CERTIFIED RELIABILITY ENGINEER (CRE)
BODY OF KNOWLEDGE (BoK)

The topics in this Body of Knowledge include additional detail in the form of subtext explanations and the cognitive level at which the questions will be written. This information will provide useful guidance for both the Examination Development Committee and the candidates preparing to take the exam. The subtext is not intended to limit the subject matter or be all-inclusive of what might be covered in an exam. It is intended to clarify the type of content to be included in the exam. The descriptor in parentheses at the end of each entry refers to the highest cognitive level at which the topic will be tested. A more comprehensive description of cognitive levels is provided at the end of this document.

I. Reliability Fundamentals (29 questions)

A. Leadership Foundations

1. **Benefits of reliability engineering**
   Describe the value that reliability has on achieving company goals and objectives, and how reliability engineering techniques and methods improve programs, processes, products, systems, and services. (Understand)

2. **Interrelationship of safety, quality, and reliability**
   Describe the relationship of and distinguish between reliability and quality. Describe the importance of safety in reliability engineering and how reliability impacts safety. (Understand)

3. **Reliability engineer leadership responsibilities**
   Describe how to be a reliability champion by influencing program decisions and facilitating cross-functional communication. Understand the fundamentals of reliability strategy, including its mission, vision, objectives, and requirements. (Understand)

4. **Reliability engineer role and responsibilities in the product lifecycle**
   Describe how the reliability engineer influences the product lifecycle, including their role in anticipating the impact of reliability on risk and costs in the design review process and ensuring performance over time. (Understand)

5. **Project management in reliability engineering**
   Apply key practices in requirements management, use Gantt charts, and understand the critical path method (CPM). (Apply)

6. **Function of reliability in engineering**
   Describe how reliability techniques can be used to apply best practices in engineering (e.g., measuring reliability early), how industry standards can impact reliability, and how reliability can inform the decision analysis process. (Analyze)

7. **Ethics in reliability engineering**
   Identify appropriate ethical behaviors for a reliability engineer in various situations. (Evaluate)

8. **Supplier reliability assessments**
   Explain how supplier reliability impacts the overall reliability program. Describe key reliability concepts that should be included in supplier reliability assessments. Continuously assess supplier reliability to ensure they meet established reliability standards. (Analyze)

9. **Performance monitoring**
   Describe the importance of performance monitoring in maintaining compliance with product reliability and safety standards. Identify key points in the product lifecycle where both process and product reliability data are collected and evaluated. Integrate essential reliability elements like defect tracking and reliability growth monitoring (e.g., key performance indicators [KPIs], overall equipment effectiveness [OEE], Duane growth model, and Crow-AMSAA Model) to ensure continuous adherence to these requirements. (Understand)

B. Reliability Foundations

1. **Basic reliability terminology**
   Clarify fundamental reliability terms and the corresponding metrics, including concepts related to system reliability (e.g., durability, failure rate, mean time to failure [MTTF], mean time between failures [MTBF], mean time between critical failure [MTBCF], and the bathtub curve), maintainability (e.g., service interval, mean time to repair [MTTR], mean time between maintenance [MTBM], and mean downtime [MDT]), and availability (e.g., operational availability, achieved availability, and inherent availability). (Apply)

2. **Drivers of reliability requirements and targets**
   Describe how customer expectations, industry standards, safety considerations, liability issues, and regulatory concerns drive reliability requirements. Assess expected use conditions or use cases, align reliability requirements with environmental, social, and governance (ESG) policies, and draw valuable insights from lessons learned. (Understand)

3. **Corrective and preventive action (CAPA)**
   Evaluate specific situations that call for corrective and preventive actions. Explore the implementation of these actions and assess the effectiveness of the measures taken. (Evaluate)

4. **Root cause analysis**
   Assess root cause analysis by using specialized tools, such as fishbone diagrams, 5 whys, and 8D to investigate the causes of degradation and failure. (Evaluate)

5. **Product lifecycle engineering stages**
Examine how different lifecycle stages—concept / design, development / test, introduction, growth, maturity, and decline—affect reliability. Inspect the cost issues related to each of those stages, including aspects like product maintenance (both scheduled and unscheduled), life expectancy, and software defect phase containment. (Understand)

6. **Economics of product maintainability and availability**
Describe the cost tradeoffs associated with product maintainability strategies and availability. (Understand)

7. **Cost of poor reliability**
Describe the financial and non-financial expenses (e.g., availability, credibility, business operations, and reputation) incurred because of poor reliability. (Understand)

8. **Quality triangle**
Describe the relationship between cost, time, and quality with respect to reliability. (Understand)

9. **Six sigma methodologies**
Describe how six sigma principles serve as a supportive framework for enhancing reliability engineering practices. Explain how reliability engineering aligns with the principles of the DMAIC (Define, Measure, Analyze, Improve, Control) process, continuous improvement, and lean methodologies. (Understand)

10. **Systems engineering and integration**
Comprehend the relationship between reliability engineering and systems engineering, with a focus on integrating components and their interactions within a system. (Understand)

II. Risk Management (25 questions)

A. Identification

1. **Risk management techniques**
   Use risk management tools and processes to identify, document, and monitor environmental, liability, and security concerns. Incorporate methodologies such as p-diagrams to discern potential failure modes and use cases to conceptualize different real-world scenarios and interactions. Evaluate and prioritize risks related to safety, economics, performance, and customer satisfaction. Address these risks within an appropriate risk management framework. (Evaluate)

2. **Risk assessment**
   Employ different techniques for assessing and prioritizing risks including qualitative, quantitative, and semi-quantitative methods. Apply risk ranking methods to ascertain the potential impacts, considering likelihood and prioritization factors. Use probabilistic risk assessment (PRA) to categorize risk events and to understand the potential impacts. Perform vulnerability and threat-based assessments to analyze and gauge the susceptibility of the system to various threats. (Analyze)

3. **Types of risk**
   Examine the various types of operational risks (e.g., technical, scheduling, safety, and environmental), strategic risks (e.g., brand, reputation, stakeholder, and regulatory compliance), financial risks, cybersecurity risks, and analytical risks (e.g., informed and inherent) and their relationship to reliability. (Analyze)

B. Analysis

1. **Fault tree analysis (FTA)**
   Use fault tree analysis (FTA) to evaluate the potential failures within a product or process. Employ action priority to categorize and prioritize the necessary corrective actions. (Analyze)

2. **Failure mode and effects analysis (FMEA)**
   Define and distinguish between failure mode and effects analysis (FMEA), failure mode, effects, and criticality analysis (FMECA), functional failure mode and effects analysis (FFMEA), and use failure mode and effects analysis (UFMEA). Evaluate these techniques for use on systems, products, processes, and designs. (Evaluate)

3. **Common mode failure analysis**
   Describe common mode failure (also known as common cause failure) and how it affects risk. (Understand)

4. **Hazard analysis**
   Explain how hazard analysis informs the development process and how the information obtained from it is used by reliability engineers. (Understand)

5. **Risk matrix**
   Explain the application of risk matrices in evaluating risk, focusing on how they aid in assessing the likelihood and the severity of potential adverse events or outcomes. (Understand)

6. **System safety**
   Identify safety-related issues by analyzing multiple sources including customer feedback, design data, field data, and other pertinent information. Prioritize safety concerns, focusing on those that possess the highest risk of occurrence and impact. Determine steps to minimize the improper or unintended use of equipment, products, or processes, aligning with safety system. Employ tradeoff analysis to determine the optimal risk control measures. (Evaluate)

C. Mitigation

Identify appropriate risk mitigation plans by integrating the guidelines and principles outlined in standards such as ISO 31000 and ISO 55000. Assess risk control plans that incorporate effective controls, aiming to minimize both inherent risks and their subsequent impacts, focusing on safety, liability, and regulatory compliance. Distinguish between the reliability goals of As Low As Reasonably Practical (ALARP), As Low As Reasonably Achievable (ALARA), and As Low As Possible (ALAP). (Evaluate)

III. Probability and Statistics for Reliability (35 questions)

A. Basic Concepts

1. **Basic statistics**
Define basic statistical terms such as population, parameter, sample, and statistic. Understand statistical concepts such as sampling and the central limit theorem. Differentiate between parametric and non-parametric (e.g., Kaplan-Meier Analysis) statistical methods. Use appropriate methods to estimate and interpret statistical values. (Analyze)

2. **Basic probability concepts**
Apply basic probability concepts such as independence, mutually exclusive events, and conditional probability. Calculate probabilities using tools and techniques (e.g., probability trees and expected frequency trees) and interpret their meaning. (Analyze)

3. **Probability distributions**
Analyze reliability data using appropriate statistical distributions such as binomial, Poisson, exponential, Weibull, normal, log-normal, chi-square, and Student's t distribution. Interpret the associated probability plots for each continuous distribution. Assess goodness of fit to a distribution. (Analyze)

4. **Probability functions**
Assess various probability functions (e.g., cumulative distribution functions [CDFs], probability density functions [PDFs], and hazard functions) and recognize their application in various situations. (Evaluate)

5. **Sampling plans for statistics and reliability testing**
Use various theories, tables, and formulas to determine appropriate sample sizes or testing time needed for statistical and reliability testing. Incorporate representative and randomized sampling techniques. (Apply)

6. **Statistical process control (SPC) and capability studies (C_p, C_{pk}, P, and P_{pk}).**
Apply statistical process control (SPC), capability studies, and their associated indices (e.g., C_p, C_{pk}, P, and P_{pk}) and describe how they relate to reliability. Considering differing sample sizes, select control charts to represent variability over time. (Apply)

7. **Confidence and tolerance intervals**
Compute confidence intervals and tolerance intervals to analyze reliability with chosen confidence. Assess the use of confidence and tolerance intervals for reliability analysis using Weibull, normal, and lognormal distributions. Describe how point estimates are used to determine the interval. (Evaluate)

B. Data Management

1. **Sources and uses of reliability data**
   Analyze the sources of reliability data (e.g., prototype, development, test, field, warranty, published data, big data, and the internet of things [IoT]). Recognize the unique advantages and limitations of each for measuring and enhancing product reliability. Consider the importance of normalizing datasets and transformations. (Analyze)

2. **Types of data**
   Evaluate and distinguish among diverse data types, including attributes versus variables and discrete versus continuous. Determine whether the data is censored or complete and whether it is univariate or multivariate. Describe the implications of deploying parametric and nonparametric statistical methods, identifying the underlying assumptions and applicable conditions of each. Recognize the different scales of measurement, including nominal, ordinal, interval, and ratio. Align analysis tools—such as Nevada chart analysis, survival analysis, and the cox proportional hazard model—with the inherent characteristics and requirements of the respective data types. (Evaluate)

3. **Data collection methods**
   Identify and select appropriate data collection methods (e.g., surveys, automated tests, automated monitoring, and reporting tools) to meet various data analysis objectives and data quality needs. (Evaluate)

4. **Data summary and reporting**
   Analyze the collected data and assess its accuracy, precision, usefulness, and integrity. Employ analytical techniques, such as bad actor analysis. Use artificial intelligence (AI) to delve deeper into the analysis. Select appropriate graphical representations, such as Pareto charts, scatter plots, and box and whisker plots. Summarize, interpret, and present the analyzed data, choosing methods aligned with the varying data types, originating sources, and the specified output requirements. (Create)

5. **Failure analysis methods**
   Diagnose failures by using a diverse array of failure analysis tools and techniques. Implement physics of failure-based analyses, including methods such as scanning electron microscopy (SEM), scanning acoustic microscopy (SAM), infrared inspection, and radiography analysis. Conduct mechanical and materials analysis, applying specific material testing and measurement techniques like tensile testing, shear testing, viscosity measurement, and vibration testing. Incorporate physical analysis methods including visual, ultrasonic, and electrical analysis. Engage in verification like cycle testing and non-destructive testing (NDT) and employ advanced predictive technologies to anticipate and mitigate potential failures. (Understand)

6. **Failure reporting, analysis, and corrective action system (FRACAS)**
   Identify elements necessary for FRACAS and demonstrate the importance of a closed-loop process. (Evaluate)

IV. Reliability Planning, Testing, and Modeling (35 questions)

A. Planning

1. **Reliability test strategies**
   Evaluate and develop suitable test strategies, such as truncation, test-to-failure, degradation, growth plan, and Test, Analyze, and Fix (TAAF), for various phases of product development. Consider customer profiles, including those reflecting normal and heavy usage. Implement a ‘zero failure’ test to assess reliability. (Evaluate)

2. **Environmental factors and use conditions**
   Analyze various environmental factors and use conditions such as temperature, humidity, and vibration, along with stresses like severity of service, electrostatic discharge (ESD), throughput, and duty cycle, to which a product may be exposed. Incorporate the application of multiple stress factors (e.g., highly accelerated life testing [HALT]) to assess their simultaneous impact on a product. (Analyze)

3. **Failure consequence**
   Describe the importance of recognizing the consequences linked to different failure modes, including the severity and occurrence of such failure modes, when establishing reliability acceptance criteria. (Understand)

4. **Failure criteria**
   Establish failure criteria by considering customer requirements, user needs, system functions, system requirements, and warranty terms and conditions. (Understand)

5. **Test environment**
   Evaluate the test environment by considering the system location and operational conditions and incorporate these into the test plan to ensure the implementation of an appropriate test strategy. Validate test capability and conduct the tests following the verified methods. Evaluate and formulate decisions based on the test results, providing rationale and support for each decision made. (Evaluate)

B. Testing

Describe the purpose, advantages, and limitations of various hardware and software / firmware tests, emphasizing the different approaches and methodologies required for each. Use common models to develop test plans, evaluate risks, and interpret test results, ensuring comprehensive reliability and functionality assessment.

1. **Accelerated life tests** (e.g., single-stress, multiple-stress, sequential stress, step-stress, HALT, and margin tests) (Evaluate)
2. **Stress screening** (e.g., ESS, HASS, and burn-in tests) (Evaluate)
3. **Qualification / demonstration testing** (e.g., sequential tests and fixed-length tests) (Evaluate)
4. **Degradation (wear-to-failure) testing** (Evaluate)
5. **Software / firmware reliability** (e.g., software design reliability, software reliability prediction, software design and development models, and software reliability allocation) (Understand)

6. **Software testing** (e.g., white-box, black-box, operational profile, fault-injection, software validation and quality assurance, software verification, qualitative versus quantitative reliability testing, built-in testing [BIT], and regression testing to verify code integrity) (Understand)

C. Modeling

1. **Reliability block diagrams and models**
   Generate and analyze various types of block diagrams and models, including series, parallel, partial redundancy, time dependent, K out of N, and shared load. (Evaluate)

2. **Physics of failure and failure mechanisms**
   Identify various potential failure mechanisms including fracture, corrosion, memory corruption, excessive deformation, creep, and delamination, and their underlying physical processes. (Apply)

3. **Failure models**
   Select appropriate theoretical models to assess or predict failure rates, such as Arrhenius, S-N curve, and Coffin-Manson model for temperature cyclic stress. (Analyze)

4. **Reliability prediction methods**
   Explain various reliability prediction methods—including Monte Carlo Simulation, part stress analysis, parts count prediction, Markov analysis, neural networks, and machine learning—to assess both repairable and non-repairable components and systems and describe the inputs into the model. (Understand)

5. **Design prototyping**
   Describe the advantages and limitations of prototyping and rapid prototyping technologies to enhance product reliability. Employ phase diagrams to model various equipment scenarios across different mission profiles. Determine the correlation of prototype results to simulated results (e.g., digital twins and damage modeling). (Understand)

V. Lifecycle Reliability (26 questions)

A. Reliability Design Techniques

1. **Design evaluation techniques (validation and verification)**
   Explain how validation, verification, and other review techniques are used to assess the reliability of a product's design at various lifecycle stages. (Apply)

2. **Stress-strength analysis**
   Apply the stress-strength analysis method of calculating probability of failure and interpret the results. (Analyze)

3. **Design of experiments (DOE)**
   Develop and interpret the results of a standard design of experiments (DOE), including both full-factorial and fractional factorial designs, integrating methodologies such as analysis of variance (ANOVA) and blocking for hard to control factors (e.g., planned grouping). Use replication and randomization to optimize the robustness and validity of the experimental findings. (Analyze)

4. **Reliability optimization**
   Employ a diverse range of strategies to enhance reliability, considering user needs while balancing constraints such as cost, schedule, and weight along with other design requirements. (Apply)

5. **Human factors**
   Describe the relationship between human factors and reliability engineering, considering user safety, understanding user and usage profiles, and analyzing associated failure modes and mechanisms. (Understand)

6. **Design for X (DFX)**
   Apply DFX techniques such as design for manufacturability, testability, and maintainability. (Apply)

7. **Design for Reliability (DfR)**
   Apply DfR to meet reliability requirements throughout the product or system lifecycle. Integrate tools such as finite element analysis (FEA) to assess and optimize design robustness and to forecast potential areas of failure or stress within the system or product. Make design decisions emphasizing the achievement of built-in reliability and fault tolerance / avoidance as fundamental goals. (Analyze)

B. Parts and Systems Development

1. **Materials, components, equipment, and software selection techniques**
   Apply techniques (e.g., derating and commercial off-the-shelf [COTS], safe operating area [SOA] criteria) for selecting materials and components to meet reliability goals and requirements. Select software for product and evaluation equipment functionality (e.g., vibration stand and thermal chambers). (Analyze)

2. **Parts standardization and system simplification**
   Describe the importance of standardization, simplification, and parts re-use to meet reliability goals and requirements. Incorporate reliability-centered maintenance (RCM) to maintain the inherent reliability of system components while ensuring optimal performance and longevity. (Apply)

C. Maintainability

1. **Maintenance strategies**
   Develop a maintenance plan incorporating various strategies (e.g., predictive maintenance, repair or replace decision-making, spare parts analysis / forecasting, and equipment warranties). (Apply)

2. **Preventive maintenance (PM) analysis**
   Define and use PM tasks, optimum PM intervals, and other elements of this analysis. Identify situations when PM is not effective. (Apply)

3. **Corrective maintenance analysis**
   Describe and apply the elements of corrective maintenance analysis (e.g., fault-isolation time, repair / replace time, skill level, and crew hours). (Apply)

Levels of Cognition
Based on Bloom's Taxonomy – Revised (2001)

In addition to **content** specifics, the subtext for each topic in this BOK also indicates the intended **complexity level** of the test questions for that topic. These levels are based on "Levels of Cognition" (from Bloom's Taxonomy – Revised, 2001) and are presented below in rank order, from least complex to most complex.

Remember
Recall or recognize terms, definitions, facts, ideas, materials, patterns, sequences, methods, principles, etc.

Understand
Read and understand descriptions, communications, reports, tables, diagrams, directions, regulations, etc.

Apply
Know when and how to use ideas, procedures, methods, formulas, principles, theories, etc.

Analyze
Break down information into its constituent parts and recognize their relationship to one another and how they are organized; identify sublevel factors or salient data from a complex scenario.

Evaluate
Make judgments about the value of proposed ideas, solutions, etc., by comparing the proposal to specific criteria or standards.

Create
Put parts or elements together in such a way as to reveal a pattern or structure not clearly there before; identify which data or information from a complex set is appropriate to examine further or from which supported conclusions can be drawn.