SIX SIGMA BLACK BELT PROGRAMME

CONTENTS

1. BLACK BELT PROGRAMME OBJECTIVE

The black belt (BB) is a full-time six sigma programme member who has responsibility for selecting & prioritising projects, leading projects, deploying project learnings and training and mentoring green belts. He is trained in advanced project management and statistical analysis tools. He is expected to contribute between €250K and €1M to the company's operating profit each year by undertaking process improvement projects that lead to enhanced customer satisfaction.

BB candidates are selected for training on the basis of their ability to lead cross functional teams to be successful problem solvers, and their potential to progress to higher levels within the organisation. In general they are dynamic "can do" personnel. The BB role is often a temporary one of 2-4 years duration.

On completion of the BB certification programme participants will be able to lead a cross functional project team using a range of lean and six sigma project management, problem solving, change management and statistical analysis tools.

2. READING LIST

Pyzdek & Keller, (2010, third edition) *The Six Sigma Handbook*, McGraw Hill, New York, USA.

Breyfogle III, FW (2003 - 2nd Edition), *Implementing Six Sigma,* Wiley New Jersey, USA

Liker, J. (2004) *The Toyota Way*, McGraw Hill, New York, USA.

Snee, R.D. & Hoerl, R.W. (2003) *Leading Six Sigma,* Prentice Hall, New Jersey

Naumann, E. & Hoisington, S. (2001), *Customer Centric Six Sigma,* American Society for Quality, Milwaukee, USA

Seddons, J (2003), *Freedom From Command & Control, a Better Way to Make the Work Work*, Vanguard, Buckingham

Mascitelli, R. (2002), *Building a Project-Driven Enterprise*, Technology Perspectives, Northridge, CA

Welch, J. (2005) *Winning,* Harper Collins, New York

Brook, Q S (2006 – 2nd Edition) *Lean Six Sigma and Minitab,* (if using Minitab)

3. SOFTWARE AND HARDWARE REQUIREMENTS

- Laptop computer for each candidate (5 to be supplied by Lean Ireland)
- Minitab, JMP or an appropriate software application (laptops with Minitab can be supplied by Lean Ireland during workshops)

4. PROJECT SELECTION CRITERIA

4.1 Selection and Approval Criteria

BB projects are selected according to the following criteria:

- designed to enhance customer satisfaction and grow the business
- in line with corporate and site objectives
- preferably derived from annual VSM or process mapping project prioritisation exercises
- capable of realising €100,000 or greater operating profit increase for the organisation
- cross functional in composition, and
- must address a current process or system failure.

To ensure consistent standards in project selection it is recommended that the organisation develops a standard business case template that takes the above factors and others as appropriates into account. Each BB project should be evaluated and approved by the site lean six sigma leader, the steering committee and the project champion in advance of BB training.

The finance department is responsible for appointing a cost accountant (or accountants) to approve the project projected savings, in advance of the work commencing on the project. The cost accountant is responsible for signing off on all recorded cost savings, and/or additional revenues, when the project work is complete.

In training, it is preferable that each BB selects a different type of project. This will ensure greater benefit to the group, and the organisation.

If the project is sufficiently large in scope, more than one BB can work on it and still achieve certification.

4.2 Cross Department Deployment

Following project implementation, BBs have responsibility for overseeing/mentoring the cross deployment of the process improvement in the organisation e.g. in a household retailer, an improvement in the Google rankings, website hits and sales of the FMCG division should be deployed as appropriate of the white goods division.

5. THE PROJECT SPONSOR

Each BB candidate must have the support and understanding of a sponsor prior to programme commencement. The sponsor is responsible for:

- approving the project objective, budget and timeline
- conducting formal stage gate reviews to ensure the project remains on track and is true to the lean and six sigma DMAIC approach
- removing barriers to progress as they arise
- formally confirming the project gains on completion of the project
- recommending the BB for certification.

Prior to programme commencement each project champion will undergo a two hour induction on supporting black belts, setting performance goals & monitoring progress.

6. PROJECT MENTORING AND STAGE GATE REVIEWS

6.1 The Role of the Mentor

Each BB is assigned a mentor at the commencement of the BB training programme. The role of the mentor is to:

- guide and encourage the BB through the project lifecycle;
- provide supplementary training where necessary;
- ensure project timelines are managed;
- support the project champion in the stage gate review process, and to
- assist the BB in preparing for the BB exam and the BB certification review.

6.2 Stage Gate Reviews

Formal stage gate reviews are held at each of the DMAIC stages of BB project execution. The purpose of the review is to ensure that the BB project team has fulfilled all of the criteria associated with each project phase, prior to moving to the next phase. Present at the stage gate review are: the champion, the BB, the team and the BB mentor. The stage gate review also provides the BB and the project team the opportunity to share concerns with those in a position to provide help and guidance.

7. PROGRAMME STRUCTURE AND CONTENT

7.1 Summary BB Programme Structure

- Formal workshops: 20 days, in blocks of 3 or 4 days over six months. Total workshop contact hours = 160 hours (assumes no preparatory green belt training).
- Project work: One project will typically take between 6 to 10 months elapsed time to complete. Typically, full time BBs will work on 2 to 3 projects at a time as well as mentoring GBs.
- Examination: BBs will complete an internationally recognised six sigma examination prior to certification. The most popular agencies are the American Society for Quality (www.asq.org) and the International Quality Federation (www.iqfnet.org).
- Certification: a six sigma black belt certification is awarded to the candidate following attendance at the workshops; successful completion of the required number of projects, and successful completion of the six sigma examination.

7.2 Six Sigma Examinations

American Society for Quality (ASQ):

- The paper-based ASQ exam can be taken two times per year in Ireland. Currently there is an exam centre in Shannon.
- The computer based online examination is administered by Prometric at the Irish Financial Services Centre in Dublin. The online examination may be sat multiple times per year.

See http://asq.org/cert/six-sigma-black-belt/bok

8. SAMPLE CERTIFICATION GUIDELINES*

(to be agreed by Client and Lean Ireland)

ITEM	GUIDELINE CERTIFICATION STANDARD
Workshops attended	**20**
Projects completed	**1 or 2**
Addition to operating profit	**€100K or greater,** **per project led**
Green belt projects mentored	**2**
Six sigma examination	**1 (ASQ or IQF)**
Other	**to be specified by client e.g. modules taught**

*ISO 13053 standards are observed, with some variation introduced by individual clients

9. CRITICAL SUCCESS FACTORS

- Expectation setting amongst management in the organisation, in particular in relation to the time, effort and support required
- Sponsor preparation & engagement
- Organisation investment/key career move
- Candidate selection/full time position
- Project selection
- Training standards/formal certification
- Project success/publicity and cross deployment
- Reward & recognition/retention strategy

10. REFERENCES

ISO13053-1 Quantitative methods in process improvement -- Six Sigma -- Part 1: DMAIC methodology (http://www.iso.org/iso/catalogue_detail?csnumber=52901)

American Society for Quality (ASQ) Black Belt Body of Knowledge (http://asq.org/cert/six-sigma-black-belt/bok)

APPENDIX:

AMERICAN SOCIETY FOR QUALITY
CERTIFIED SIX SIGMA BLACK BELT (CSSBB)
BODY OF KNOWLEDGE

See http://asq.org/cert/six-sigma-black-belt/bok

The topics in this Body of Knowledge include additional detail in the form of subtext explanations and the cognitive level at which test questions will be written. This information will provide guidance for the candidate 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 meant 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 maximum cognitive level at which the topic will be tested. A complete description of cognitive levels is provided at the end of this document.

I. ORGANIZATION-WIDE PLANNING AND DEPLOYMENT (QUESTIONS 12)

A. Organization-wide considerations

1. Fundamentals of six sigma and lean methodologies

Define and describe the value, foundations, philosophy, history, and goals of these approaches, and describe the integration and complementary relationship between them. (Understand)

2. Six sigma, lean, and continuous improvement methodologies

Describe when to use six sigma instead of other problem-solving approaches, and describe the importance of aligning six sigma objectives with organizational goals. Describe screening criteria and how such criteria can be used for the selection of six sigma projects, lean initiatives, and other continuous improvement methods. (Apply)

3. Relationships among business systems and processes

Describe the interactive relationships among business systems, processes, and internal and external stakeholders , and the impact those relationships have on business systems. (Understand)

4. Strategic planning and deployment for initiatives

Define the importance of strategic planning for six sigma projects and lean initiatives. Demonstrate how hoshin kanri (X-matrix), portfolio analysis, and other tools can be used in support of strategic deployment of these projects. Use feasibility studies, SWOT analysis (strengths, weaknesses, opportunities, and threats), PEST analysis (political, economic, social, and technological) and contingency planning and business continuity planning to enhance strategic planning and deployment. (Apply)

B. Leadership

1. Roles and responsibilities

Describe the roles and responsibilities of executive leadership, champions, sponsors, process owners, master black belts, black belts, and green belts in driving six sigma and lean initiatives. Describe how each group influences project deployment in terms of providing or managing resources, enabling changes in organizational structure, and supporting communications about the purpose and deployment of the initiatives. (Understand)

2. Organizational roadblocks and change management

II. ORGANIZATIONAL PROCESS MANAGEMENT AND MEASURES (10 QUESTIONS)

Describe how an organization's structure and culture can impact six sigma projects. Identify common causes of six sigma failures, including lack of management support and lack of resources. Apply change management techniques, including stakeholder analysis, readiness assessments, and communication plans to overcome barriers and drive organization-wide change. (Apply)

A. Impact on stakeholders

Describe the impact six sigma projects can have on customers, suppliers, and other stakeholders. (Understand)

B. Benchmarking

Define and distinguish between various types of benchmarking, e.g., best practices, competitive, collaborative, breakthrough. Select measures and performance goals for projects resulting from benchmarking activities. (Apply)

C. Business measures

1. Performance measures

Define and describe balanced scorecard, key performance indicators (KPIs), customer loyalty metrics, and leading and lagging indicators. Explain how to create a line of sight from performance measures to organizational strategies. (Analyze)

2. Financial measures

Define and use revenue growth, market share, margin, net present value (NPV), return on investment (ROI), and cost-benefit analysis (CBA). Explain the difference between hard cost measures (from profit and loss statements) and soft cost benefits of cost avoidance and reduction. (Apply)

III. TEAM MANAGEMENT (18 QUESTIONS)

A. Team formation

1. Team types and constraints

Define and describe various teams, including virtual, cross-functional, and self-directed. Determine what team type will work best for a given a set of constraints, e.g., geography, technology availability, staff schedules, time zones. (Apply)

2. Team roles and responsibilities

Define and describe various team roles and responsibilities for leader, facilitator, coach, and individual member. (Understand)

3. Team member selection criteria

Describe various factors that influence the selection of team members, including the ability to influence, openness to change, required skills sets, subject matter expertise, and availability. (Apply)

4. Team success factors

Identify and describe the elements necessary for successful teams, e.g., management support, clear goals, ground rules, timelines. (Apply)

B. Team facilitation

1. Motivational techniques

Describe and apply techniques to motivate team members. Identify factors that can demotivate team members and describe techniques to overcome them. (Apply)

2. Team stages of development

Identify and describe the classic stages of team development: forming, storming, norming, performing, and adjourning. (Apply)

3. Team communication

Describe and explain the elements of an effective communication plan, e.g., audience identification, message type, medium, frequency. (Apply)

4. Team leadership models

Describe and select appropriate leadership approaches (e.g., direct, coach, support, delegate) to ensure team success. (Apply)

C. Team dynamics

1. Group behaviors

Identify and use various conflict resolution techniques (e.g., coaching, mentoring, intervention) to overcome negative group dynamics, including dominant and reluctant participants, groupthink, rushing to finish, and digressions. (Evaluate)

2. Meeting management

Select and use various meeting management techniques, including using agendas, starting on time, requiring pre-work by attendees, and ensuring that the right people and resources are available. (Apply)

3. Team decision-making methods

Define, select, and use various tools (e.g., consensus, nominal group technique, multi-voting) for decision-making. (Apply)

D. Team training

1. Needs assessment

Identify the steps involved to implement an effective training curriculum: identify skills gaps, develop learning objectives, prepare a training plan, and develop training materials. (Understand)

2. Delivery

Describe various techniques used to deliver effective training, including adult learning theory, soft skills, and modes of learning. (Understand)

3. Evaluation

Describe various techniques to evaluate training, including evaluation planning, feedback surveys, pre-training and post-training testing. (Understand)

IV. DEFINE (20 QUESTIONS)

A. Voice of the customer

1. Customer identification

Identify and segment customers and show how a project will impact both internal and external customers. (Apply)

2. Customer data collection

Identify and select appropriate data collection methods (e.g., surveys, focus groups, interviews, observations) to gather voice of the customer data. Ensure the data collection methods used are reviewed for validity and reliability. (Analyze)

3. Customer requirements

Define, select, and apply appropriate tools to determine customer needs and requirements, including critical-to-X (CTX when 'X' can be quality, cost, safety, etc.), CTQ tree, quality function deployment (QFD), supplier, input, process, output, customer (SIPOC) and Kano model. (Analyze)

B. Business case and project charter

1. Business case

Describe business case justification used to support projects. (Understand)

2. Problem statement

Develop a project problem statement and evaluate it in relation to baseline performance and improvement goals. (Evaluate)

3. Project scope

Develop and review project boundaries to ensure that the project has value to the customer. (Analyze)

4. Goals and objectives

Identify SMART (specific, measureable, actionable, relevant and time bound) goals and objectives on the basis of the project's problem statement and scope. (Analyze)

5. Project performance measurements

Identify and evaluate performance measurements (e.g., cost, revenue, delivery, schedule, customer satisfaction) that connect critical elements of the process to key outputs. (Analyze)

6. Project charter review

Explain the importance of having periodic project charter reviews with stakeholders. (Understand)

C. Project management (PM) tools

Identify and use the following PM tools to track projects and document their progress. (Evaluate)

1. Gantt charts

2. Toll-gate reviews

3. Work breakdown structure (WBS)

4. RACI model (responsible, accountable, consulted and informed)

D. <u>Analytical tools</u>

Identify and use the following analytical tools throughout the DMAIC cycle. (Apply)

1. Affinity diagrams

2. Tree diagrams

3. Matrix diagrams

4. Prioritization matrices

5. Activity network diagrams

V. MEASURE (25 QUESTIONS)

A. Process characteristics

1. Process flow metrics

Identify and use process flow metrics (e.g., work in progress (WIP), work in queue (WIQ), touch time, takt time, cycle time, throughput) to determine constraints. Describe the impact that "hidden factories" can have on process flow metrics. (Analyze)

2. Process analysis tools

Select, use and evaluate various tools, e.g., value stream maps, process maps, work instructions, flowcharts, spaghetti diagrams, circle diagrams, gemba walk. (Evaluate)

B. Data collection

1. Types of data

Define, classify, and distinguish between qualitative and quantitative data, and continuous and discrete data. (Evaluate)

2. Measurement scales

Define and use nominal, ordinal, interval, and ratio measurement scales. (Apply)

3. Sampling

Define and describe sampling concepts, including representative selection, homogeneity, bias, accuracy, and precision. Determine the appropriate sampling method (e.g., random, stratified, systematic, subgroup, block) to obtain valid representation in various situations. (Evaluate)

4. Data collection plans and methods

Develop and implement data collection plans that include data capture and processing tools, e.g., check sheets, data coding, data cleaning (imputation techniques). Avoid data collection pitfalls by defining the metrics to be used or collected, ensuring that collectors are trained in the tools and understand how the data will be used, and checking for seasonality effects. (Analyze)

C. Measurement systems

1. Measurement system analysis (MSA)

Use gauge repeatability and reproducibility (R&R) studies and other MSA tools (e.g., bias, correlation, linearity, precision to tolerance, percent agreement) to analyze measurement system capability. (Evaluate)

2. Measurement systems across the organization

Identify how measurement systems can be applied to marketing, sales, engineering, research and development (R&D), supply chain management, and customer satisfaction data. (Understand)

3. Metrology

Define and describe elements of metrology, including calibration systems, traceability to reference standards, and the control and integrity of measurement devices and standards. (Understand)

D. Basic statistics

1. Basic statistical terms

Define and distinguish between population parameters and sample statistics, e.g., proportion, mean, standard deviation. (Apply)

2. Central limit theorem

Explain the central limit theorem and its significance in the application of inferential statistics for confidence intervals, hypothesis tests, and control charts. (Understand)

3. Descriptive statistics

Calculate and interpret measures of dispersion and central tendency. (Evaluate)

4. Graphical methods

Construct and interpret diagrams and charts, e.g., box-and-whisker plots, scatter diagrams, histograms, normal probability plots, frequency distributions, cumulative frequency distributions. (Evaluate)

5. Valid statistical conclusions

Distinguish between descriptive and inferential statistical studies. Evaluate how the results of statistical studies are used to draw valid conclusions. (Evaluate)

E. Probability

1. Basic concepts

Describe and apply probability concepts, e.g., independence, mutually exclusive events, addition and multiplication rules, conditional probability, complementary probability, joint occurrence of events. (Apply)

2. Distributions

Describe, interpret, and use various distributions, e.g., normal, Poisson, binomial, chi square, Student's t, F, hypergeometric, bivariate, exponential, lognormal, Weibull. (Evaluate)

F. Process capability

1. Process capability indices

Define, select, and calculate Cp and Cpk. (Evaluate)

2. Process performance indices

Define, select, and calculate Pp, Ppk, Cpm, and process sigma. (Evaluate)

3. General process capability studies

Describe and apply elements of designing and conducting process capability studies relative to characteristics, specifications, sampling plans, stability and normality. (Evaluate)

4. Process capability for attributes data

Calculate the process capability and process sigma level for attributes data. (Apply)

5. Process capability for non-normal data

Identify non-normal data and determine when it is appropriate to use Box-Cox or other transformation techniques. (Apply)

6. Process performance vs. specification

Distinguish between natural process limits and specification limits. Calculate process performance metrics, e.g., percent defective, parts per million (PPM), defects per million opportunities (DPMO), defects per unit (DPU), throughput yield, rolled throughput yield (RTY). (Evaluate)

7. Short-term and long-term capability

Describe and use appropriate assumptions and conventions when only short-term data or only long-term data are available. Interpret the relationship between short-term and long-term capability. (Evaluate)

VI. ANALYZE (22 QUESTIONS)

A. Measuring and modeling relationships between variables

1. Correlation coefficient

Calculate and interpret the correlation coefficient and its confidence interval, and describe the difference between correlation and causation. (Evaluate)

2. Linear regression

Calculate and interpret regression analysis, and apply and interpret hypothesis tests for regression statistics. Use the regression model for estimation and prediction, analyze the uncertainty in the estimate, and perform a residuals analysis to validate the model. (Evaluate)

3. Multivariate tools

Use and interpret multivariate tools (e.g., factor analysis, discriminant analysis, multiple analysis of variance (MANOVA)) to investigate sources of variation. (Evaluate)

B. Hypothesis testing

1. Terminology

Define and interpret the significance level, power, type I, and type II errors of statistical tests. (Evaluate)

2. Statistical vs. practical significance

Define, compare, and interpret statistical and practical significance. (Evaluate)

3. Sample size

Calculate sample size for common hypothesis tests: equality of means and equality of proportions. (Apply)

4. Point and interval estimates

Define and distinguish between confidence and prediction intervals. Define and interpret the efficiency and bias of estimators. Calculate tolerance and confidence intervals. (Evaluate)

5. Tests for means, variances, and proportions

Use and interpret the results of hypothesis tests for means, variances, and proportions. (Evaluate)

6. Analysis of variance (ANOVA)

Select, calculate, and interpret the results of ANOVAs. (Evaluate)

7. Goodness-of-fit (chi square) tests

Define, select, and interpret the results of these tests. (Evaluate)

8. Contingency tables

Select, develop, and use contingency tables to determine statistical significance. (Evaluate)

9. Non-parametric tests

Understand the importance of the Kruskal-Wallis and Mann-Whitney tests and when they should be used. (Understand)

C. Failure mode and effects analysis (FMEA)

Describe the purpose and elements of FMEA, including risk priority number (RPN), and evaluate FMEA results for processes, products, and services. Distinguish between design FMEA (DFMEA) and process FMEA (PFMEA), and interpret their results. (Evaluate)

D. Additional analysis methods

1. Gap analysis

Analyze scenarios to identify performance gaps, and compare current and future states using predefined metrics. (Analyze)

2. Root cause analysis

Define and describe the purpose of root cause analysis, recognize the issues involved in identifying a root cause, and use various tools (e.g., 5 whys, Pareto charts, fault tree analysis, cause and effect diagrams) to resolve chronic problems. (Analyze)

3. Waste analysis

Identify and interpret the seven classic wastes (overproduction, inventory, defects, over-processing, waiting, motion, transportation) and resource under-utilization. (Analyze)

VII. IMPROVE (21 QUESTIONS)

A. Design of experiments (DOE)

1. Terminology

Define basic DOE terms, e.g., independent and dependent variables, factors and levels, response, treatment, error, nested. (Understand)

2. Design principles

Define and apply DOE principles, e.g., power, sample size, balance, repetition, replication, order, efficiency, randomization, blocking, interaction, confounding, resolution. (Apply)

3. Planning experiments

Plan and evaluate DOEs by determining the objective, selecting appropriate factors, responses, and measurement methods, and choosing the appropriate design. (Evaluate)

4. One-factor experiments

Design and conduct completely randomized, randomized block, and Latin square designs, and evaluate their results. (Evaluate)

5. Two-level fractional factorial experiments

Design, analyze, and interpret these types of experiments, and describe how confounding can affect their use. (Evaluate)

6. Full factorial experiments

Design, conduct, and analyze these types of experiments. (Evaluate)

B. Lean methods

1. Waste elimination

Select and apply tools and techniques for eliminating or preventing waste, e.g., pull systems, kanban, 5S, standard work, poka-yoke. (Analyze)

2. Cycle-time reduction

Use various tools and techniques for reducing cycle time, e.g., continuous flow, single-minute exchange of die (SMED), heijunka (production leveling). (Analyze)

3. Kaizen

Define and distinguish between kaizen and kaizen blitz and describe when to use each method. (Apply)

4. Other improvement tools and techniques

Identify and describe how other process improvement methodologies are used, e.g., theory of constraints (TOC), overall equipment effectiveness (OEE). (Understand)

C. Implementation

Develop plans for implementing proposed improvements, including conducting pilot tests or simulations, and evaluate results to select the optimum solution. (Evaluate)

VIII. CONTROL (15 QUESTIONS)

A. Statistical process control (SPC)

1. Objectives

Explain the objectives of SPC, including monitoring and controlling process performance, tracking trends, runs, and reducing variation within a process. (Understand)

2. Selection of variables

Identify and select critical process characteristics for control chart monitoring. (Apply)

3. Rational subgrouping

Define and apply the principle of rational subgrouping. (Apply)

4. Control chart selection

Select and use control charts in various situations: ,, individual and moving range (ImR), p, np, c, u, short-run SPC, and moving average. (Apply) $RX-sX-$

5. Control chart analysis

Interpret control charts and distinguish between common and special causes using rules for determining statistical control. (Analyze)

B. Other controls

1. Total productive maintenance (TPM)

Define the elements of TPM and describe how it can be used to consistently control the improved process. (Understand)

2. Visual controls

Define the elements of visual controls (e.g., pictures of correct procedures, color-coded components, indicator lights), and describe how they can help control the improved process. (Understand)

C. Maintain controls

1. Measurement system reanalysis

Review and evaluate measurement system capability as process capability improves, and ensure that measurement capability is sufficient for its intended use. (Evaluate)

2. Control plan

Develop a control plan to maintain the improved process performance, enable continuous improvement, and transfer responsibility from the project team to the process owner. (Apply)

D. Sustain improvements

1. Lessons learned

Document the lessons learned from all phases of a project and identify how improvements can be replicated and applied to other processes in the organization. (Apply)

2. Documentation

Develop or modify documents including standard operating procedures (SOPs), work instructions, and control plans to ensure that the improvements are sustained over time. (Apply)

3. Training for process owners and staff

Develop and implement training plans to ensure consistent execution of revised process methods and standards to maintain process improvements. (Apply)

4. Ongoing evaluation

Identify and apply tools (e.g., control charts, control plans) for ongoing evaluation of the improved process, including monitoring leading indicators, lagging indicators, and additional opportunities for improvement. (Apply)

IX. DESIGN FOR SIX SIGMA (DFSS) FRAMEWORK AND METHODOLOGIES (7 QUESTIONS)

A. Common DFSS methodologies

Identify and describe DMADV (define, measure, analyze, design, and validate) and DMADOV (define, measure, analyze, design, optimize, and validate). (Understand)

B. Design for X (DFX)

Describe design constraints, including design for cost, design for manufacturability (producibility), design for test, and design for maintainability. (Understand)

C. Robust designs

Describe the elements of robust product design, tolerance design, and statistical tolerancing. (Understand)

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.