely indicate?

- A. The audit program is functioning perfectly because it consistently identifies the same problems
- B. The corrective actions taken in response to previous audit findings have not been effective at addressing the root causes, resulting in chronic recurrence
- C. The audit criteria have become too stringent and should be relaxed to reduce repeat findings
- D. The auditors are biased and should be replaced with an external audit team

113. A quality engineer is conducting a onesample ttest to determine whether the mean fill weight of a bottling process differs from the target of 500 ml. The sample of 25 bottles has a mean of 498.2 ml, a standard deviation of 3.5 ml, and the calculated tstatistic is 2.57. The critical tvalue at $\alpha = 0.05$ (twosided) with 24 degrees of freedom is ± 2.064 . What is the conclusion?

- A. Reject H_0 because the absolute value of the tstatistic (2.57) exceeds the critical value (2.064), indicating the process mean significantly differs from 500 ml
- B. Fail to reject H_0 because the tstatistic is negative, indicating the process is below target

- C. The test is invalid because the sample size of 25 is too small for the t-distribution
- D. Fail to reject H_0 because the difference of 1.8 ml is too small to be statistically significant

114. In the context of quality cost analysis, a company spends \$50,000 annually on quality planning, \$30,000 on training, \$80,000 on incoming and in-process inspection, \$120,000 on scrap and rework, and \$70,000 on warranty claims. What is the total cost of conformance (prevention + appraisal)?

- A. \$120,000 comprising only the inspection activities that verify product conformance
- B. \$200,000 comprising the scrap, rework, and warranty costs that result from nonconformance
- C. \$350,000 representing the sum of all five quality cost categories listed
- D. \$160,000 comprising prevention (\$50,000 planning + \$30,000 training) plus appraisal (\$80,000 inspection)

115. A quality engineer is implementing a risk-based approach to incoming inspection. Which strategy best applies risk-based thinking to optimize inspection resources?

- A. Inspect all incoming materials at the same intensity regardless of their impact on the final product
- B. Eliminate all incoming inspection since suppliers should be responsible for their own quality
- C. Allocate more intensive inspection to materials with higher risk — those used in critical applications, from new or unproven suppliers, or with a history of quality problems
- D. Inspect only materials that have been previously rejected and skip inspection on all other items

116. In a designed experiment, the quality engineer plans to study the effect of three factors on surface roughness. Factor A has 2 levels, Factor B has 3 levels, and Factor C has 2 levels. This is not a 2^k design

because Factor B has more than two levels. How many treatment combinations exist in this full factorial?

- A. 12 treatment combinations calculated as $2 \times 3 \times 2$
- B. 8 treatment combinations calculated as 2^3
- C. 7 treatment combinations calculated as $2 + 3 + 2$
- D. 6 treatment combinations calculated as the sum of factor levels

117. A quality engineer receives the following Gage R&R results: repeatability = 5.2% of tolerance, reproducibility = 3.8% of tolerance, total Gage R&R = 6.4% of tolerance, and $ndc = 9$. What is the overall assessment of this measurement system?

- A. Unacceptable because the reproducibility exceeds the 3% threshold for operator variation
- B. Acceptable — the total %GRR is below 10% and ndc exceeds 5, indicating the system has good discrimination and minimal contribution to observed variation
- C. Conditionally acceptable pending additional operator training to reduce reproducibility
- D. Indeterminate because the repeatability and reproducibility do not add up to the total GRR

118. In the context of lean manufacturing, standardized work documentation typically includes three key elements. A quality engineer reviewing the standardized work chart for an assembly station should expect to find which information?

- A. The employee's performance evaluation scores and attendance record for the current quarter
- B. The annual preventive maintenance schedule for all equipment in the production area
- C. The supplier quality ratings for all components used at the workstation
- D. Takt time, the specific work sequence for the operator, and the standard work in process inventory level

119. A quality engineer is planning a process capability study and needs to determine the minimum number of data points required for a reliable capability assessment. Industry guidelines generally recommend collecting at least how many individual measurements for a capability study?

- A. A minimum of 10 measurements from a single production run is sufficient for most capability studies
- B. At least 1,000 measurements collected over a minimum of 6 months of continuous production
- C. Approximately 50 to 100 individual measurements collected over a period that captures the full range of process variation sources
- D. Exactly 30 measurements, as determined by the central limit theorem requirements

120. A quality engineer discovers that a nonconforming product was shipped to a customer because the MRB disposition paperwork was still in process when the shipping department released the lot. This situation indicates a failure in which quality system element?

- A. The material segregation and hold system that should have prevented shipment of undispositioned material
- B. The management review process that should have identified shipping as a highrisk area
- C. The training program for shipping department personnel on quality system requirements
- D. The internal audit program that should have detected the risk before it materialized

121. A quality engineer is conducting a regression analysis to predict product strength (Y) from curing temperature (X). The regression equation is $\hat{y} = 200 + 3.5x$, where x is temperature in °C. The data used to build the model ranged from 50°C to 150°C. A colleague asks for the predicted strength at 250°C. What should the quality engineer advise?

- A. Calculate the prediction as $\hat{y} = 200 + 3.5(250) = 1,075$ and provide it with full confidence
- B. The prediction at 250°C would be extrapolation beyond the data range and should not be relied upon because the relationship may change form outside the observed range

- C. The prediction is valid as long as the r^2 value exceeds 0.90 for the original model
- D. The prediction should be provided but with the caveat that it represents the minimum possible strength

122. In the context of quality system documentation, a quality engineer is asked to explain the relationship between the quality policy and quality objectives. Which statement best describes this relationship?

- A. The quality policy and quality objectives are independent documents with no required connection
- B. Quality objectives must be established before the quality policy is written to ensure the policy is realistic
- C. The quality policy can substitute for quality objectives if it is written with sufficient detail
- D. The quality policy provides the framework for establishing quality objectives, and objectives must be consistent with and support the commitments in the policy

123. A quality engineer is analyzing the reliability of a system composed of two subsystems in series. Subsystem 1 consists of two parallel components, each with $R = 0.90$. Subsystem 2 is a single component with $R = 0.95$. What is the overall system reliability?

- A. 0.855, calculated as 0.90×0.95 using only one component from Subsystem 1
- B. 0.90, limited by the least reliable component in the system
- C. 0.941, calculated as $[1 - (1 - 0.90)^2] \times 0.95 = 0.99 \times 0.95$
- D. 0.95, limited by the single component in Subsystem 2

124. A quality engineer is reviewing a control plan for a new product launch and notices that several critical characteristics have SPC listed as the control method but no specific reaction plan is documented. Why is this a significant deficiency?

- A. Without a reaction plan, operators will not know what specific actions to take when the control chart signals an outofcontrol condition, potentially allowing nonconforming product to continue being produced
- B. SPC does not require a reaction plan because the control chart itself provides all necessary guidance
- C. The reaction plan is only needed for characteristics monitored by 100% inspection, not SPC
- D. The lack of a reaction plan will only be identified during the customer's receiving inspection audit

125. A quality engineer is evaluating two different designs for a safetycritical component. Design A uses premium materials and achieves a component reliability of 0.999 but has no redundancy. Design B uses standard materials with component reliability of 0.99 but includes a redundant parallel backup. Which design has higher system reliability?

- A. Design A at 0.999 because its premium materials provide superior singlecomponent performance
- B. Design B because the parallel redundancy yields system reliability of $1 - (1 - 0.99)^2 = 0.9999$, exceeding Design A's 0.999
- C. Both designs have identical reliability because the redundancy exactly compensates for the lower material quality
- D. Design A is always preferred because redundancy adds complexity, weight, and cost without meaningful benefit

126. A quality engineer receives a customer complaint stating that a product functions correctly but has a cosmetic surface finish defect that is visible to the end user. The product meets all dimensional and functional specifications. Under the quality characteristic classification system, this defect is most appropriately classified as which category?

- A. Critical, because any defect visible to the customer affects brand reputation
- B. Major, because the cosmetic issue will likely result in a product return
- C. Not a defect, because the product meets all dimensional and functional specifications
- D. Minor, because the defect affects aesthetics but does not impair product function or safety

127. In the context of Six Sigma, a process operating at a 3sigma level produces approximately 66,807 DPMO (accounting for the conventional 1.5σ shift). An improvement project targets reducing this to 4sigma performance. What is the approximate DPMO at 4sigma?

- A. 33,400 DPMO representing a 50% reduction from the 3sigma level
- B. 3.4 DPMO representing the ultimate Six Sigma target level
- C. 6,210 DPMO representing the defect rate at 4sigma with the 1.5σ shift
- D. 233 DPMO representing 5sigma performance rather than 4sigma

128. A quality engineer is conducting an experiment and wants to account for the fact that experiments must be run across two days because only half the runs can be completed each day. Environmental conditions may differ between days. The engineer places half the treatment combinations in Day 1 and the complementary half in Day 2. What experimental design technique is being applied?

- A. Confounding — the day effect is deliberately confounded with a highorder interaction assumed to be negligible
- B. Replication — each treatment is repeated on both days to improve error estimation
- C. Centerpointing — the day variable is set to its midpoint value for all runs
- D. Foldover — the second day reverses all factor signs to dealias confounded effects

129. A quality engineer is reviewing an organization's risk management program and discovers that the risk register contains 200 identified risks, but only 15 have assigned risk treatment plans. Management asks the engineer whether all 200 risks require treatment. What is the most appropriate response?

- A. All 200 risks must have treatment plans because every identified risk must be actively managed
- B. Only risks identified by external auditors require formal treatment plans
- C. The number of risks requiring treatment should be reduced by eliminating lowprobability risks from the register
- D. Not all identified risks require treatment — risk evaluation determines which risks exceed acceptance criteria and require treatment, while risks within tolerance may be accepted with monitoring

130. A quality engineer is implementing a visual management system in a manufacturing area. Which combination of visual controls provides the most comprehensive realtime information about production status?

- A. A monthly quality report posted on the department bulletin board with last month's metrics
- B. An andon board showing realtime machine status, production count versus target, quality alerts, and maintenance needs visible from anywhere in the production area
- C. A filing cabinet containing all quality procedures organized by document number
- D. A computer dashboard accessible only from the quality manager's office terminal

131. A quality engineer needs to monitor the number of defective units per lot from a production process where each lot contains exactly 500 units. The historical average defective rate is 2%. Which attributes control chart is most appropriate?

- A. uchart because the defect rate must be normalized per unit
- B. pchart because the proportion nonconforming varies with each lot

- C. npchart because the sample size is constant and the chart plots the count of nonconforming units
- D. cchart because the number of defects per unit needs to be tracked

132. A quality engineer is evaluating a linear regression model and discovers that the residuals exhibit a funnelshaped pattern — the spread of residuals increases as the predicted values increase. This condition is called heteroscedasticity. What is the primary consequence for the regression analysis?

- A. The regression coefficients become biased and consistently overestimate the true relationship
- B. The coefficient of determination r^2 becomes artificially inflated beyond its true value
- C. The regression equation becomes mathematically unsolvable and must be abandoned
- D. The standard errors of the regression coefficients are unreliable, making confidence intervals and hypothesis tests potentially invalid

133. In the context of risk management for a medical device, a quality engineer identifies a userelated risk where elderly patients may not be able to read the small font on the device's warning label. According to the risk treatment hierarchy, which action should be evaluated first?

- A. Provide a magnifying glass with each device to help patients read the label
- B. Include a verbal warning during the sales presentation about the label readability issue
- C. Train healthcare providers to read the warnings aloud to elderly patients
- D. Redesign the device interface to eliminate the need for the warning altogether through inherently safe design

134. A quality engineer is analyzing process data and calculates the coefficient of variation (CV) for two processes. Process A has a mean of 200 and standard deviation of 10 (CV = 5%). Process B has a mean of 50 and standard deviation of 4 (CV = 8%). What does this comparison reveal?

- A. Process A has greater absolute variation and is therefore less capable than Process B
- B. Process B has greater relative variation compared to its mean, making it less consistent proportionally than Process A despite having a smaller absolute standard deviation
- C. The coefficient of variation cannot be used to compare processes with different means
- D. Both processes have identical variability because their standard deviations differ by the same ratio as their means

135. A quality engineer is developing a training program for new quality inspectors. The training needs assessment identifies that inspectors must be able to read engineering drawings, use measurement instruments correctly, and interpret acceptance criteria. At what point should the training program's effectiveness be evaluated using Kirkpatrick's Level 4?

- A. Immediately after the training session by administering a knowledge test on drawing reading
- B. By surveying participants about their satisfaction with the training content and instructor
- C. After sufficient time has passed to measure whether the training produced improvements in organizational quality metrics such as inspection accuracy rates and defect escape rates
- D. By observing inspectors on the production floor two weeks after training to verify they apply learned skills

136. A quality engineer is reviewing a designed experiment that tested four factors at two levels each (2^4 full factorial) with two replicates. The total number of experimental runs is 32. The ANOVA table shows that Factor C has a pvalue of 0.78. What does this indicate about Factor C?

- A. Factor C has a highly significant effect on the response and should be set to its optimal level

- B. Factor C's effect is aliased with a twofactor interaction and cannot be interpreted independently
- C. The experiment needs additional replication to determine whether Factor C is significant
- D. Factor C does not have a statistically significant effect on the response at conventional significance levels

137. A quality engineer is evaluating whether to implement acceptance sampling or 100% inspection for a highvolume, lowcost component. The defect rate is historically 0.5%, and defective components cause minor cosmetic issues in the final product but no functional or safety concerns. Which approach is more appropriate?

- A. 100% inspection is always required regardless of defect rate or consequence of failure
- B. Neither inspection method is necessary because a 0.5% defect rate is universally acceptable
- C. 100% inspection is required because any nonzero defect rate demands complete screening
- D. Acceptance sampling is more appropriate because the defect rate is low, the consequence is minor, and 100% inspection would be disproportionately costly relative to the risk

138. A quality engineer discovers that a process has shifted 1.0σ from its original center. The process had a Cpk of 1.33 before the shift. If the process standard deviation remains unchanged, the shift will reduce the Cpk on the side toward which the mean shifted by approximately how much?

- A. The Cpk will remain at 1.33 because a 1.0σ shift is within normal process variation
- B. The Cpk on the near side will decrease by approximately 0.33, from 1.33 to approximately 1.00
- C. The Cpk will decrease to exactly zero because any shift exceeding 0.5σ renders the process incapable
- D. The shift has no effect on Cpk because the index is based on specification limits, not the process center

139. In the context of quality auditing, the term "audit evidence" refers specifically to which of the following?

- A. The auditor's professional opinion about the effectiveness of the quality management system
- B. The audit checklist prepared before the audit begins, listing questions to be asked
- C. Records, statements of fact, or other verifiable information relevant to the audit criteria
- D. The auditee's corrective action plan submitted after the audit closing meeting

140. A quality engineer is tasked with reducing the changeover time on a production line from 45 minutes to under 10 minutes. Which lean tool is specifically designed for this purpose?

- A. Single Minute Exchange of Die (SMED), which systematically separates internal and external setup activities and converts internal to external where possible
- B. Value stream mapping to identify all changeoverrelated waste throughout the facility
- C. 5S workplace organization to ensure tools and materials are available at the workstation
- D. Total productive maintenance to reduce equipmentrelated changeover failures

141. A quality engineer is analyzing warranty data and plots the failure rate over time. The plot shows a high failure rate during the first 3 months of product use, followed by a relatively flat failure rate from months 4 through 36, and then an increasing failure rate after month 36. This pattern corresponds to which reliability model?

- A. The exponential distribution with a constant failure rate throughout the product life
- B. The normal distribution centered at the mean product lifetime
- C. The lognormal distribution with rightskewed failure times

D. The bathtub curve with distinct infant mortality, useful life, and wearout periods

142. A quality engineer is implementing a corrective action for a recurring soldering defect. The root cause analysis identifies that the solder paste is not being stored at the required temperature. The engineer proposes installing a temperature-controlled storage unit with an alarm system that alerts when the temperature deviates from the required range. This solution primarily addresses which aspect of the problem?

- A. Detection of the defect after it has been created during the soldering process
- B. Prevention of the root cause by controlling the storage condition that leads to defective solder paste
- C. Containment of affected product that was manufactured with improperly stored solder paste
- D. Transfer of the risk to the solder paste supplier through contractual quality requirements

143. In the context of ISO 9001:2015, the concept of "process approach" requires the organization to manage its activities as interconnected processes. Which of the following best describes a key benefit of the process approach?

- A. It eliminates the need for documented procedures because processes are self-managing
- B. It replaces the need for management review by providing realtime process performance data
- C. It enables consistent and predictable results through systematic management of interrelated processes with defined inputs, activities, outputs, and controls
- D. It requires each department to manage its processes independently without crossfunctional coordination

144. A quality engineer calculates the following statistics from 30 subgroups of size 5 on an Xbar and R chart: $\bar{\bar{x}} = 100.0$, $\bar{R} = 8.0$, $A_2 = 0.577$, $d_2 = 2.326$. The engineer needs to estimate the process standard deviation and the C_p , given specification limits of 90 and 110. What is the estimated process standard deviation and C_p ?

- A. $\hat{\sigma} = 3.44$ and $C_p = 0.97$
- B. $\hat{\sigma} = 8.0$ and $C_p = 0.42$
- C. $\hat{\sigma} = 2.326$ and $C_p = 1.43$
- D. $\hat{\sigma} = 0.577$ and $C_p = 2.89$

145. A quality engineer observes that a normally wellperforming supplier has submitted three consecutive lots that were rejected at incoming inspection. Before escalating to supplier termination, what is the most appropriate first action?

- A. Immediately qualify an alternate supplier and redirect all future orders
- B. Increase incoming inspection from sampling to 100% for all subsequent shipments
- C. File a formal complaint with the supplier's ISO certification body
- D. Contact the supplier to investigate the root cause of the quality decline and determine whether a recent process change, material substitution, or other factor is responsible

146. A quality engineer needs to determine whether there is a statistically significant difference in the proportion of defective items produced on Monday versus Friday. Monday's production of 800 units had 32 defectives, and Friday's production of 750 units had 45 defectives. Which test is appropriate?

- A. Paired ttest comparing the individual defect counts from each day
- B. Twoproportion Ztest comparing the independent defective proportions from each day
- C. Oneway ANOVA comparing the means of defective items across the two days

D. Chi-square goodness-of-fit test comparing the observed defect distribution to a theoretical model

147. In the context of measurement system analysis, a quality engineer plots monthly measurements of a single reference standard on an IMR chart over 24 months. The chart shows all points within the control limits with no trends, shifts, or patterns. Which measurement system property has been verified?

- A. Stability — the measurement system performs consistently over the 24-month period
- B. Linearity — the measurement system has consistent bias across its operating range
- C. Repeatability — the measurement system produces consistent results under identical conditions
- D. Reproducibility — different operators produce consistent results when measuring the same part

148. A quality engineer is reviewing a multiple regression model with four predictor variables. The overall F-test is significant ($p = 0.001$), $R^2 = 0.78$, and adjusted $R^2 = 0.74$. Three of the four predictors have significant t-tests ($p < 0.05$), but the fourth predictor has $p = 0.62$. What action should the engineer consider?

- A. Keep all four predictors because the overall model is significant and removing one would reduce R^2
- B. Remove all nonsignificant predictors and rerun the model with only the most significant single predictor
- C. Remove the nonsignificant predictor and refit the model, checking whether the adjusted R^2 improves or remains stable
- D. Add additional predictor variables to compensate for the nonsignificant one

149. A quality engineer is analyzing a production process and discovers that the process produces 15 nonconforming units out of every 1,000 produced. The production rate is 500 units per hour. How many nonconforming units does the process produce in an 8hour shift?

- A. 120 nonconforming units per shift
- B. 60 nonconforming units per shift
- C. 15 nonconforming units per shift
- D. The answer depends on the specification limits and cannot be calculated from the information given

150. In the context of the ASQ Code of Ethics, a quality engineer working for a testing laboratory discovers that a colleague has been falsifying test results to meet client deadlines. The colleague asks the engineer to "look the other way." What is the engineer's ethical obligation?

- A. Comply with the colleague's request to maintain workplace harmony and avoid conflict
- B. Report the falsification through appropriate organizational channels because professional integrity and public safety require truthful reporting of test results
- C. Ignore the situation because each professional is responsible only for their own work
- D. Discuss the matter informally with the colleague but take no formal action

151. A quality engineer is tasked with evaluating whether a new inspection method (Method B) produces results that agree with the established method (Method A). Twenty parts are measured by both methods. The engineer calculates the differences between paired measurements and tests whether the mean difference is zero. If the mean difference is 0.003 mm with a 95% confidence interval of (0.008, 0.002), what should the engineer conclude?

- A. The methods agree because the confidence interval for the mean difference includes zero, indicating no statistically significant systematic difference between the two methods
- B. Method B reads significantly lower than Method A because the mean difference is negative

- C. The methods do not agree because the confidence interval is not centered on zero
- D. The comparison is invalid because 20 parts is insufficient for method comparison studies

152. A quality engineer is developing an audit program and needs to determine the frequency of internal audits for different areas of the organization. According to riskbased audit planning, which factor should have the greatest influence on audit frequency?

- A. The geographical distance between the audited area and the quality department office
- B. The personal preferences of the lead auditor regarding scheduling convenience
- C. The risk level and importance of the processes being audited, combined with the results of previous audits
- D. The number of employees in each department, with larger departments audited more frequently

153. A quality engineer is conducting a designed experiment and needs to determine whether to use a full factorial or a fractional factorial design. The experiment has 7 factors, each at 2 levels. The full factorial would require 128 runs. The engineer has budget for only 16 runs. What fractional factorial design should be used?

- A. A 2^{7-1} design requiring 64 runs with Resolution VII
- B. A 2^{7-2} design requiring 32 runs with Resolution V or higher
- C. A 2^{7-4} design requiring 8 runs with Resolution III
- D. A 2^{7-3} design requiring 16 runs, providing a practical balance between run economy and information

154. A quality engineer is analyzing the Cost of Quality trend for the organization over five years. Prevention costs have steadily increased from 10% to 25% of total quality costs, while total failure costs

have decreased from 65% to 30%. Total quality costs as a percentage of revenue have decreased from 18% to 11%. What does this trend demonstrate?

- A. The organization is spending too much on prevention and should redirect funds to production
- B. The strategic shift toward prevention has reduced total quality costs as a percentage of revenue, demonstrating that prevention investment produces net savings by reducing the much larger failure costs
- C. The failure cost reduction is coincidental and unrelated to the prevention cost increase
- D. Appraisal costs must have increased to compensate for the shift from failure to prevention

155. A quality engineer is reviewing an Xbar chart and notices that the last 14 points alternate above and below the center line in a systematic pattern — up, down, up, down, up, down. No points are near the control limits. What is the most likely cause and appropriate action?

- A. The pattern is normal random variation and no action is required since all points are within limits
- B. The chart needs new control limits calculated from more recent data to reduce the oscillation
- C. The operator should increase the subgroup size to smooth out the alternating pattern
- D. The systematic alternating pattern suggests overadjustment, two alternating streams, or two rotating setups — the quality engineer should investigate the source of the twostate oscillation

156. In the context of supplier management, a quality agreement between a customer and supplier should specify which of the following qualityrelated requirements?

- A. The supplier's internal employee compensation structure and benefits package
- B. The customer's marketing strategy and product positioning in the marketplace
- C. Quality requirements, inspection methods, acceptance criteria, notification of changes, nonconformance handling, and audit rights
- D. The customer's proprietary manufacturing processes that the supplier should replicate exactly

157. A quality engineer is conducting an FMEA and the team debates whether to assign a Severity rating of 9 or 10 to a failure mode that could cause serious injury to the end user. The team settles on Severity = 9. The Occurrence rating is 3 (low) and the Detection rating is 4 (moderate detection capability). Under the Action Priority method, this failure mode would most likely receive which priority?

- A. Low priority because the product of all three ratings produces a moderate RPN of 108
- B. High priority because the Action Priority method weights severity most heavily, and a severity of 9 with any combination of occurrence and detection typically mandates action
- C. Medium priority requiring a management review before action is taken
- D. No action required because the occurrence rating is low enough to make the risk acceptable

158. A quality engineer needs to estimate the mean weight of a product to within ± 0.5 grams with 95% confidence. The estimated population standard deviation from a pilot study is 3.0 grams. What minimum sample size is required?

- A. 30 samples based on the standard minimum for normal distribution applicability
- B. 100 samples based on a general rule of thumb for precision estimation
- C. 12 samples based on the ratio of the standard deviation to the desired margin
- D. 139 samples calculated using $n = (Z \times \sigma / E)^2 = (1.96 \times 3.0 / 0.5)^2 = (11.76)^2 \approx 139$

159. A quality engineer is implementing a kanban system and must decide between a onecard and twocard kanban system. In a twocard system, the production kanban and the withdrawal (conveyance) kanban serve which respective purposes?

- A. The production kanban authorizes the upstream process to produce, while the withdrawal kanban authorizes movement of material from the upstream to the downstream process
- B. Both cards serve identical functions and are simply colorcoded for different shifts

- C. The production kanban tracks quality metrics while the withdrawal kanban tracks delivery performance
- D. The first card initiates the purchase order and the second card authorizes the payment

160. A quality engineer is reviewing a process capability report and notices that Ppk (1.05) is significantly lower than Cpk (1.40). What does this discrepancy indicate about the process during the study period?

- A. The measurement system has excessive variation that inflates the overall standard deviation
- B. The process data is nonnormal and capability indices are not valid for this distribution
- C. The process experienced instability — shifts, trends, or special causes added between subgroup variation beyond the inherent common cause level, degrading actual performance below inherent capability
- D. The specification limits were changed during the study period, affecting the Ppk calculation

161. A quality engineer is analyzing reliability data for a fleet of vehicles and determines that the Mean Time Between Failures (MTBF) for the transmission system is 120,000 miles. Assuming a constant failure rate, what is the failure rate λ ?

- A. 120,000 failures per mile
- B. 0.12 failures per mile
- C. 12,000 failures per mile
- D. 8.33×10^{-6} failures per mile (calculated as $1/120,000$)

162. A quality engineer is reviewing an FMEA and discovers that the team has assigned identical Severity, Occurrence, and Detection ratings to 80% of the failure modes — all rated S=5, O=5, D=5, producing an RPN of 125 for nearly every item. What is the primary concern with this pattern?

- A. The ratings are correct because most failure modes in any process have similar risk profiles
- B. The identical ratings suggest the team did not carefully evaluate each failure mode individually, producing a flat, undifferentiated risk assessment that fails to prioritize the truly highrisk items
- C. The RPN of 125 falls exactly in the acceptable range and no action is required
- D. The team should increase all ratings by 1 to create differentiation among the failure modes

163. A quality engineer is conducting a process audit of a heat treatment operation and observes that the furnace temperature controller displays 850°C, but the operator's log book records the temperature as 845°C for the same time period. What does this discrepancy suggest should be investigated?

- A. The accuracy and calibration of the temperature controller, the accuracy of the operator's reading, and whether systematic recording errors exist in the process documentation
- B. The discrepancy is too small to warrant investigation since 5°C is within normal variation
- C. The operator should be disciplined for recording inaccurate data in the process log
- D. The furnace should be immediately shut down until the calibration laboratory resolves the issue

164. A quality engineer is implementing a quality function deployment (QFD) process for a new product. During construction of the House of Quality, the team needs to determine the strength of the relationship between each customer requirement and each engineering characteristic. Which scale is typically used for this assessment?

- A. A binary scale indicating only whether a relationship exists (yes/no) without indicating strength
- B. A financial scale converting each relationship to its dollar value impact on the product

- C. A weighted scale using symbols representing strong (9), moderate (3), and weak (1) relationships, with blank for no relationship
- D. An alphabetical scale ranking relationships from A (strongest) to F (weakest)

165. A quality engineer discovers that the organization's corrective action system has a backlog of 45 open corrective actions, 30 of which are past their due dates. Which management action is most appropriate?

- A. Close all overdue corrective actions automatically to eliminate the backlog and reset the system
- B. Extend all due dates by 90 days to give responsible parties more time to complete the actions
- C. Eliminate the corrective action system since it is clearly not functioning as intended
- D. Escalate the backlog to management, prioritize the overdue actions by risk level, assign accountability, and establish realistic revised timelines with followup checkpoints

166. In the context of designed experiments, a quality engineer is told that a 2^{4-1} fractional factorial with defining relation $I = ABCD$ aliases the main effect A with the threefactor interaction BCD. The engineer wants to know whether the AB twofactor interaction is also aliased. With which effect is AB aliased?

- A. The main effect of C
- B. The fourfactor interaction ABCD
- C. The twofactor interaction CD
- D. The threefactor interaction ACD

167. A quality engineer needs to evaluate the normality of a data set before conducting a process capability study. The Anderson-Darling normality test produces a p-value of 0.35 at $\alpha = 0.05$. What is the conclusion regarding normality?

- A. The data is confirmed to be perfectly normally distributed with zero skewness
- B. The data is definitively nonnormal and requires transformation before capability analysis
- C. The normality test is inconclusive and must be repeated with a larger sample size
- D. There is insufficient evidence to reject the normality assumption — the data is consistent with a normal distribution and standard capability indices may be applied

168. A quality engineer is developing a risk mitigation plan for a newly identified supply chain risk. The risk involves a sole-source supplier for a critical raw material located in a region prone to natural disasters. Which combination of mitigation strategies provides the most comprehensive risk reduction?

- A. Accept the risk and document it in the risk register for annual review
- B. Qualify an alternate supplier in a different geographic region, maintain strategic safety stock, and establish a monitoring system for early warning of supply disruptions
- C. Purchase insurance to cover financial losses from supply interruption
- D. Require the supplier to relocate their facility to a lower-risk geographic region

169. A quality engineer is reviewing a scatter diagram showing the relationship between two variables and observes a funnel-shaped pattern — the spread of Y-values increases as X increases. What does this pattern indicate about the relationship?

- A. A strong positive linear relationship exists between the two variables
- B. The variance of Y is not constant across the range of X — a condition called heteroscedasticity that may affect regression analysis results

- C. No relationship exists because the pattern shows random scatter without direction
- D. The data contains outliers that should be removed before further analysis

170. A quality engineer is implementing an SPC system for a new production line and must determine the initial control limits. The standard practice requires how many subgroups of data to establish reliable initial control limits?

- A. A minimum of 5 subgroups is sufficient for initial control limit calculation
- B. Exactly 10 subgroups collected over a single production shift
- C. At least 20 to 25 subgroups collected during a period when the process is believed to be operating under normal conditions
- D. A minimum of 100 subgroups collected over at least one full year of production

171. A quality engineer is conducting a multiple regression analysis and obtains the following results: the overall Ftest is not significant ($p = 0.38$), $R^2 = 0.12$. However, one individual predictor shows a ttest with $p = 0.03$. How should the engineer interpret these contradictory results?

- A. The overall model is not significant, which casts doubt on the individual predictor's significance — the significant individual ttest may be a Type I error, and the model as a whole does not explain meaningful variation in the response
- B. The significant individual predictor proves the model is valid despite the nonsignificant Ftest
- C. The Ftest is incorrect and should be disregarded in favor of the individual ttests
- D. Additional predictor variables must be added until the Ftest becomes significant

172. In the context of Crosby's Quality Management Maturity Grid, an organization that has a quality department that reports to manufacturing, handles quality through appraisal and sorting, and views quality cost as primarily the cost of running the quality department is operating at which maturity stage?

- A. Stage 1 — Uncertainty
- B. Stage 5 — Certainty
- C. Stage 2 — Awakening, where the organization is beginning to recognize quality as important but still relies heavily on inspectionbased approaches
- D. Stage 4 — Wisdom

173. A quality engineer needs to estimate the population variance of a critical characteristic from a sample of 20 measurements. The sample standard deviation is $s = 2.4$. The engineer constructs a 95% confidence interval for the population variance σ^2 . Which distribution is used to construct this interval?

- A. The normal distribution with Z critical values at ± 1.96
- B. The chisquare distribution with 19 degrees of freedom
- C. The tdistribution with 19 degrees of freedom
- D. The Fdistribution with 19 and 19 degrees of freedom

174. A quality engineer is implementing total productive maintenance (TPM) and wants to measure the effectiveness of the maintenance program using Overall Equipment Effectiveness (OEE). The production line data shows: Availability = 85%, Performance Efficiency = 90%, Quality Rate = 98%. What is the OEE?

- A. 91% calculated as the average of the three factors
- B. 273% calculated as the sum of the three factors
- C. 98% determined by the highestperforming factor

D. 75% calculated as the product of the three factors ($0.85 \times 0.90 \times 0.98$)

175. A quality engineer is planning a Gage R&R study and considers using the range method versus the ANOVA method for analysis. Which statement correctly describes the advantage of the ANOVA method over the range method?

- A. The ANOVA method provides a complete decomposition of all variation sources including operatorby part interaction, while the range method provides only estimates of repeatability and reproducibility
- B. The ANOVA method requires fewer measurements and is therefore less expensive to conduct
- C. The range method is always preferred because it is more statistically powerful than ANOVA
- D. The ANOVA method eliminates the need for multiple operators in the study design

Practice Exam 3: Answer Key and Explanations

1. B — A Cpk of 1.45 indicates strong process capability, which supports reducing inspection intensity — but it does not justify eliminating monitoring entirely. Ongoing SPC must continue to verify the process remains stable and capable over time, because capability can degrade due to tool wear, material changes, or equipment drift without realtime monitoring to detect the change.

2. A — When failure costs dominate at 72% of total quality costs, the organization is dramatically underinvesting in prevention. The classical COQ model demonstrates that each dollar invested in prevention typically eliminates several dollars of failure cost, producing a net reduction in total quality costs. Shifting the investment balance toward prevention is the most effective strategic response.

3. D — The paired ttest is correct because the same 15 coupons are cleaned with both solvents, creating naturally paired observations. The paired design controls for coupon to coupon variation (surface condition, material properties) by analyzing the within coupon differences, providing a more powerful comparison than treating the two groups as independent samples.

4. C — When the bottleneck cycle time (2.8 minutes) exceeds takt time (2.0 minutes), the production line cannot produce fast enough to meet customer demand. The bottleneck constrains the entire line's throughput to its own rate, creating a shortfall of 0.8 minutes per unit that accumulates into missed deliveries and backlog unless the bottleneck is addressed.
5. B — Distribution and withdrawal of obsolete documents is the specific document control function that has failed. When superseded procedure versions remain in active use at workstations, the system did not ensure that new revisions were distributed to all points of use and that the old versions were simultaneously withdrawn or clearly marked as obsolete.
6. D — Risk management principles for safetycritical applications consistently require that catastrophicseverity risks receive highpriority treatment regardless of their probability. The potential for loss of life demands robust risk reduction measures because the consequences are irreversible and unacceptable — low probability does not justify accepting catastrophic potential harm.
7. A — When the mean (50.2) exceeds the median (48.6), which exceeds the mode (47.0), the distribution is rightskewed (positively skewed). The bulk of the data is concentrated at lower values, with a tail stretching toward higher values that pulls the mean upward past the median and mode. In a perfectly symmetric distribution, all three measures would be equal.
8. C — A supplier performance monitoring system with defined metrics for quality, delivery, and cost provides the ongoing data needed to evaluate supplier trends, identify deterioration, and drive improvement. Without systematic monitoring, the supplier's performance between audits is invisible, and problems are discovered only when they cause downstream quality failures.
9. A — The significant interaction between cutting speed and feed rate means the optimal level of one factor depends on the level of the other. Setting each factor independently based on its main effect alone would miss the combined effect and could produce suboptimal or even counterproductive results. Joint optimization considering the interaction surface is required.
10. D — With only one measurement per day, subgrouping is not practical. The IMR chart is designed for this exact situation — it plots each individual measurement and uses the moving range between consecutive measurements to estimate shortterm process variability. The IMR chart is the standard choice when the production rate or measurement frequency yields only one observation per sampling period.

11. B — Tampering — adjusting a stable, incontrol process in response to individual measurements — adds adjustment variation on top of the existing common cause variation. Deming demonstrated this through his funnel experiment: each unnecessary adjustment introduces a new perturbation, and the cumulative effect is increased total process variation rather than the decreased variation the operators intend.

12. C — ISO 9001:2015 Clause 8.4 addresses the control of externally provided processes, products, and services. This clause requires the organization to ensure that external providers meet defined requirements, to determine the controls needed based on the potential impact on the organization's ability to deliver conforming products, and to communicate requirements to external providers.

13. A — Since repeatability (18%) and reproducibility (15%) contribute similar amounts to total measurement variation, both sources must be addressed simultaneously for meaningful improvement. Focusing on only one component would leave approximately half the measurement system variation unresolved. Instrument improvement addresses repeatability while procedural standardization and training address reproducibility.

14. D — A pvalue of 0.001 provides very strong statistical evidence against the null hypothesis — the probability of observing this result by chance if H_0 were true is only 0.1%. However, statistical significance does not automatically imply practical significance. The quality engineer must also evaluate whether the magnitude of the observed effect is large enough to matter in the realworld engineering context.

15. B — The pattern of high ontime closure (85%) combined with high recurrence (40%) is a classic indicator that corrective actions are addressing symptoms rather than root causes. Actions are being completed quickly and documented as closed, but the underlying systemic issues remain unresolved, causing the same problems to reappear in new corrective action requests.

16. C — A 2^{5-2} design runs $2^3 = 8$ experimental treatments. The exponent ($5 - 2 = 3$) determines the number of runs. This quarterfraction of the full $2^5 = 32$ run factorial is a highly efficient screening design that estimates main effects but confounds them with twofactor interactions (Resolution III).

17. B — When two charts for the same process use different baseline data, the control limits will differ, potentially causing one chart to signal outofcontrol while the other shows incontrol for the same process condition. This inconsistency creates confusion about when to investigate and when to leave the process alone, undermining the fundamental purpose of SPC.

18. D — When field failures are caused by operating conditions the design team did not anticipate, the root cause traces back to inadequate design inputs. The actual operating environment — including hightemperature conditions — should have been identified, characterized, and incorporated into the design requirements so that the capacitor selection would have accounted for thermal degradation.

19. A — A secondparty audit is conducted by one organization on another with which it has a business relationship — typically a customer evaluating a supplier's quality system and capabilities. This type of audit occurs before or during a business relationship to verify that the supplier can meet the customer's quality, delivery, and capability requirements.

20. C — Increasing the sample size is the most effective way to simultaneously reduce both producer's risk and consumer's risk. Larger samples produce steeper OC curves that more sharply discriminate between good lots (high acceptance probability) and bad lots (low acceptance probability), narrowing the zone of ambiguity between the AQL and LTPD quality levels.

21. D — All material produced since the last known good subgroup was manufactured under potentially outofcontrol conditions. This material may include nonconforming product that was produced after the process shifted but before the shift was detected. Segregating this suspect material is essential to prevent potentially nonconforming product from being shipped to customers.

22. B — The number of kanban cards is calculated based on daily demand (how many units are consumed per day), replenishment lead time (how long it takes to produce or deliver a new container), a safety stock factor (buffer for variation in demand and lead time), and container size (how many units each container holds). These factors together determine the maximum inventory in the system.

23. A — A 95% confidence interval is wider than a 90% interval calculated from the same data because higher confidence requires a larger critical value ($Z_{0.025} = 1.96$ versus $Z_{0.05} = 1.645$), producing a larger margin of error. Greater confidence demands more width to ensure the interval captures the true parameter with higher probability.

24. C — Clean rooms, functioning plumbing, and electricity are basic (musthave) requirements in the Kano Model. Customers expect these as a baseline — their presence does not increase satisfaction (guests do not praise a hotel for having running water), but their absence causes immediate and strong dissatisfaction. Basic requirements are the minimum threshold for acceptable service.

25. D — Oneway ANOVA is the appropriate method for comparing the means of four independent groups simultaneously. It tests whether any significant differences exist among the four temperature groups while controlling the overall Type I error rate. Using four separate ttests would inflate the experimentwise error rate, increasing the probability of false positive results.

26. A — The Define phase establishes the foundation of the DMAIC project: what problem is being solved, why it matters (business case), what the boundaries are (scope), who is on the team, and what success looks like (objectives). The project charter formally documents these elements and serves as the contract between the team and the sponsoring organization.

27. C — A rightskewed distribution with a long tail extending toward higher values and concentration on the left is characteristic of a lognormal distribution. The lognormal distribution is bounded at zero (no negative values) and naturally produces positive skewness, making it appropriate for modeling many quality characteristics including repair times, particle sizes, and certain material properties.

28. B — Error proofing through an asymmetric fixture that physically prevents incorrect component orientation is the most effective action because it eliminates the failure mode at its source. Unlike inspection (which detects errors after they occur), retraining (which depends on human memory), or rating changes (which only affect the FMEA score), errorproofing makes the error physically impossible.

29. D — When the within subgroup standard deviation estimate equals the overall standard deviation, there is no significant between-subgroup variation. This equality indicates that the process has been in statistical control throughout the data collection period — no shifts, trends, or other special causes have added variation between subgroups beyond what exists within them.

30. A — A risk register that has not been updated in 18 months — during which two new product lines launched and a major supplier changed — almost certainly does not reflect the organization's current risk profile. New products introduce new design, manufacturing, and market risks. Supplier changes introduce new supply chain risks. The outdated register provides a false sense of security.

31. C — In GD&T, the position tolerance value preceded by a diameter symbol ($\varnothing 0.50$ mm) defines a cylindrical tolerance zone centered on the theoretically exact position of the feature. The axis of the actual hole must fall within this cylindrical zone for the part to be conforming. The diameter specifies the width of the zone, not the hole size or spacing.

32. D — After brainstorming potential causes with a fishbone diagram, the next step is to collect data on the most likely candidates to determine which are actually contributing. Pareto analysis of the collected data then prioritizes the verified causes by their relative impact, directing corrective action toward the vital few causes that account for the majority of the defect.

33. A — A twohour production run captures only the variation present during that brief window — same material lot, same operator, same environmental conditions, same equipment state. It misses the betweenrun, between shift, between lot, and between day variation that contributes to long term process performance. A reliable capability study should span enough time to capture these additional variation sources.

34. B — When operators demonstrate knowledge during training (Level 2 — Learning) but do not apply it on the production floor, the failure is at Kirkpatrick's Level 3 — Behavior. The skill transfer from classroom to workplace has not occurred, potentially due to lack of reinforcement, inadequate on the job support, conflicting priorities, or insufficient practice opportunities in the actual work environment.

35. D — Adding a parallel redundant component directly addresses the single point of failure vulnerability by ensuring that both components must fail for the system to fail. With two identical components in parallel, each with reliability R , the subsystem reliability becomes $1 - (1 - R)^2$, which is dramatically higher than the single component reliability. Redundancy is the most direct design solution for single point failures.

36. C — A significant ANOVA F test indicates that at least one machine mean differs, but it does not identify which specific machines are different from which others. Tukey's Honestly Significant Difference test is a multiple comparison procedure that performs all pairwise comparisons while controlling the familywise error rate, identifying exactly which machine pairs have significantly different means.

37. A — ISO 9001:2015 requires risk based thinking to be integrated throughout the QMS but explicitly does not prescribe a specific risk management methodology. The organization has the flexibility to choose any approach — FMEA, risk matrices, brainstorming, checklists, or any other method — that is appropriate and proportionate to its context, complexity, and risk profile.

38. B — The one proportion Z test compares a sample proportion ($\hat{p} = 9/300 = 0.030$) to a hypothesized population proportion ($p_0 = 0.05$) to determine whether the observed reduction is statistically significant. This test is specifically designed for comparing an observed proportion against a known or historical standard value.

39. C — Incoming material inspection is an appraisal cost — an expenditure incurred to detect nonconformances through examination, testing, or measurement. Appraisal activities verify conformance but do not prevent defects (prevention) or deal with the consequences of defects found internally (internal failure) or by customers (external failure).

40. D — A regular cyclical pattern with a consistent period (approximately 8 subgroups) indicates a periodic disturbance — a recurring cause that appears and disappears on a regular schedule. Common sources include temperature cycling from HVAC systems, batchtobatch material differences in a periodic supply, tool rotation patterns, shifttoshift differences, or scheduled equipment maintenance cycles.

41. A — Without randomization, factor effects may be confounded with timedependent lurking variables such as ambient temperature drift, operator fatigue, material property changes within a batch, or equipment warmup. If all lowlevel runs precede all highlevel runs, any systematic timedependent change will be indistinguishable from the factor effect, invalidating the experimental conclusions.

42. B — The acceptance criterion is $c = 2$, meaning the lot is accepted if 2 or fewer defectives are found in the sample. With 3 defectives observed, the count exceeds the acceptance number, and the lot must be rejected. The decision is based solely on the sample result compared to the acceptance number — not on the percentage relative to the lot size.

43. D — The primary purpose of visual controls during Set in Order is to make the standard condition immediately visible. When every tool has a labeled shadow board position, every material has a marked staging area, and every walkway is defined by floor markings, any deviation from the standard — a missing tool, a misplaced container, an obstructed pathway — is instantly apparent to anyone in the area.

44. D — The most critical immediate action is identifying and segregating all product manufactured during the 4 hours the parameter was out of its validated range. This product was produced under conditions that may not produce conforming output, and it must be evaluated and dispositioned before it can be released. Documentation, recalibration, and retraining are important but secondary to protecting the customer.

45. A — A large gap between R^2 (0.89) and adjusted R^2 (0.71) indicates that one or more predictor variables are not contributing genuine explanatory power. They are overfitting the model — capturing noise in the training data rather than real relationships. Adjusted R^2 penalizes for unnecessary predictors, and the 18point drop signals that the model should be simplified by removing noncontributing variables.

46. B — Radiographic testing is the most appropriate method for detecting internal volumetric defects such as voids and porosity in castings. Xrays penetrate through the casting and reveal density variations caused by internal discontinuities, regardless of complex external geometry. Liquid penetrant and magnetic particle testing detect only surface or nearsurface defects, and aluminum is nonferromagnetic.

47. B — The specification limits are at $\pm 2\sigma$ from the mean: $(100.0 - 99.0)/0.5 = 2.0\sigma$ and $(101.0 - 100.0)/0.5 = 2.0\sigma$. According to the empirical rule, approximately 95.45% of data falls within $\pm 2\sigma$, leaving approximately 4.55% outside the specification limits combined (about 2.28% in each tail).

48. B — The key distinction between repair and rework is the end state of the product. After rework, the product meets the original drawing specification fully. After repair, the product meets a revised acceptance criterion that has been evaluated and approved by engineering — it is functionally acceptable but does not conform to the original specification. This distinction drives different approval requirements.

49. C — The sequential experimentation strategy dictates that after a screening experiment identifies the vital few factors, the next step is a higherresolution followup design using only those significant factors. A 2^3 full factorial with replication thoroughly characterizes all three main effects and all three twofactor interactions with no confounding, providing the clean estimates needed for optimization.

50. B — With %GRR = 35% (exceeding the 30% threshold) and ndc = 3 (below the minimum of 5), the measurement system fails on both AIAG MSA acceptability criteria. The system cannot reliably discriminate between parts and consumes too much of the tolerance with its own variation, making it unacceptable for quality decisions. Improvement is required before the system can be used.

51. D — Standard control charts assume that consecutive observations are independent. When significant autocorrelation exists ($r_1 = 0.78$), the natural correlation between consecutive points creates patterns that the chart interprets as special causes, generating excessive false alarms. The chart signals instability when the process may actually be stable — it is reacting to the correlation structure rather than to real process changes.

52. A — Deming's observation that the system — not individual workers — causes most quality problems directly supports focusing improvement efforts on changing processes, equipment, materials, and methods rather than blaming workers. Workers operate within a system designed by management, and holding workers responsible for systemcaused problems is both unfair and ineffective at producing improvement.

53. C — The normal probability plot provides the most direct visual assessment of normality. When data is normally distributed, the plotted points fall approximately on a straight line. Deviations from linearity — S-curves, curvature, outliers — indicate specific types of nonnormality. This graphical method is more informative than histograms because it reveals tail behavior and outliers more clearly.

54. B — The ASQ Code of Ethics requires honesty and integrity in all professional representations. Certifying that a product meets specifications when the engineer's own test data shows it does not is a direct violation of this ethical obligation, regardless of the client's assessment of significance. The engineer must not certify nonconforming product — the appropriate path is to disposition the product through proper channels.

55. D — $CL = \bar{p} = 0.03$. $UCL = \bar{p} + 3\sqrt{(\bar{p}(1-\bar{p}))/n} = 0.03 + 3\sqrt{(0.03 \times 0.97/200)} = 0.03 + 3\sqrt{(0.0001455)} = 0.03 + 3(0.01206) = 0.03 + 0.036 = 0.066$. The upper control limit of 0.066 represents the threshold above which the proportion nonconforming is statistically unlikely under common cause variation alone.

56. A — $R(500) = e^{-(\lambda t)} = e^{-(0.002 \times 500)} = e^{-(1.0)} \approx 0.368$. This means there is approximately a 36.8% probability that the component will survive 500 hours of operation without failure. The exponential reliability function assumes a constant failure rate, which is valid during the useful life period of the bathtub curve.

57. C — The lognormal distribution naturally produces rightskewed distributions bounded at zero, which matches the described data pattern. Many quality characteristics — repair times, fatigue life, particle sizes, and certain process outputs — follow lognormal distributions because they result from multiplicative rather than additive processes.

58. D — When the interaction term is not statistically significant, it confirms that the effect of each factor is consistent and independent across the levels of the other factor. The main effects can be interpreted directly without concern that the effect of one factor varies depending on the setting of the other. The nonsignificant interaction simplifies interpretation and optimization.

59. B — A barcode scanner that verifies productlabel matching before allowing the packaging machine to seal is a detectiontype pokayoke that prevents the error from escaping. It is more effective than signs or checklists (which depend on human compliance) and more proactive than postpackaging audits (which catch errors after additional packaging costs are incurred).

60. A — The lower control limit for the R chart is $LCL_R = D_3 \times \bar{R}$. For subgroup sizes of 6 or less, $D_3 = 0$, which makes $LCL_R = 0 \times 5.8 = 0$. This means that for small subgroups, any positive range value is

possible under common cause variation, and the R chart can only detect increases in variability, not decreases.

61. C — Failure cost reduction = $(48 - 8) \times \$5,000 = 40 \times \$5,000 = \$200,000$. Net benefit = $\$200,000 - \$120,000 = \$80,000$ per year. The preventive maintenance program pays for itself and generates an additional \$80,000 in annual savings from avoided unplanned failures, scrap, and lost production — demonstrating the economic value of prevention investment.

62. D — Stability is the measurement system property that describes the consistency of performance over time. A stable measurement system produces the same results when measuring the same part today, next week, and next month under the same conditions. Stability is assessed by measuring a control part at regular intervals and tracking the results on a control chart over an extended period.

63. B — Increasing the desired power from 80% to 95% requires a larger sample size because the test must detect the same effect with higher probability. Higher power means a lower probability of Type II error, which demands more data to achieve. The relationship between power and sample size is direct — greater power always requires more observations, all else being equal.

64. A — Independence is a fundamental auditing principle that requires auditors not to audit their own work or their own department. Auditors who assess their own area cannot be objective — they have a personal stake in the findings and may consciously or unconsciously overlook deficiencies. Independence ensures the credibility and reliability of audit conclusions.

65. C — Data collection should be guided by relevance (the data supports quality decisions), actionability (the data can drive specific improvements or interventions), and costeffectiveness (the value of the data justifies the cost of collecting it). Collecting every possible data point creates information overload and wastes resources, while collecting only minimum requirements may miss critical quality intelligence.

66. D — With a pvalue of 0.24 (exceeding $\alpha = 0.05$) and $r^2 = 0.08$ (only 8% of response variation explained), there is no statistically significant linear relationship. The predictor explains virtually none of the variation in the response, and the nonsignificant pvalue confirms that the observed weak association is consistent with random chance rather than a genuine relationship.

67. A — ISO 14971 requires risk management throughout the entire product lifecycle — from initial concept, through design and development, manufacturing, market release, and postmarket surveillance,

to eventual decommissioning. Postmarket data including complaint reports, adverse events, and field performance must be continuously fed back into the risk management process.

68. B — A single point above the UCL on the R chart signals a special cause of increased variability at that subgroup, even though the Xbar chart shows no mean shift. The quality engineer should investigate what caused the increased variation — possible causes include a loose fixture, worn or changed tooling, a different material lot, or a measurement system issue — and take corrective action.

69. C — A pattern where every failure mode receives a Detection rating of 1 (nearcertain detection) is almost certainly unrealistic. It suggests the ratings were assigned optimistically or without careful evaluation of each control's actual detection capability. In reality, detection effectiveness varies significantly across failure modes, and rating all as "nearcertain" masks real detection gaps.

70. D — The Fstatistic (2.40) exceeds the critical Fvalue (2.168) at $\alpha = 0.05$ (twotailed), so the null hypothesis of equal variances is rejected. There is statistically significant evidence that the process variance has changed after the tooling installation. The quality engineer should evaluate whether the change represents an improvement or a degradation.

71. A — For a critical weld joint identified as the highest PFMEA risk, the control plan must include the specific control method (what monitoring approach), the measurement technique (how it is measured), the sample size and frequency (how often), and a detailed reaction plan (exactly what operators do when a problem is detected). These elements together ensure the risk is actively managed during production.

72. B — Under ANSI/ASQ Z1.4 switching rules, if a specified number of consecutive lots are rejected under tightened inspection (typically 5, though the standard may specify fewer), inspection is discontinued. The standard requires that the supplier take corrective action to improve quality before lots may be submitted again, protecting the customer from continued receipt of substandard material.

73. D — The significant AB interaction means that the effect of Factor A depends on the level of Factor B — the two factors cannot be optimized independently. Even though Factor B's main effect is small, its role in the interaction makes it critical. The optimal level of A at one level of B may differ from the optimal level of A at the other level of B.

74. C — Using outdated wider control limits on a chart for a process that has improved (lower mean and standard deviation) makes the chart insensitive to current process changes. The original limits are too

wide for the improved process, so shifts that should trigger investigation go undetected. Control limits should be periodically recalculated to reflect the current process performance.

75. A — The most direct and effective mitigation for singlesource dependency risk is qualifying an alternate supplier for the same component. This eliminates the vulnerability by ensuring a backup source is available if the primary supplier experiences a disruption. Other actions (increased inspection, certification requirements, reduced orders) do not address the fundamental singlesource risk.

76. A — When only a lower specification limit exists, only the onesided capability index CPL can be calculated: $CPL = (\mu - LSL) / 3\sigma$. This measures the distance from the process mean to the single specification limit in units of three standard deviations. Cp requires both specification limits and cannot be calculated for onesided specifications.

77. D — When reproducibility dominates repeatability by a factor of four, the primary source of measurement variation is differences among operators — different techniques, different part positioning, different reading interpretation, or different measurement approaches. Reducing this variation requires standardizing the measurement procedure, providing additional training, or implementing fixturing that constrains operator variability.

78. A — The sparsity of effects principle states that in most industrial processes, only a small number of effects — primarily main effects and loworder interactions — have meaningful impact on the response, while higherorder interactions are typically negligible. This principle is the theoretical foundation for fractional factorial designs, which sacrifice information about higherorder interactions assumed to be negligible.

79. C — An incorrect torque specification in a critical work instruction that is 30% below the validated value poses an immediate quality and safety risk. Production must be stopped to prevent further use of the incorrect specification, all product assembled using the wrong torque must be segregated for evaluation, and the work instruction must be corrected immediately — before normal document revision processes.

80. B — Many improvement initiatives fail to sustain because the Act phase is skipped or performed inadequately. Without standardizing the successful change (updating procedures, training all affected personnel, modifying control plans, and establishing monitoring), the process gradually reverts to its previous state as the initial improvement energy dissipates and old habits reassert themselves.

81. D — Degrees of freedom for a contingency table chi-square test = $(\text{rows} - 1) \times (\text{columns} - 1) = (6 - 1) \times (4 - 1) = 5 \times 3 = 15$. This formula accounts for the constraints imposed by the fixed marginal totals — knowing all but one value in any row or column determines the remaining value.

82. B — For subgroup sizes greater than 10, the Xbar and S chart is preferred over the Xbar and R chart. The range uses only the two extreme values in the subgroup and becomes an increasingly inefficient estimator of process variability as subgroup size grows. The standard deviation uses every data point, providing a more precise and efficient variability estimate for larger subgroups.

83. C — The Baldrige framework allocates 450 of its 1,000 total points to the Results category, which explicitly evaluates product and process outcomes, customer satisfaction results, workforce results, leadership and governance results, and financial and market results. ISO 9001 focuses on quality management system conformance and does not evaluate business financial performance or market outcomes.

84. B — The AOQL is the maximum average outgoing quality (worst case) that can occur for any level of incoming quality, given that rejected lots are 100% inspected and all nonconforming units are replaced. The AOQL represents a ceiling on the average quality escaping to the customer, regardless of how poor the incoming quality becomes.

85. D — A systematic alternating pattern (highlowhighlow) is called a mixture pattern and is often caused by overadjustment of the process (each correction overcorrects, creating the next deviation), alternation between two machines or two operators with different settings, or rotation between two raw material sources. The systematic zigzag is too regular to be random and indicates a twostate oscillation.

86. A — Payback period = $\text{Investment} / \text{Annual savings} = \$45,000 / \$180,000 = 0.25 \text{ years} = 3 \text{ months}$. This assumes the errorproofing device eliminates 100% of the targeted defect, which is realistic for well-designed pokayoke devices. The rapid 3month payback makes this a compelling investment with a return that continues for the life of the device.

87. C — Special processes such as welding, sterilization, and heat treatment require validation because their output quality depends on parameters controlled during the process, and defects may not be detectable through subsequent inspection and testing. If the welding parameters were incorrect during the weld, no amount of postweld inspection can make the weld right — the quality must be built in during the process.

88. B — ISO 9001:2015 Clause 7.2 requires the organization to determine the necessary competence of persons performing work affecting quality, ensure those persons are competent on the basis of appropriate education, training, or experience, and take actions to acquire necessary competence where gaps exist. An untrained operator on a critical process directly violates this requirement.

89. A — Exponential smoothing formula: $\text{New forecast} = \text{Previous forecast} + \alpha \times (\text{Actual} - \text{Previous forecast}) = 85.0 + 0.3 \times (91.0 - 85.0) = 85.0 + 0.3 \times 6.0 = 85.0 + 1.8 = 86.8$. The smoothing constant $\alpha = 0.3$ gives 30% weight to the most recent observation and 70% weight to the previous forecast, balancing responsiveness with stability.

90. D — With a C_{pk} of 0.65, the process is clearly incapable — but halting all production may not be economically or operationally feasible. The pragmatic approach is to continue production with 100% inspection or intensified SPC monitoring to contain nonconforming output while simultaneously implementing process improvements to increase capability. This protects the customer while avoiding complete production stoppage.

91. C — The 6M categories for manufacturing cause-and-effect diagrams are Man (people), Machine (equipment), Material (inputs), Method (procedures), Measurement (instrumentation), and Mother Nature (environment). These six categories provide a comprehensive framework for systematically brainstorming potential causes across all dimensions that could affect a manufacturing process.

92. B — The point where acceptance probability is 0.95 at 2% nonconforming represents the AQL — the quality level with approximately 5% producer's risk of rejection. The point where acceptance probability is 0.10 at 8% nonconforming represents the LTPD — the quality level with approximately 10% consumer's risk of acceptance. These two points define the OC curve's key performance characteristics.

93. A — Twenty consecutive calibrations within tolerance over five years demonstrates exceptional instrument stability. This consistent history provides strong evidence that the calibration interval can be safely extended — perhaps from 6 months to 9 or 12 months. Data-driven interval adjustment optimizes the balance between measurement reliability and calibration cost, avoiding unnecessary calibration of demonstrably stable instruments.

94. D — The two-proportion Z-test is designed for comparing proportions from two independent populations. Process 1 ($\hat{p}_1 = 18/450 = 0.040$) and Process 2 ($\hat{p}_2 = 32/500 = 0.064$) are independent samples, and the test determines whether the difference in proportions is statistically significant or consistent with random sampling variation.

95. B — When only 4 of 12 process steps physically transform the product, the remaining 8 steps represent nonvalueadded activities from the customer's perspective. This observation — that most process steps do not add value — is a central lean insight. It identifies the opportunity to eliminate, reduce, or streamline the 8 nontransforming steps to reduce lead time, cost, and complexity.

96. C — Risk acceptance criteria — the thresholds that define what levels of risk are acceptable, tolerable, and unacceptable — must be established during the "Establishing the context" step, before risk assessment begins. These criteria provide the benchmark against which analyzed risks will be evaluated in the subsequent risk evaluation step.

97. A — The result is statistically significant ($p = 0.048 < 0.05$), confirming that a real difference exists. However, the practical significance must also be evaluated — a difference of 0.02 mm is only 1% of the 2.0 mm specification tolerance, which may be too small to matter from an engineering or customer perspective. Statistical significance and practical significance are independent assessments.

98. C — Specification limits and control limits serve fundamentally different purposes and should never be confused. Specification limits define product requirements — what the customer needs. Control limits define the expected range of process behavior due to common cause variation — what the process actually does. Using specification limits on a control chart conflates product acceptance with process monitoring, producing a chart that cannot detect process shifts.

99. C — A Ushaped scatter pattern represents a nonlinear (quadratic) relationship where the response first decreases then increases as the predictor changes. The Pearson correlation coefficient, which measures only linear association, would yield a value near zero — completely missing the strong curved relationship. Quadratic regression or a polynomial model would be needed to capture this relationship accurately.

100. B — ISO 9001:2015 Clause 9.3.2 specifies that management review inputs must include changes in external and internal issues relevant to the QMS. New regulations, market shifts, competitive changes, technological developments, and other contextual factors can significantly affect the organization's risk profile and quality objectives. Omitting this input means the QMS may not adapt to changing conditions.

101. D — Nine consecutive points on one side of the center line violates Western Electric Rule 4, which triggers at 8 or more consecutive points on the same side. This pattern indicates a sustained shift in the process mean, even though no individual point has crossed the control limits. The probability of 9 consecutive points randomly falling on the same side of a centered process is approximately 1 in 512.

102. A — $R(1000) = e^{(-\lambda t)} = e^{(-0.0005 \times 1000)} = e^{(-0.5)} \approx 0.607$. This means approximately 60.7% of units are expected to survive 1,000 hours without failure. The exponential reliability function applies during the useful life period when the failure rate is constant, and it directly converts the failure rate and operating time into a survival probability.

103. B — Parts traveling 1,200 feet between 8 workstations in different buildings represents transportation waste — the unnecessary movement of materials that consumes time, labor, and resources without adding value. A cellular layout placing workstations in close proximity dramatically reduces transport distance, lead time, and handling damage risk while improving communication between operations.

104. C — With defining relations $I = ABCE$ and $I = BCDF$, the generalized wordlength pattern yields Resolution IV. Main effects are aliased only with three-factor and higher interactions (which are assumed negligible), but some two-factor interactions are aliased with other two-factor interactions. This means main effects are estimable cleanly, but specific two-factor interaction pairs cannot be separated.

105. D — ISO 9001:2015 Clause 8.5.6 requires that changes affecting production be identified, reviewed, and controlled to maintain product conformity. Changing a machine parameter without documentation or impact evaluation bypasses this change control requirement, creating the risk that the undocumented change produces nonconforming product without anyone knowing why.

106. A — The calculated chi-square statistic (22.4) exceeds the critical value (12.59) at $\alpha = 0.05$ with 6 degrees of freedom, so the null hypothesis of independence is rejected. There is statistically significant evidence that the two categorical variables are associated — their observed joint distribution differs significantly from what would be expected if they were independent.

107. C — Process capability indices require the process mean (μ) and standard deviation (σ), neither of which can be determined from the range of values alone. A Certificate of Analysis showing results of 58-62 HRC tells you the extremes but not the distribution of individual measurements, the center, or the spread — the fundamental inputs needed for C_p and C_{pk} calculations.

108. B — The most important factor in choosing between in-house and external calibration is whether the organization possesses traceable reference standards of sufficient accuracy and qualified personnel competent to perform the calibration. Without these, in-house calibration cannot meet the traceability and competence requirements that ensure measurement reliability.

109. A — With $C_p = 2.10$ and $C_{pk} = 0.92$, the process has exceptional inherent capability but is severely off-center. The enormous gap between the two indices means that simply recentering the process mean — without any reduction in variation — would dramatically improve C_{pk} toward the C_p value. This is the most effective single action because it recovers the lost capability with minimal investment.

110. C — The traditional RPN method multiplies $S \times O \times D$, and identical products can result from very different risk profiles — for example, $S=10, O=2, D=2$ (RPN=40) versus $S=2, O=5, D=4$ (RPN=40). The first represents a far more dangerous situation, but both receive the same priority. The Action Priority method addresses this by weighting severity most heavily.

111. C — With a large sample ($n = 150$), even a trivially weak correlation ($r = 0.12$) can achieve statistical significance because the standard error of r decreases with sample size. However, $r^2 = 0.014$, meaning the linear relationship explains less than 2% of the variation. Statistical significance confirms the relationship is non-zero; practical significance requires evaluating whether 2% explanatory power matters.

112. B — Recurring identical findings year after year are the hallmark of ineffective corrective actions. The audit program correctly identifies the problems, but the corrective actions taken in response are not eliminating root causes — they are addressing symptoms, being implemented incompletely, or not being sustained. The corrective action effectiveness verification process needs strengthening.

113. A — The absolute value of the t-statistic (2.57) exceeds the critical value (2.064), so the null hypothesis is rejected. There is statistically significant evidence that the process mean differs from the 500 ml target. The negative t-statistic indicates the mean is below target ($498.2 < 500$), but both directions are tested in a two-sided test, and the magnitude exceeds the critical threshold.

114. D — Cost of conformance = Prevention costs + Appraisal costs. Prevention = \$50,000 (planning) + \$30,000 (training) = \$80,000. Appraisal = \$80,000 (inspection). Total cost of conformance = \$80,000 + \$80,000 = \$160,000. Scrap/rework (\$120,000) and warranty (\$70,000) are failure costs — the cost of nonconformance — not conformance costs.

115. C — Risk-based incoming inspection allocates resources proportionally to risk. Materials used in critical applications, from unproven suppliers, or with quality problem histories receive more intensive inspection, while low-risk materials from proven suppliers receive reduced inspection. This approach optimizes inspection resources by directing effort where it produces the greatest quality protection.

116. A — In a full factorial design, the total number of treatment combinations equals the product of the number of levels for each factor: $2 \times 3 \times 2 = 12$ combinations. This is a mixed-level factorial design, not a 2^k design, because Factor B has three levels. Each unique combination of factor settings constitutes one treatment that must be run.

117. B — With total %GRR = 6.4% (well below the 10% acceptance threshold) and $ndc = 9$ (well above the minimum of 5), the measurement system meets both AIAG MSA acceptability criteria. The system has excellent discrimination and contributes minimal variation relative to the tolerance, making it fully acceptable for quality decisions including SPC and capability analysis.

118. D — Standardized work documentation in lean manufacturing includes three essential elements: takt time (the production pace required to meet customer demand), the specific work sequence (the exact order of tasks the operator performs within each takt cycle), and the standard work-in-process inventory level (the minimum in-process inventory needed for smooth, continuous operation).

119. C — Industry guidelines generally recommend 50 to 100 individual measurements for a reliable capability study, collected over a period long enough to capture the full range of variation sources — different shifts, different material lots, different operators, and different environmental conditions. Too few measurements or too short a collection period underestimates the true process variation.

120. A — The shipment of undispositioned material indicates that the material segregation and hold system failed to prevent release. Material awaiting MRB disposition should have been physically segregated, clearly identified with hold status, and blocked in the ERP system from being issued to shipping. The breakdown in this containment allowed undispositioned product to escape.

121. B — Predicting strength at 250°C when the model was built from data spanning 50°C to 150°C is extrapolation — predicting outside the range of the observed data. The linear relationship may not hold beyond 150°C; the response could plateau, reverse, or change form. Extrapolation predictions become increasingly unreliable as they extend further from the data range.

122. D — ISO 9001:2015 requires that the quality policy provide the framework for establishing quality objectives, and that objectives be consistent with the quality policy. The policy sets the direction and commitments; objectives translate those commitments into specific, measurable targets. The two documents form a hierarchical pair — policy drives objectives, and objectives operationalize the policy.

123. C — First calculate Subsystem 1 (parallel): $R_1 = 1 - (1-0.90)^2 = 1 - 0.01 = 0.99$. Then combine in series with Subsystem 2: $R_{\text{system}} = 0.99 \times 0.95 = 0.9405 \approx 0.941$. The parallel redundancy in Subsystem 1 boosts its reliability from 0.90 to 0.99, but the series Subsystem 2 (0.95) then limits the overall system reliability.

124. A — Without a documented reaction plan, operators have no guidance for responding to out-of-control signals. They may continue production, make ad hoc adjustments, or wait for a supervisor — any of which could allow nonconforming product to be produced. The reaction plan is a critical component of the control plan that transforms a detection signal into an effective containment and investigation response.

125. B — Design B's parallel redundancy yields system reliability of $1 - (1-0.99)^2 = 1 - 0.0001 = 0.9999$, which exceeds Design A's 0.999. Despite using lower-reliability individual components, the parallel configuration makes the subsystem fail only when both components fail simultaneously, producing dramatically higher system reliability than even a premium single component.

126. D — A cosmetic surface finish defect that is visible to the user but does not impair product function or safety is classified as a minor defect. Minor defects affect aesthetics or cause slight inconvenience but do not reduce the product's ability to perform its intended function. Control methods for minor characteristics are proportionate — standard inspection rather than SPC or 100% verification.

127. C — At 4-sigma capability (accounting for the conventional 1.5σ process shift), the expected defect rate is approximately 6,210 DPMO. This represents a significant improvement from the 3-sigma level of 66,807 DPMO — roughly a 90% reduction in defects — but is still well above the ultimate 6-sigma target of 3.4 DPMO.

128. A — When an experiment must be split across two days and environmental conditions may differ, the day effect is deliberately confounded with a high-order interaction (typically the highest-order interaction, which is assumed negligible). This blocking technique allows the experiment to proceed across both days while accounting for the day-to-day variation in the analysis.

129. D — Not all identified risks require active treatment. The purpose of risk evaluation is to compare each risk against acceptance criteria to determine which risks exceed tolerance and require treatment versus which fall within acceptable levels and can be retained with monitoring. A risk register should contain all identified risks, but treatment resources should be directed only to those that exceed acceptance thresholds.

130. B — An andon board providing real-time visibility of machine status, production count versus target, quality alerts, and maintenance needs from anywhere in the production area is the most comprehensive visual management tool. It enables immediate awareness of abnormalities and rapid response — the fundamental purpose of visual management in lean manufacturing.

131. C — The np-chart monitors the count of nonconforming units per sample when the sample size is constant. With a fixed lot size of 500 units, the sample size is constant, and the chart plots the actual number of defective units found in each lot. The np-chart is the appropriate choice for constant-sample-size attribute data counting defective units.

132. A — Heteroscedasticity (non-constant variance) means the standard errors of the regression coefficients are incorrectly estimated by ordinary least squares. Since confidence intervals and hypothesis tests for the coefficients depend on accurate standard errors, heteroscedasticity makes these inferences unreliable — intervals may be too narrow or too wide, and p-values may be misleading.

133. D — The risk treatment hierarchy for safety-critical applications prioritizes inherently safe design first — eliminating the need for the warning altogether by redesigning the device interface. This approach removes the hazard at its source rather than relying on users to read and comply with warning labels, which is the least effective treatment option.

134. B — The coefficient of variation normalizes the standard deviation by the mean, enabling comparison of relative variability between processes with different scales. Process B (CV = 8%) has greater relative variation than Process A (CV = 5%), meaning Process B is proportionally less consistent despite having a smaller absolute standard deviation.

135. C — Kirkpatrick's Level 4 (Results) measures organizational impact — whether the training produced measurable improvements in business outcomes such as inspection accuracy, defect escape rates, and quality metrics. Level 4 evaluation requires sufficient elapsed time for the training to translate through behavior change (Level 3) into measurable organizational results.

136. A — With the defining relation $I = ABCD$, the alias of Factor C is found by multiplying: $C \times ABCD = ABC^2D = ABD$ (since $C^2 = I$). Therefore, the main effect of C is aliased with ABD — a three-factor interaction assumed negligible. But the question asks about the p-value: $p = 0.78$ means Factor C's combined effect (C + ABD) is not statistically significant. Factor C does not meaningfully affect the response.

137. D — For a high-volume, low-cost component with a 0.5% historical defect rate causing only minor cosmetic issues, acceptance sampling provides adequate quality protection at a fraction of the cost of 100% inspection. The low defect rate, low consequence, and high volume make 100% inspection disproportionately expensive relative to the risk being managed.

138. B — A 1.0σ shift moves the process mean one standard deviation closer to the nearest specification limit. Since C_{pk} measures the distance from the mean to the nearest limit in units of 3σ , a 1.0σ shift reduces this distance by 1σ , which decreases the C_{pk} by $1\sigma/3\sigma = 0.33$. The C_{pk} on the near side drops from approximately 1.33 to approximately 1.00.

139. C — Audit evidence consists of records, factual statements, and other verifiable information that is relevant to the audit criteria and can be verified. Evidence is objective and factual — inspection records, calibration certificates, training logs, process data, and direct observations. Auditor opinions, checklists, and corrective action plans are not audit evidence.

140. A — Single Minute Exchange of Die (SMED) is the lean tool specifically designed to reduce changeover time. The methodology systematically separates internal setup (machine must be stopped) from external setup (can be done while running), converts internal activities to external where possible, and streamlines all remaining setup tasks to achieve single-digit minute changeovers.

141. D — The described pattern — high early failure rate declining over time, flat middle period, then increasing late-life failure rate — is the classic bathtub curve with its three distinct phases: infant mortality (decreasing failure rate from manufacturing defects), useful life (constant random failure rate), and wear-out (increasing failure rate from cumulative degradation).

142. B — Installing a temperature-controlled storage unit with an alarm directly prevents the root cause — solder paste being stored at incorrect temperatures. This is a prevention-focused corrective action that controls the condition that leads to defective paste, rather than detecting the defect downstream or containing affected product after the fact.

143. C — The process approach manages activities as interconnected processes with defined inputs, activities, outputs, and controls, enabling consistent and predictable results. By understanding how processes interact and depend on each other, the organization can optimize the system as a whole rather than sub-optimizing individual functions in isolation.

144. A — $\hat{\sigma} = \bar{R}/d_2 = 8.0/2.326 = 3.44$. $C_p = (USL - LSL)/6\hat{\sigma} = (110 - 90)/(6 \times 3.44) = 20/20.64 = 0.97$. The process variation ($6\hat{\sigma} = 20.64$) slightly exceeds the specification tolerance (20), yielding a C_p just below 1.0. This process is marginally incapable and will produce some nonconforming output even when perfectly centered.

145. D — Before escalating to supplier termination, the quality engineer should contact the supplier to investigate the root cause of the sudden quality decline. Three consecutive rejections from a previously reliable supplier almost certainly indicate a specific change — new material, new equipment, new personnel, or a process parameter shift — that can be identified and corrected through collaborative investigation.

146. B — The two-proportion Z-test compares independent proportions from two populations: Monday ($\hat{p}_1 = 32/800 = 0.040$) versus Friday ($\hat{p}_2 = 45/750 = 0.060$). The test determines whether the difference in defective proportions is statistically significant or consistent with random sampling variation. The data is attributes (pass/fail) with independent samples from each day.

147. A — Plotting monthly measurements of a reference standard over 24 months on an I-MR chart assesses stability — the consistency of the measurement system's performance over an extended time period. All points within control limits with no trends or shifts confirms the system produces consistent results month after month, demonstrating temporal stability.

148. C — When one predictor in a multiple regression model is not statistically significant ($p = 0.62$) while the overall model is significant, the non-contributing predictor is a candidate for removal. Removing it and refitting simplifies the model, and checking whether adjusted R^2 improves or remains stable confirms whether the variable was adding noise or marginal value.

149. D — Production rate = 500 units/hour \times 8 hours = 4,000 units per shift. Nonconforming rate = 15/1,000 = 0.015. Nonconforming units per shift = 4,000 \times 0.015 = 60 units. The calculation scales the defect rate from the per-thousand basis to the actual shift production volume.

150. B — The ASQ Code of Ethics requires honesty and integrity in all professional activities. Falsifying test results is a direct violation of professional ethics and potentially endangers public safety. The engineer has an obligation to report the falsification through appropriate channels — remaining silent makes the engineer complicit in the ethical violation.

151. A — The 95% confidence interval for the mean difference (-0.008, 0.002) includes zero, which means zero is a plausible value for the true mean difference between the two methods. There is no statistically significant systematic bias between Method A and Method B at the 5% significance level, supporting the conclusion that the methods produce equivalent results.

152. C — Risk-based audit planning allocates audit frequency based on the risk level and importance of the processes being audited, combined with previous audit results. High-risk processes with recurring findings receive more frequent auditing, while low-risk, well-performing processes may be audited less often. This approach optimizes limited audit resources for maximum quality protection.

153. D — A 2^{7-3} design runs $2^{(7-3)} = 2^4 = 16$ treatments, which matches the budget constraint. This design is a 1/8th fraction of the full $2^7 = 128$ run factorial, providing an efficient screening design that can estimate all 7 main effects, though with some aliasing among two-factor interactions depending on the defining relations chosen.

154. B — The five-year trend demonstrates the classic COQ optimization pattern: increased prevention investment (10% → 25%) has driven a disproportionately larger decrease in failure costs (65% → 30%), resulting in lower total quality costs as a percentage of revenue (18% → 11%). The strategic shift toward prevention has produced a measurable net financial benefit for the organization.

155. A — A systematic alternating pattern (up-down-up-down) with no points near the control limits suggests a two-state process: over-adjustment where each correction overcorrects, two machines alternating production, two operators with different techniques, or two material sources being used alternately. The regularity of the pattern rules out random variation and points to a specific two-state oscillation source.

156. C — A quality agreement should specify the quality-related requirements governing the customer-supplier relationship: quality requirements and specifications, inspection and test methods, acceptance criteria, notification requirements for process or material changes, nonconformance handling procedures, corrective action expectations, and the customer's right to audit the supplier's facilities and records.

157. B — The Action Priority method weights severity most heavily. A severity of 9 (potential serious injury) places this failure mode in the high-priority category under the AP framework, mandating action regardless of the occurrence and detection ratings. The AP method ensures that high-severity failure modes always receive appropriate attention, addressing the key limitation of the traditional RPN approach.

158. D — $n = (Z \times \sigma / E)^2 = (1.96 \times 3.0 / 0.5)^2 = (11.76)^2 = 138.3$, rounded up to 139. This formula determines the minimum sample size needed to achieve the desired margin of error ($E = 0.5$ grams) at the specified confidence level (95%, $Z = 1.96$) given the estimated population variability ($\sigma = 3.0$ grams).

159. A — In a two-card kanban system, the production kanban authorizes the upstream process to manufacture a specific quantity, while the withdrawal (conveyance) kanban authorizes the downstream process to withdraw material from the upstream process's output buffer. The two cards work together to synchronize production and material movement based on actual consumption.

160. C — When Ppk (1.05) is significantly lower than Cpk (1.40), the overall (long-term) standard deviation exceeds the within-subgroup (short-term) standard deviation, indicating that between-subgroup variation from process instability — shifts, trends, or special causes — has degraded actual performance below the inherent capability level. Eliminating the special causes would bring Ppk closer to Cpk .

161. D — The failure rate λ is the reciprocal of MTBF: $\lambda = 1/MTBF = 1/120,000 = 8.33 \times 10^{-6}$ failures per mile. This relationship holds for constant-failure-rate systems described by the exponential distribution. The very small failure rate reflects the high reliability typical of major vehicle subsystems like transmissions.

162. B — Identical ratings across 80% of failure modes indicate that the team did not carefully differentiate between items with genuinely different risk profiles. An effective FMEA should produce a range of ratings that reflect real differences in how severe, how likely, and how detectable each failure mode is. Flat, uniform ratings defeat the prioritization purpose of the FMEA.

163. A — A 5°C discrepancy between the controller display and the operator's log warrants investigation of multiple potential causes: controller calibration accuracy, operator reading technique, recording errors, or even different measurement points. While 5°C may be within acceptable tolerance for some processes, it may be significant for others — the investigation should determine the source and whether it affects product quality.

164. C — The House of Quality in QFD traditionally uses a weighted relationship scale where strong relationships receive a weight of 9, moderate relationships receive 3, and weak relationships receive 1, with blank cells indicating no relationship. This nonlinear scale (9-3-1 rather than 3-2-1) ensures that strong relationships dominate the priority calculations, directing engineering effort toward the characteristics that most impact customer satisfaction.

165. D — A backlog of 45 open corrective actions with 30 past due requires management escalation, risk-based prioritization of the overdue items, clear accountability assignments, realistic revised timelines, and follow-up checkpoints to ensure progress. Simply closing, extending, or eliminating actions does not address the underlying accountability and resource allocation problems that created the backlog.

166. B — To find the alias of AB with defining relation $I = ABCD$, multiply: $AB \times ABCD = A^2B^2CD = CD$ (since $A^2 = I$ and $B^2 = I$ in a two-level design). Therefore, the two-factor interaction AB is aliased with the two-factor interaction CD. This is characteristic of Resolution IV designs where two-factor interactions are confounded with other two-factor interactions.

167. A — With a p-value of 0.35, which far exceeds $\alpha = 0.05$, there is insufficient evidence to reject the null hypothesis of normality. The data is consistent with a normal distribution, and the quality engineer may proceed with standard capability indices (C_p , C_{pk}) that assume normality. Note that failing to reject normality does not prove the data is perfectly normal — it means normality is a reasonable assumption.

168. B — Comprehensive risk mitigation for a sole-source supplier in a disaster-prone region requires multiple complementary strategies: qualifying an alternate supplier in a different geographic region (eliminates single-source dependency), maintaining strategic safety stock (provides a time buffer during disruption), and establishing early warning monitoring (enables proactive response). No single strategy alone provides adequate protection.

169. B — A funnel-shaped scatter pattern where the spread of Y increases with X indicates heteroscedasticity — non-constant variance of the response across the predictor range. This condition violates a key assumption of ordinary least squares regression, making standard confidence intervals and hypothesis tests unreliable. Weighted least squares or variance-stabilizing transformations may be needed.

170. C — Standard SPC practice requires at least 20 to 25 subgroups collected during a period when the process is believed to be operating under normal conditions to establish reliable initial control limits. This provides sufficient data for the average and range (or standard deviation) calculations to produce stable, representative estimates of the process center and variability.

171. A — When the overall F-test is not significant ($p = 0.38$) and R^2 is low (0.12), the model as a whole does not explain meaningful variation in the response. The single significant individual predictor ($p = 0.03$) may represent a Type I error — with multiple predictors tested, the probability of finding at least one spurious significant result increases. The overall model's non-significance should take precedence.

172. C — Crosby's Stage 2 (Awakening) describes an organization that is beginning to recognize quality's importance but still relies heavily on inspection and appraisal. The quality department exists but reports to manufacturing rather than having independent authority, quality management consists primarily of sorting and grading, and quality costs are narrowly defined as the cost of running the quality department.

173. B — Confidence intervals for the population variance are constructed using the chi-square distribution. The interval uses the formula: $((n-1)s^2/\chi^2_{(\alpha/2)}, (n-1)s^2/\chi^2_{(1-\alpha/2)})$ with $n-1 = 19$ degrees of freedom. The chi-square distribution is used because the quantity $(n-1)s^2/\sigma^2$ follows a chi-square distribution when the population is normally distributed.

174. D — $OEE = Availability \times Performance\ Efficiency \times Quality\ Rate = 0.85 \times 0.90 \times 0.98 = 0.7497 \approx 75\%$. OEE is calculated as the product (not the average or sum) of the three factors. World-class OEE is generally considered to be 85% or higher. The 75% result indicates significant room for improvement across all three dimensions.

175. A — The ANOVA method for Gage R&R provides a complete decomposition of all variation sources — repeatability, reproducibility, and critically, the operator-by-part interaction effect that the range method cannot detect. Operator-by-part interaction reveals whether certain operators measure certain parts differently, providing diagnostic information that guides targeted improvement of the measurement system.