MASTER OF TECHNOLOGY (M.TECH)
IN
QUALITY, RELIABILITY AND OPERATIONS RESEARCH

COURSE STRUCTURE

The Master of Technology in Quality, Reliability and Operations Research is conducted in four semesters, two semesters each in the first and second years. The courses for study and examinations in each semester are as follows.

SUBJECTS (COURSES) FOR INSTRUCTION AND GRADES

SEMESTER I (500 Marks)

[Duration: 16 weeks (14 weeks of class): July to December]

Engineering Stream	Statistics Stream
Probability	Electrical & Electronics Engineering
Statistical Methods – I	Engineering Drawing & Workshop – I
Operations Research – I	Operations Research – I
Programming Techniques & Data Structure	Programming Techniques & Data Structure
Quality Management & Systems	Quality Management & Systems

SEMESTER II (500 Marks)

[Duration: 16 weeks (14 weeks of class): January to May]*

Engineering Stream	Statistics Stream
Elements of Stochastic Processes	Mechanical Engineering
Statistical Methods – II	Workshop – II
SQC	SQC
Reliability – I	Reliability – I
Industrial Engineering & Management	Industrial Engineering & Management

* A ten-week Summer Internship starts immediately after Semester II examination. The summer internship will carry 100 marks which will be carried forward in Semester IV.

SEMESTER III (500 Marks)

(Engineering + Statistics Stream)

[Duration: 16 weeks (14 weeks of class): July to December]

Subjects	Subjects (Elective)**
Operations Research - II	Advanced SQC
Industrial Experimentation	Advanced Multivariate Analysis
Reliability - II	Applied Stochastic Processes and Time Series Modeling
Elective - I	Business Analytics
Elective - II	Six Sigma
	Software Engineering
	Database Management System

** The elective subjects to be offered will be decided by the teachers' committee. Any two electives will have to be chosen by the students from the list of electives being offered.

SEMESTER IV (500 Marks)

(Engineering + Statistics Stream)

[Duration: Jan to June]

Dissertation and/or Project* (400 marks)	Starting on first working day of January
	Completing on last working day of June
Summer Internship (100 marks)	Carried forward from Semester II

* Dissertation/ Project will be supervised by the faculty member(s) of the institute

SYLLABI OF COURSES

SEMESTER I

PROBABILITY

1. Concept of probability (6)

Introduction and citation of examples for applications of probability. Classical definition of probability and its drawbacks. Sample space and events. Concept of random experiment with examples. Axiomatic definition of probability. Discrete and general probability space. Properties of probability. Conditional probability, Bayes' theorem. Independence of events, pair wise and mutual independence.

2. Combinatorial probability (4)

Probability of occurrence of at least one and exactly *mmmm* events, Birth day problems, Matching problems, and Occupancy problems.

3. Concept of random variables and probability distributions (10)

Definition of random variable, Discrete random variables - their p.m.f. and c.d.f. Continuous random variables and their p.d.f. and c.d.f.

Mathematical expectation and variance and their properties; mgf, pgf and cf. – definitions, properties and relationship. Statement of uniqueness theorem of cf and its applications. Moments, their properties and interpretation. Moments through p.g.f. mgf and cf. Variance of sum of independent random variables. Conditional expectation. Conditional variance.

4. Discrete random variable and its distribution (8)

Binomial, Poisson, geometric, negative binomial, hypergeometric distributions: their properties, relationship and simple approximations. (Hypergeometric to binomial and binomial to Poisson). Numerical examples. Statistical tables for individual and cumulative probabilities. Marginal and conditional density functions, independence of discrete random variables. Distribution of the sum of two or more discrete independent random variables.

5. Continuous random variable and its distribution (8)

Uniform, normal, gamma, beta, exponential, Weibull, Cauchy, lognormal distributions. Relationship between gamma and Poisson, beta and binomial distributions. Cumulative probabilities. Independence of continuous random variables. Distribution of sum, product and ratio of two independent random variables. Some derived distributions such as χ^2, t and F distributions. Order statistics and distribution of range.

6. Bivariate random variables (8)

Bivariate distribution - marginal and conditional density. Bivariate normal distribution. Correlation coefficient and its properties.

7. Limit Theorems (6)

Chebyshev's lemma, Chebyshev's inequality, Weak law of large numbers (WLLN), Central limit theorem (Lindbergh & Levy). De Moivre's theorem; examples of application of these limit theorems in Statistical Quality Control.

References:

1. S.M. Ross, Introduction of Probability Models, Academic Press, New York.
2. S.M. Ross. *A First Course in Probability.* 9th Ed. Pearson Education Limited
3. P.G. Hoel, S.C. Port and C.J. Stone: *Introduction to Probability Theory.* Houghton Mifflin, Boston.
4. W. Feller: *Introduction to the Theory of Probability and its Applications*, Vol. 1. John Wiley, New York.
5. M. Fisz. *Probability Theory and Mathematical Statistics.* Wiley, London.
6. E. Parzen. *Modern Probability Theory and its applications.* John Wiley, New York.
7. A.M. Mood, F.A.Graybill, D.C. Boes. *Introduction to the Theory of Statistics.* McGraw Hill, New York.
8. H. Cramér. *Mathematical Methods of Statistics.*
9. Kai Lai Chung. *Elementary Probability Theory with Stochastic Processes.* Springer Verlag, New York.

STATISTICAL METHODS-I

1. Introduction (4)

Definition of Statistics. Scope, purpose and objectives. Population and Sample, Measurement scales. Types of Data. Primary and secondary Data.

2. Descriptive Statistics (18)

Classification and tabulation of univariate data. Graphical representation – line diagram, bar diagram, and pie chart. Frequency distribution and histogram. Frequency and cumulative frequency curve. Descriptive measures - central tendency, quantiles, dispersion, coefficient of variation, skewness and kurtosis. Bivariate data – summarization, marginal and conditional frequency distribution, scatter diagram, correlation coefficient, rank correlation and correlation ratio.

3. Sampling Techniques (8)

Random numbers. Sampling frame. Concepts of random sampling from finite and infinite populations. Simple random sampling (with replacement and without replacement). Expectation and standard error of sample mean and proportion.

4. Estimation (10)

Principles of statistical inference. Formulation of problems with examples. Point estimation. Estimator and estimate. Criteria for good estimates - unbiasedness, consistency, efficiency and sufficiency. Method

of moments estimation and maximum likelihood estimation. Fisher Information matrix. Properties of maximum likelihood estimator. Confidence intervals.

5. Distribution Fitting (4)

Fitting of univariate distribution by graphical method (PP and QQ plots).

6. Simulation (6)

Simulation from common univariate distributions (discrete and continuous) and bivariate normal distribution.

References:

1. Fundamentals of Statistics, Vol. I - A. M. Goon, M. K. Gupta and B. Dasgupta.
2. Applied Statistics and Probability for Engineers – D. C. Montgomery and G. C. Runger.
3. Statistical Methods - G.W. Snedecor and W.G. Cochran.
4. Statistical Concepts & Methods - G.K. Bhattacharya and R.A. Johnson.
5. An outline of Statistical Theory, Vol. II – A. M. Goon, M. K. Gupta and B. Dasgupta.
6. Mathematical Statistics – Parimal Mukhopadhyay.
7. An Introduction to Probability Theory and Mathematical Statistics – V. K. Rohatgi.
8. Modern Mathematical Statistics – E. J. Dudewicz and S. N. Mishra.
9. Sampling Techniques – W. G. Cochran.
10. Elements of Simulation – Byron J. T. Morgan.

OPERATIONS RESEARCH-I

1. Introduction to OR (2):

Origin of OR and its definition. Concept of optimizing performance measure, Types of OR problems, Deterministic vs. Stochastic optimization, Phases of OR problem approach – problem formulation, building mathematical model, deriving solutions, validating model, controlling and implementing solution.

2. Linear Programming (22):

Linear programming – Examples from industrial cases, formulation & definitions, Matrix form, Implicit assumptions of LPP.

Some basic concepts and results of linear algebra – Vectors, Matrices, Linear Independence/Dependence of vectors, Rank, Basis, System of linear eqns., Hyperplane, Convex set, Convex polyhedron, Extreme points, Basic feasible solution etc.

Geometric method: 2-variable case, Special cases – infeasibility, unboundedness, redundancy & degeneracy, Sensitivity analysis.

Simplex Algorithm – slack, surplus & artificial variables, computational details, big-M method, identification and resolution of special cases through simplex iterations.

Duality – formulation, results, fundamental theorem of duality, dual-simplex and primal-dual algorithms.

3. Transportation and Assignment problems (5):

TP - Examples, Definitions – decision variables, supply & demand constraints, formulation, Balanced & unbalanced situations, Solution methods – NWCR, minimum cost & VAM, test for optimality (MODI method), degeneracy & its resolution.

AP - Examples, Definitions – decision variables, constraints, formulation, Balanced & unbalanced situations, Solution method – Hungarian, test for optimality (MODI method), degeneracy & its resolution.

4. **PERT – CPM (3):**

Project definition, Project scheduling techniques – Gantt chart, PERT & CPM, Determination of critical paths, Estimation of Project time and its variance in PERT using statistical principles, Concept of project crashing/time-cost trade-off.

5. Inventory Control (8):

Functions of inventory and its disadvantages, ABC analysis, Concept of inventory costs, Basics if inventory policy (order, lead time, types), Fixed order-quantity models – EOQ, POQ & Quantity discount models. EOQ models for discrete units, sensitivity analysis and Robustness, Special cases of EOQ models for safety stock with known/unknown stock out situations, models under prescribed policy, Probabilistic situations.

6. Queuing Theory (6):

Definitions – queue (waiting line), waiting costs, characteristics (arrival, queue, service discipline) of queuing system, queue types (channel vs. phase),

Kendall's notation, Little's law, steady state behaviour, Poisson's Process & queue, Models with examples - M/M/1 and its performance measures; M/M/m and its performance measures; brief about some special models.

7. Simulation Methodology (4):

Definition and steps of simulation, random number, random number generator, Discrete Event System Simulation – clock, event list, Application in Scheduling, Queuing systems, Inventory systems.

References:

1. Principles of OR with Application to Managerial Decisions : H.M. Wagner, Prentice Hall.
2. Introduction to Operations Research : F.S. Hiller and G.J. Lieberman, Addison Wesley.
3. Operations Research : An Introduction- H.A. Taha, Macmillan, N.Y.
4. Operations Research and Management Science, Hand Book: Edited By A. Ravi Ravindran, CRC Press, Taylor & Francis Group.

5. Linear Programming: G. Hadley, Addison Wesley.
6. Linear Programming & Network flows - M.S. Bazaraa, J J Jarvis and H D Sherali, John Wiley.
7. Linear Programming and Extensions: G.Dantzig, Princeton, N.J.
8. Linear Programming : K.G. Murthy, John Wiley
9. Fundamentals of Project Management: James P. Lewis, American Management Association, 2007.
10. Management Guide to PERT/CPM: Wiest & Levy, 2nd edn, PHI
11. Project Management and Control - Narendra Singh, Himalaya Publishing House
12. Project Management: A Managerial Approach: Jack R. Meredith and Samuel J. Mantel, John Wiley & Sons 2009.
13. Project Management: A Systems Approach to Planning, Scheduling and Controlling. By Herold Kerzner, John Wiley Inc., 2009.
14. Project Management: 24 steps to help you master any project: By Gary R. Heerkens, McGraw-Hill 2007.
15. Modern Inventory Management : J.W. Prichard and R.H. Eagle, John Wiley.
16. Material Management in Inventory Systems : M.K. Starr and R.J. Tersine, North Holland.
17. Queues : D.R. Cox and W.L. Smith
18. Analysis of Queuing Systems - J.A. White, J.W. Schmidt and G.K. Bennet, Academic Press.
19. Elements of Queuing Theory - Thomas L. Saaty, McGraw Hill
20. Introduction to Queuing Theory - B.V. Gnedenko and I.N. Kovalenko
21. Queues, Inventories and maintenance – Philip M. Morse
22. Queues and inventories – N.U. Prabhu
23. Queuing systems theory – Leonard Kleinrock
24. Narsing Deo, System Simulation with Digital Computer PHI (EEE)
25. Geoferry Gordan, System Simulation, PHI (EEE)
26. W.D.Kelton, R.P. Sadowski (1998), Simulation with Arena, Mc Graw Hill International

PROGRAMMING TECHNIQUES AND DATA STRUCTURES

1. **Programming Techniques and Structures (8):** C-language and structural programming concepts. Use of sequential files.

2. **Data Structures (20):** Formal definitions, operations, implementations and applications of basic data structures; array, stack, queue, dequeue, priority queue, linked lists, doubly linked list, binary tree and traversal algorithms, threaded binary tree. Implementation.

3. **Search Techniques (12):** Binary search, Fibonacci search, binary search tree, height balanced tree, heap, AVL tree, B-tree, hashing techniques. Implementation.

4. **Sorting Techniques (10):** Bubble sort, insertion sort, heap sort, merge and quick sort. External sorting techniques. Implementation.

5. **Programming assignments**

References:

1. Data Structures using C - A.M. Tanenbaum and M.J. Augesestein, Y. Langsan
2. The Art of Computer programming, Vol. I - D.E. Kunth
3. C Programming Language – Brian W Karnighan and Dennis M Ritchie
4. Introduction to Algorithms – Cormen Thomas H, Leiserson Charles E, Rivest Ronald L

QUALITY MANAGEMENT SYSTEMS

1. **Introduction to Quality and Quality Management – evolution, needs and perspectives (4):** Historical evolution of quality movement and quality management. Major questions addressed by the concepts of quality and quality management. Different definitions, dimensions and views of quality. Quality of products, services, projects and systems. Distinction between defensive and strategic approach to quality. Quality and profitability as well as sustenance. Importance of quality in society.
2. **Different Models of Quality Management (2):** Introduction to the theory of Quality management. Concept of Quality management models. Introduction to models like MBNQA and EFQM.
3. **Customer Satisfaction Models (4):** Concepts of customers. Internal and external customers. Different types of customers like regulatory bodies, public, external customers who pay etc. Chain of internal customers to deliver value to the external customers. Concepts of customer satisfaction and dissatisfaction. Measuring customer satisfaction – concepts of latent variables and indicators. Different Customer Satisfaction Models like ACSI, SCSB, ECSI etc.
4. **Concepts of service quality (2):** concepts of intangibility, inseparability and heterogeneity. Introduction to service quality dimensions and SERVQUAL. Critiques of SERVQUAL and some alternatives.
5. **Cost of Quality (4):** Definition of cost of quality. Components of costs of quality. Identification of different costs of quality in different organizations. Different views regarding costs of quality. Quality assurance perspectives.
6. **Six sigma and other improvement initiatives (6):** Concepts of quantitative, process based improvement. Introduction to different types of processes. Activities and processes – distinction between Business Value Added (BVA), Regulatory Value Added (RVA) and Non Value Added (NVA) activities. Process maps and their usage in Quality Management. Concepts of effectiveness, efficiency and performance measurement. R – D – M – A – I – C – S – I and other road maps for six-sigma. Overview of lean six-sigma.
7. **Views and theories of eminent quality experts (4):** Approach of eminent experts like Deming, Juran, Crosby, Taguchi, Ishikawa, Fiegenbaum, Shigeo Shingo. Discussions on Deming's 14 points as a theory of quality management.
8. **Evaluation of Management Thinking and typical barriers to Quality (4):** Thinking of Frederick Taylor, Max Weber, Henry Fayol; Human Relations and Maslow's need hierarchy; organizational structure and layers of action; impact of theory of management on quality practices. Overall view of Quality management.
9. **Current Management Systems (20):** ISO 9000 QMS, ISO 14000 EMS, OHSAS 18000, SA 8000 and other systems.

References:

1. Quality Management – Graeme Knowles
2. Quality Planning and Analysis – Juran and Gryna
3. Out of the crisis – Deming
4. Quality – A critical introduction – John Beckford
5. Delivering Service Quality – Zeithmal, Parasuraman and Berry
6. Total Quality Control – A V Feigenbaum
7. The ISO 9000 book – John T Rabbitt
8. Quality management essentials – David Hoyle
9. Six Sigma - The Breakthrough Management Strategy Revolutionizing the World's Top Corporations by Mikel Harry, and Richard Schroeder
10. The Six Sigma Handbook by Thomas Pyzdek and Paul A. Keller
11. Practitioner's Guide for Statistics and Lean Six Sigma for Process Improvements by Mikel J. Harry, Prem S. Mann, Ofelia de Hodgins, Chris Lacke and Richard Hulbert

ELECTRICAL AND ELETRONICS ENGINEERING

1. Basic Electrical Systems & Control: (25)

D.C. and A.C. circuits (including three phase circuits), Electromagnetic induction, Principles of D.C. motors and generators, Transformers, Alternators and A.C. motors. Feedback and feed forward control, Stability of control systems, Kirchoff's law, analysis of RLC circuits, Network theorems.

2. Electronics: (25)

Principles of semiconductor diodes and transistors, Transistor biasing and RC-coupled amplifiers, Operational amplifiers, Feedback amplifiers, Oscillators, Pulse and digital Circuits.

References:

1. Electronics: fundamentals and applications- D. Chattopadhyay, P. C. Rakshit.
2. Fundamentals of Electrical engineering and electronics - B.L. Theraja.
3. Electrical Technology - B.L. Theraja, A.K. Theraja
4. Network, lines and Fields -J.D. Ryder, Asia publishing.
5. Electronics Engineering Principle - J.D. Ryder, McGraw Hill.
6. Integrated Electronics : Analog and Digital Circuits and systems - S. Millman and C.C. Halkias, McGraw Hill
7. Analysis and Design of feedback control systems - G.J. Thaler and R.G. Brown, McGraw Hill.
8. Operational Amplifiers, design and applications- J.G. Graeme and T.E. Tobey, McGraw Hill.
9. Transistor Engineering - A.B. Phillips, McGraw Hill.
10. Digital Electronics with engineering applications- T.P. Sifferlen & V. Vartanian, Prentice Hall, N. Jercy

ENGINEERING DRAWING AND WORKSHOP – I

1. **Engineering Drawing (30)**

   Basic concept of orthogonal projection, third angle and first angle projections, scale of drawing and dimensioning, theory of section and conventional sectional view, offset section, revolved section, auxiliary view.

   Convention of representing screw threads in a drawing, diametral clearance in bolt holes and their spacing, standard bolt diameters, bolt circle diameter and flange diameter.

   Concept of fitting boss and alignment, standard key, key ways and spline, dimensioning parts before assembly and after assembly, Duplication of dimensions and cumulative errors, representing gears by pitch circles in a drawings.

   Computer aided graphics, sketch-pad concept, features drawing and simple topographical representation of product (practical demonstration with OMC drafting machine).

2. **Basic workshop practices, including exercises on Electrical and Electronics Engineering (20)**

SEMESTER II

ELEMENTS OF STOCHASTIC PROCESSES

1. **Concept of a stochastic process: (4)**
   State space and parameter space. Examples of various types of stochastic processes.
2. **Markov processes and Markov chains: (5)**
   Definition and Examples
3. **Discrete Time Parameter, Time Homogeneous Markov Chains: (35)**
   a) Transition probabilities, Chapman-Kolmogorov equations, First passage time (8)
   b) Communication among states. Classification of states. Definition of recurrence, transience, positive and null recurrence, periodicity (10)
   c) Stability of Markov chain. Limiting probabilities. (3)
   d) Absorption probabilities. (3)
   e) Examples of Markov chains: 2-state chains; Birth and Death chain, Random walk, Ehrenfest chain, Gambler's ruin chain etc. (2)
   f) Modeling of common industrial and real life systems as Markov chains. Examples of waiting line and inventory models (9)
4. **Poisson processes: (6)**
   Postulates for Poisson processes. Inter-event times and their distributions; Properties of Poisson processes.

References:

1. U.N. Bhatt & G. K. Miller: *Elements of Applied Stochastic Process.* 3rd Ed. John Wiley, New York.

2. W. Feller: *Introduction to the Theory of Probability and its Applications*, Vol. 1. 3rd Ed. John Wiley, New York.
3. P.G. Hoel, S.C. Port and C.J. Stone: *Introduction to Stochastic Processes.* Houghton Mifflin, Boston.
4. S. Karlin and H.M. Taylor: A First course in Stochastic Processes, 2nd Ed. Academic Press, Boston.
5. J.Medhi. *Stochastic Processes.* 2nd Ed. New Age International, New Delhi.
6. S.M. Ross. *An Introduction to Probability Models*, 10th Ed. Academic Press, CA.
7. S.M. Ross. *Stochastic Processes.* 2nd Ed. John Wiley, New York.

STATISTICAL METHODS – II

1. Introduction (2)

Principles of Statistical Inference. Formulation of the problems with examples.

2. Tests of Hypotheses (14)

Simple and composite hypotheses. Null and alternative hypotheses. Tests - type I and type II error and power. Most powerful test, uniformly most powerful test and uniformly most powerful unbiased test. Neyman-Pearson Lemma. Likelihood ratio test. Testing of mean and variance of normal population (one sample and two samples). Exact and asymptotic tests of proportions. Chi squared test for goodness of fit. $r \times c$ contingency tables.

3. Linear Statistical Models (6)

Definition of linear model. One way and two way ANOVA models. ANCOVA – one way classification with single covariate.

4. Linear Regression (20)

Simple linear regression. Estimation of parameters. Properties of least square estimators. Estimation of error variance. Confidence intervals. Prediction Interval.

Multivariate data. Multiple linear regression. Multiple and partial correlation. Detection of Collinearity. Stepwise regression.

Validation of model assumptions. Detection of outliers, influential observation and autocorrelation.

5. Non-parametric Inference (8)

Comparison with parametric inference, Use of order statistics. Confidence interval for fractile. Sign test, Wilcoxon signed rank test, Mann-Whitney test, Run test, Kolmogorov-Smirnov test. Spearman's and Kendall's test. Kruskal–Wallis test, Anderson-Darling test for normality.

References:

1. Fundamentals of Statistics (Vol. I and Vol. II) - A. M. Goon, M. K. Gupta and B. Dasgupta.
2. Applied Statistics and Probability for Engineers – D. C. Montgomery and G. C. Runger

3. Statistical Methods - G.W. Snedecor and W.G. Cochran.
4. Statistical Concepts & Methods - G.K. Bhattacharya and R.A. Johnson.
5. Introduction to Linear Regression Analysis - D.C. Montgomery and E. Peck.
6. Practical Nonparametric Statistics - W.J. Conover.
7. Applied Regression Analysis - N. Draper and H. Smith.
8. Regression Analysis: Concepts and Applications – F. A. Graybill and H. K. Iyer.
9. Regression Analysis by Example – S. Chatterjee and A. S. Hadi.
10. An outline of Statistical Theory, Vol. II – A. M. Goon, M. K. Gupta and B. Dasgupta.
11. Mathematical Statistics – Parimal Mukhopadhyay.
12. An Introduction to Probability Theory and Mathematical Statistics – V. K. Rohatgi.
13. Modern Mathematical Statistics – E. J. Dudewicz and S. N. Mishra.

SQC

1. Introduction to SQC (6)

Dimensions of quality, quality definition, stratification, check sheet, Pareto analysis, Ishikawa diagram, box plot & schematic box plot, concept of common & special causes of variation, type I & type II errors, Juran's feedback control, Deming's PDCA/PDSA.

2. SPC Techniques (30)

$\overline{X}$ - R chart, $\overline{X}$ - S chart, X-MR chart, p-chart, np-chart, c-chart, u-chart, demerit system, process capability indices (C_p, C_{pk}, C_{pm}, C_{pmk}), scatter plot, Pearsonian correlation coefficient, sloping control chart, economic process centering, operating characteristic functions of $\overline{X}$ - chart & R-chart, average run length function of Shewhart control chart, Exponentially Weighted Moving Average (EWMA) control chart, Cumulative Sum (CUSUM) control chart, modified control chart, gage repeatability & reproducibility study for measurable data, Kappa index for attribute data.

3. Acceptance Sampling (14)

Purpose of acceptance sampling; advantages & disadvantages of acceptance sampling; definitions of AOQ, AOQL, AQL, ASN, ATI, LTPD, Producer's risk, Consumer's risk; type A & type B OC curves; basic awareness about various acceptance sampling plans; mathematical proofs on probability of acceptance is an increasing function of c, decreasing function of n & decreasing function of p; single sampling attribute type plan & its determination through NOMOGRAM, double sampling plan; OC curve & function of double sampling plan; ASN for double sampling plans; usage of Grubb's table for determining double sampling plans; MIL. STD. 105-D; acceptance rectification plans (concepts of AOQ, AOQL, ATI & formulae); Dodge-Romig sampling inspection tables for single and double sampling; introduction to variable sampling plan (MIL. STD. 414).

References:

1. Statistical Quality Control – 7th edition, E.L. Grant & R.S. Leavenworth; McGraw Hill, N.Y.
2. Quality Control and Industrial Statistics – 5th edition, A.J. Duncan; Jewin, Homewood.

3. Statistical Quality Control – A Modern Introduction – Sixth edition, Douglas C. Montgomery, Wiley India
4. Principle of Quality Control, Jerry Banks, John Wiley

RELIABILITY- I

1. **Concept of Reliability (4)**

Importance of reliability, Definition of reliability and its measures. Concept of failure. Fault tree analysis. Failure mode and effect analysis (FMEA).

2. System Reliability (12)

Components and systems. Series, parallel, k-out-of-n system (including concept of redundancy) and their reliability block diagrams. Coherent system, path sets and cut sets. Structural importance of components. Modular decomposition of coherent system. Reliability of coherent system with independent components. Reliability importance of components. Concept of associated random variables. Bounds on system reliability.

3. Lifetime Models (10)

Notion of aging, concept of hazard rate for both continuous and discrete life distributions, reliability function and mean residual life. IFR and DFR class of life distributions. Bath-tub failure curve. Lifetime distributions: exponential, Weibull, log normal, gamma, Inverse Gaussian. Mixture distribution. Multiple failure modes (Competing risks model).

4. System reliability, standby redundancy and stress-strength models (8)

Reliability of systems studied in (2) under different lifetime distributions. Reliability of hot and cold standby redundant systems. Reliability of shared load parallel system. Stress- strength models. Cumulative damage model.

5. Life Testing and inference (16)

Life testing. Complete data and censored data. Type-I, Type-II, hybrid and random censoring schemes. Parametric inference based on complete and censored data using asymptotic likelihood theory. Nonparametric estimate (Life table and Kaplan-Meier) of reliability. Graphical methods (PP, QQ and TTT plots) and standard statistical tests for model validation. Life test acceptance sampling plans in exponential case. Basic concept of accelerated life testing.

References:

1. Statistical Theory of Reliability and Life Testing Probability Models; Barlow R.E. & Proschan, F., Holt, Rinehart and Winston, New York.
2. Mathematical Theory of Reliability; Barlow, R.E. and Proschan, F, John Wiley, New York.

3. System Reliability Theory: Models and Statistical Methods; Hoyland, A. And Rausand M., John Wiley, New York.
4. Reliability in Engineering Design; Kapur, K.C. and Lamberson, L.R., John Wiley, New York.
5. Statistical Models and Methods for Lifetime Data; Lawless, J.F., Wiley, New York,
6. A Primer of Reliability Theory; Grosh, D. L.
7. Life Time Data: Statistical Models and Methods; Deshpande, J. V. And Purohit, S. G., World Scientific, Singapore.
8. Statistical Methods for Reliability Data; Meeker, W. Q. and Escobar, L. A., John Wiley, New York.
9. Applied Life Data Analysis; Nelson, W. Wiley, New York.
10. Failure Mode and Effect Analysis: FMEA from Theory to Execution ; Stamatis, D. H., ASQ Quality Press.

INDUSTRIAL ENGINEERING AND MANAGEMENT

1. Industrial Engineering (28)

(a) Operations Management: (10)

What is Operations Management? Operations Strategy

Method:

Methods study: Recording techniques, critical examination, and development of alternative and implementation, Examples:

Estimation of task times by past data approach, direct time study approach, predetermined time standards approach, work sampling approach.

Machine:

Equipment selection, techniques and replacement strategies, Examples;

Break- down, preventive and predictive maintenance, distribution of breakdown time, distribution of repair time, determination of crew sizes, Scheduling.

(b) Man Management: (4)

Incentive schemes, job specification, job evaluation, work & job design.

(c) Material & Management: (10)

Planning and Control of Material: Managing Demand, Material Requirement Planning, Capacity planning, Inventory Planning. Choice of materials, standardization, value engineering and analysis.

(d) Plant Management: (4)

Plant location, plant layout, and materials handling.

2. Industrial Management (14)

(a) Introduction to management and Systems (10)

Understanding Supply Chain, Functions of management, Planning, Supply chain Co-ordination, Motivation and Control.

Decision making, Roles and role conflict, Organisation structure, Communication and information subsystem, Administration & management of change , Case studies.

(b) Management Accounting and Financial Management (4)

Introduction to financial Management, Scope & functions, structure & components of balance sheet, income statement, funding flow and cash flow, Ratio analysis, and interpretation of financial statements

3. Marketing (8)

Consumer, Demand Forecasting, Marketing strategy (Segmentation, Pricing, Distribution channel), Product life cycle & product development, Market research (techniques of data collection & information processing), Brand Management, Advertising & Promotional activity.

References:

4. Industrial Engineering and Management Science, P.R. Banga, S.C. Sharma and N.K. Agrawal
5. Operations Management: Strategy and Analysis, L. J. Krajewski, L.P. Ritzman, and M. Malhotra, 6th ed., Pearson Education, 2002.
6. Introduction to Materials Management, T. Arnold, 3rd Edition, Prentice Hall
7. Industrial Engineering and Operation research,D.M. Miller, J.W. Schmidt, John Wiley, N.Y.
8. Motion & Time study, W.N. Benjamin, Irwin, Homewood, IL
9. Industrial Engineering Handbook, H.B. Maynard (Ed.) Mc Graw Hill. N.Y.
10. Job evaluation Methods, C.W. Lytle Ronald Press N.Y.
11. Introduction to Work Study (3rd edition), ILO, Geneva ,Universal Book Corporation.
12. Management: a system and contingency analysis of managerial functions-H. Koontz and C.O. Donnell.
13. Market Research , D.J. Luck and R.S. Rubin, Prentice Hall
14. Market research-Text and cases, H.W. Blyd, R. Westfall, S.F. Stasch, Richard Allwyn Inc, Illinois
15. Marketing Management, Analysis, Planning, Implementation and Control, Philip Kotler, Prentice Hall (India).
16. Financial Management & Policy (Ninth edition), J.C. Van Horne, Prentice Hall (India)
17. Financial Management-theory & practice (2nd edn), P. Chandra, Tata McGrew Hill (India)
18. Accounting Theory and Management Accountancy, S.P. Jain and K.L. Narang, Kalyani Publishers.

MECHANICAL ENGINEERING

1. **Mechanical Properties of Materials. (13)**

   Brittleness, ductility, toughness, Engineering and true stress strain curves, Instability in tension, yielding criteria for ductile materials, tensile properties, anisotropy, Torsional properties, Hardness, Impact strength, Fatigue and Creep behaviors at low and elevated temperature.

2. **Metrology (12)**

   Objectives of Metrology, Characteristics of measuring instruments, Functional elements of instruments, classification of methods of measurement.

   Standards for measurement and standardizing organizations

   International system (SI) of units.

   Measurement uncertainty/error, types of error, methods of estimating total uncertainty in a measurement process.

   Linear measurement-steel rule, calipers, surface plates, straight edges, gauges, vernier calipers.

   Limits, Fits and Tolerances.

   Straightness, flatness, squareness, parallelism, roundness, circularity, runout.

   Surface roughness measurement.

3. **Machining (13)**

   Various machining methods and machine tools for metal cutting. Influence of various factors like speed, feed and depth of cut on tool life. Economic tool life, various angles and geometry of single point cutting tools (ISO standard). Design of single point cutting tool. Forces of turning, drilling and milling operations.

   Non conventional machining.

   NC/CNC Machines.

4. **Mechanical working of Metals:(12)**

   Plastic deformation of metals, Hot and cold working, Forging, Rolling, Extrusion, Wire drawing, Deep drawing, Stretch forming, Blanking, Piercing, Bending. Hydroforming and explosive forming.

References:

1. Production Technology by HMT, Tata McGraw Hill
2. Manufacturing and Machine tool operation, H.W. Pollack, Prentice Hall, N.Y.
3. Manufacturing Analysis, N.H. Cook, Addison- Wesley

4. Structure and Properties of Engineering Materials, R.M. Brick, A.W. Pouse, R.B. Gorden, Mc Graw Hill
5. Mechanical Metallurgy, E.M. Dieter, McGraw Hill
6. Workshop Technology, Parts 1,2,3, W.A.J. Chapman, ELBS
7. Numerical Control of Machines, S.J. Martin, ELBS.
8. Principles of Machine tools, G.C. Sen and A. Bhattacharya.
9. Fundamental of Tool design, ASTME, Prentice Hall,
10. Fundamentals of Rolling, Z. Wusatowski, Pergamon Press, Oxford.
11. Nontraditional Machining Process, R.K. Springborn (Ed.), ASTM
12. Principles of Numerical Control, J.J. Childs, Ind. Press Inc, N.Y.
13. Engineering Metrology, R.K. Jain, Khanna, N.Delhi
14. Measurement Systems- Application & Design, E.O. Doebelin, McGraw Hill
15. Handbook of Industrial Metrology, ASTME, Prentine Hall
16. Engineering Metrology, K.J. Hume, Mc Donald
17. Engineering Dimensional Metrology, L. Miller, Arnold.

WORKSHOP – II

1. **Instrumentation/ Digital Electronics (16)**
2. **Material Testing (10)**
3. **Metrology and Machining Practices (24)**

SEMESTER III

OPERATIONS RESEARCH – II

1. Integer Programming: (8)

Formulation of various problems as integer and mixed integer programming problems, Branch and bound algorithm, Cutting plane method for pure and mixed integer programming problems.

2. Nonlinear Programming: (22)

Introduction to nonlinear programming, Convex function and its generalization, Unconstraint and constraint optimization, KKT necessary and sufficient conditions for optimality, Linear complementarity problem and Lemke's complementary pivot algorithm, Quadratic programming and algorithm for solving quadratic programming problem, Separable programming, Linear fractional programming.

3. Game Theory and Decisions Making: (10)

Game theory to determine strategic behavior, Elements of decision theory and decision trees, Elements of cooperative and non-cooperative games, Two-person zero-sum game, Bimatrix games and Lemke's algorithm for solving bimatrix games.

4. **Network Analysis: (10)**

Types of network problems with examples, Flows in network, Max-flow min-cut theorem and its application, Ford-Fulkerson method.

References:

1. Integer Programming - R.S. Garfinkel and G.L. Nemhauser, John Wiley
2. Integer Programming: Theory, applications and Computations - H.M. Taha, Academic Press
3. Nonlinear Programming: Theory and Algorithms – Bazaraa, Sherali and Shetty, John Wiley
4. Nonlinear Programming- W.I. Zangwill, Prentice Hall
5. Practical Methods of Optimization - R. Fletcher, John Wiley
6. Conflicting Objectives in Decisions- D. Bell, R.L. Keenev and H. Raiffa (Eds.), John Wiley
7. Thinking Strategically- Avinash K. Dixit and B. J. Nalebuff
8. Statistical Decision Theory - James O. Berger, Springer Verlag
9. Game Theory - Guillermo Owen, Academic Press
10. Network based Management Systems -R.D. Archibald, John Wiley
11. Network Analysis for Planning and Scheduling - A. Battersby, Macmillan
12. Linear Programming and Network flows - M.S. Bazaraa, J J Jarvis and H D Sherali, John Wiley

INDUSTRIAL EXPERIMENTATION

1. Introduction (6)

Basic concepts of experimental design. Concepts of experimental unit, experimental error, factor, levels, treatments, treatment combinations and interaction. Fixed and random factors. Basic principles of experimentation. Contrasts and orthogonal contrasts. Concept of orthogonality of data.

2. Basic Designs (10)

Completely Randomized Design, Randomized Complete Block Design, Latin Square Design, Graeco-Latin Square Design, Balanced Incomplete Block Design.

3. Factorial Designs (12)

Introduction. Two-factor factorial design. 2^k and 3^k factorial designs. Confounding in 2^k and 3^k factorial design. Concept of partial confounding. Two-level and three-level fractional factorial designs. Plackett-Burman designs.

4. Nested and Split Plot Designs (6)

Two stage nested design. General m-stage nested designs. Design with nested and crossed factors. Split-plot design, Split-split plot design.

5. Orthogonal Arrays and Taguchi's Linear Graphs (6)

Linear graphs and their applications, Different types of 2 and 3 level orthogonal arrays. Multilevel arrangement. Pseudo-factor designs.

6. Response Surface Methodology (6)

Introduction, Method of steepest ascent. Analysis of second-order surface. Response surface designs for first order and second order models. Optimal designs.

7. Robust Design Concepts (4)

Background and Taguchi's concepts of robust design. Parameter design. Inner array and outer array. Signal to noise ratios. Response surface approach to robust design.

References:

1. Design and Analysis of experiments - D.C. Montgomery.
2. Design and Analysis of Experiments with SAS - John Lawson.
3. Statistics for Experimenters : An Introduction to design, data analysis and model building - G. E. P. Box, W. G. Hunter, J. S. Hunter.
4. Experimental Designs - W.G. Cochran and G.M. Cox.
5. Statistical Design and Analysis of Experiments - P.W.M. John.
6. The Design of Experiments, 14th ed. - R.A. Fisher.
7. Design and Analysis of Experiments - M .N. Das and N.C. Giri.
8. Empirical Model Building and Response Surfaces - G. E. P. Box and N. R. Draper.
9. Response Surface Methodology: Process and Product Optimization Using Designed Experiments - R. H. Myers and D. C. Montgomery.
10. Introduction to Off-line Quality Control - G. Taguchi.
11. Taguchi Techniques for Quality Engineering: Loss Function, Orthogonal Experiments, Parameter and Tolerance Design - Phillip J. Ross.
12. Experimental Design Techniques in Statistical Practice: A Practical Software-Based Approach - William P. Gardiner and G. Gettinby.
13. Optimum Experimental Designs - A. C. Atkinson and A. N. Donev.

RELIABILITY – II

Topics (1) –(4) are compulsory covering 40 lectures. Other topics may be chosen from the rest to cover 50 lectures altogether.

1. Classes of Life Distribution (8)

Classes of life distributions based on aging properties: IFR, IFRA, DFR, DFRA, NBU, NBUE, NWU, NWUE, DMRL, IMRL, etc.. Relationship between different classes of life distributions. Statement of results on closure properties.

2. Dependent components and their distributions (6)

Multivatiate distributions for dependent components. Marshal Olkin Bivariate exponential Weibull distribution and their properties. Parametric inference of bivariate models. Fatal and non-fatal shock models and bivariate exponential distribution derived from them

3. Repairable System Analysis (20)

Concept of Markov process. NHPP and renewal process. Inferential results on HPP and NHPP.

Perfect and imperfect repairs. Up-time and down-time. Availability function, average availability and limiting availability of components and coherent systems. Reliability/availability of repairable standby systems.

Analysis of data from repairable system. Maintainability; Maintainability increment, Methods of achieving optimum maintainability.

4. Reliability Optimization (6)

The basic model. Some advanced models. Optimal spare part allocation, Generalized Kettelle's algorithm.

5. Software Reliability

The basic concept and definition. Difference between hardware and software reliability, Jelinski-Moranda Model and some other relevant models. The problem of optimal release time. Some recent models.

6. Regression Models

Accelerated failure-time model and proportional hazard models.

7. Miscellaneous Topics

Warranty analysis, Bayesian reliability, Degradation Model. Multi state system reliability. Accelerated life testing.

References:

1. Statistical Theory of Reliability and Life Testing Probability Models; Barlow R.E. & Proschan, F., Holt, Rinehart and Winston, New York.
2. Mathematical Theory of Reliability; Barlow, R.E. and Proschan, F, John Wiley, New York.
3. System Reliability Theory: Models and Statistical Methods; Hoyland, A. And Rausand M., John Wiley, New York.
4. Statistical Models and Methods for Lifetime Data; Lawless, J.F., Wiley, New York.
5. Repairable System Reliability ; H. Ascher and H. Feingold, Marcel Dekker, New York.
6. Statistical Methods for the Reliability of Repairable Systems; Rigdon, S. E. And Basu, A. P., John Wiley, New York.
7. Bayesian Reliability Analysis; H.F. Martzad, R.A. Waller, John Wiley, New York.
8. Introduction to Reliability Analysis; S. Zacks, Springe Verlag, N.Y.
9. Practical Method for Reliability Data Analysis; J.I. Ansell and M.J. Phillps, Clarendon, Oxford.
10. Mathematical Methods of Reliability Theory; B.V. Gnedenko, B.V. Belyayev, K. Yu and A.D. Solovyev, Academic Press, N.Y.
11. Multistate Systems Reliability Theory with Applications; Netvig, B, John Wiley, New York.

12. Product Warranty Handbook, ed. Blischke, W. R. And Murthy, D. N. Prabhakar, Marcel Dekker Inc., New York.
13. Software Reliability; H. Pham, Springer Verlag.
14. Software Reliability and Modeling; M. Xie, World Scientific.

ADVANCED SQC

1. Advanced SPC Techniques (20)

- Group control chart for multiple stream processes
- Control chart for short run processes
- SPC with correlated quality characteristics: model-based approach and model-free approach
- Economic design of control charts: economic models of $\bar{X}$-R control chart, economic design of *p* chart
- Multivariate control chart: control chart of process mean vector and process variability matrix
- Engineering process control, Interface and integration between SPC and EPC
- Process capability analysis under non-normal situation: using data transformation, fitting standard non-normal distribution and fitting a generic family of distributions.

2. Taguchi's on-line QC Techniques (15)

- Loss function and quality level: Derivation of the loss function, uses of the loss function, economic consequences of tightening tolerances as a means to improve quality, the loss function for similar products (or for a system with independent components), the loss function and justification of improvements, quality evaluations and types of tolerances, determinations of tolerances.
- On-line quality control - attribute characteristics: Checking interval for attribute characteristics, optimal interval between successive diagnoses, frequency of process diagnosis, methods of process improvements.
- On-line feedback quality control - variable characteristics: Feedback control with measurement interval of one unit of production (mean squared drift), feedback control with measurement intervals greater than one unit of production, control systems for lot or batch types of production
- Feed forward control: β correction factor

3. Further topics in Acceptance Sampling (15)

- Continuous sampling plan and its modifications
- Skip lot sampling plan
- Bulk sampling

References:

1. Statistical Quality Control-A Modern Introduction: Douglas C. Montgomery, Wiley India
2. Statistical Process Control Methods for Long and Short Runs: Gary K. Griffith, ASQC Quality Press
3. On-line Quality Control during Production: Genichi Taguchi, Japanese Standards Association
4. Quality Engineering in Production Systems: Genichi Taguchi, Elsayed A. Elsayed and Thomas C. Hsiang, McGraw-Hill Book Company

ADVANCED MULTIVARITE ANALYSIS

1. Introduction (4):

Multivariate data, objectives of multivariate data analysis, multivariate Statistical distribution, graphical representation of multivariate data, Classification of multivariate techniques: Dependence and Interdependence techniques

2. Multivariate Normal Distributions (4):

Multivariate normal distribution and its properties, Estimation of parameters

3. Multivariate Test of Hypothesis (8):

Test for mean of multivariate normal distribution: single and two samples with known and unknown dispersion matrix. One and Two-way MANOVA

4. Principal Component and Factor Analysis (8):

Motivation. Derivation of principal components. Deciding on how many principal components to retain and interpretation. Factor analysis model, Extracting common factors and determining number of factor. Factor rotation.

5. Advanced Multiple Linear Regression Models (12):

Remedies of multicollinearity: Ridge and Principal Component Regression. Logistic regression and Poisson regression. Multivariate regression models: assumptions and parameter estimation.

6. Discrimination and Classification(8):

Motivation. Linear discriminant functions and their properties. Relation to logistic regression. Classification into Two /Several groups.

7. Cluster Analysis (6)

Distance Measures. Types of clustering. Clustering by hierarchical and partitioning methods.

References:

4. Multivariate Data Analysis, J F Hair, Jr et el.
5. An Introduction to Applied Multivariate Analysis with R, Brian Everitt, Torsten Hothorn,
6. Applied Multivariate Statistical Analysis, Richard A. Johnson and Dean W. Wichern,
7. Multi and Megavariate data Analysis – principles and Applications, L Eriksson, E Johnsson, N Kettaneh-Wold, S Wold.
8. Applied Multivariate Statistical Analysis, Third Edition Wolfgang Karl Härdle , Léopold Simar,
9. Methods of Multivariate Analysis, Third Edition, Alvin C. Rencher, 2012
10. An Introduction to Multivariate Statistical Analysis, T.W. Anderson, Applied

11. Multivariate Data Analysis, Vol I & II, J.D. Jobson, Statistical Tests for Multivariate Analysis, H. Kris.
12. Applied Linear Regression Models, J. Neter, W. Wasserman and M.H. Kutner,.
13. The Foundations of Factor Analysis, A.S. Mulaik,.
14. Introduction to Linear Regression Analysis, D.C. Montgomery and E.A. Peck,.
15. Logistic Regression: A Self Learning Text- D. G. Kleinbaum and M. Klein.
16. Modelling binary Data – D. Collette.
17. Cluster analysis for Applications, M.R. Anderberg,
18. Cluster Analysis, B. Everitt, Halsted, N.Y.
19. Multivariate Statistical Analysis, D.F. Morrison,
20. Introduction to Multivariate Analysis, G.H. Dunteman,

APPLIED STOCHASTIC PROCESSES AND TIME SERIES MODELING

1. Application of Poisson Process (8)

Applications of HPP and NHPP. Compound Poisson Processes.

2. Continuous time Markov Chain (10)

General theory of continuous time Markov chain. Kolmogorov differential equations. Pure birth process and pure death process. Birth and death processes. Application of birth and death processes to queuing theory and industrial problems.

3. Brownian Motion and Brownian Bridge (4)

4. Renewal Process (8)

Renewal equation, renewal theorem, delayed and equilibrium renewal process, alternating renewal process, renewal reward process. Excess and spent life distribution and their limiting behavior. Applications to replacement models and other problems.

5. Time Series Modeling (20)

Stationarity, time average, ACF and PACF. MA process, AR Process, ARMA and ARIMA process. Identification, estimation and various specification tests. Seasonality and seasonal difference. Forecast and its properties.

References:

1. Stochastic Processes- S. Ross, John Wiley.
2. A First Course in Stochastic Processes- S. Karlin, Academic Press
3. Stochastic Processes- J. Medhi, Wiley Eastern Limited
4. Elements of Applied Stochastic Processes - U.N. Bhatt and K. G. Miller, Wiley, New York.
5. Elementary Probability Theory with Stochastic Processes – K. L. Chung, Springer, New York.

6. Applied Economic Time Series – W. Enders, John Wiley.
7. Time Series Analysis and its Application- R. H. Shumway, D. S. Stoffer, Springer Text in Statistics.
8. Time Series Techniques for Economists- T. C. Mills, Cambridge University Press.
9. Introduction to time series and forecasting - P. J. Brockwell and R. A. Davis, Springer, New York.

BUSINESS ANALYTICS

1. **Introduction (4)**
   Introduction to usual decision making process and need for data driven decisions; directed and undirected (supervised and unsupervised) analytics; fundamental analytic tasks; examples of applications of analytics in different areas like HR, sales and marketing, operations, supply chain and in different business verticals like retail, health care, banking and financial services, manufacturing etc.; concepts of *business solutions* and implementation challenges.

2. **Classification, value estimation and association (22)**
   Naïve Bayes' classifier; Bayesian Networks; Decision trees; Generalized Additive Models; Nearest neighbour algorithms; market basket analysis; assumptions, validation, interpretation and practical usages; examples of model building.

3. **Interdependency analyses – dimension reduction (8)**
   Proposing and validating common factor models using CFA; introduction to SEM and path models; assumptions, pitfalls, validations; interpretation and practical usage; case examples

4. **Fundamentals and Building blocks of ANN (4)**
   Basic Concepts of Artificial Neural Network (ANN), Similarity with biological neurons, General characteristics, Historical development and domain specific applications, Statistical modeling and ANN. Architecture, Weights, Bias, Net Input, Threshold, Activation functions, Training and its related parameters.

5. **Learning Rules of ANN (2)**
   Hebbian, Perceptron, Delta, Competitive, Perceptron convergence theorem.

6. **Feed Forward Networks (4)**
   Multi Layer Perceptron (MLP) – Generalized Delta (Back Propagation) Learning rule, architecture, training algorithm, selection of parameters, learning constraints, application algorithm, local optimum, merits and demerits, applications
   Radial Basis Function (RBF) – architecture, training algorithm

7. **Introduction to data warehouse concepts (6)**
   Difference between operational database systems and data warehouse; data cubes; stars, snowflakes and fact constellation – schemas for multidimensional databases; OLAP operations; data warehouse architecture and usage; from OLAP to OLAM

8. **Analytics project**

References:

1. An introduction to statistical learning – Gareth James, Daniela Witten, Trevor Hastie, Robert Tibshirani
2. The elements of Statistical Learning - Trevor Hastie, Robert Tibshirani and Jerome Friedman
3. Data Mining Concepts and Techniques – Jiawei Han and Micheline Kamber
4. Handbook of Statistical Analysis and Data Mining – Robert Nisbert, John Elder, Gary Miner
5. The Data Warehouse Toolkit – The Definitive Guide to Dimensional Modelling – Ralph Kimball, Mary Ross
6. Data Mining and Business Analytics with R – Johannes Ledolter
7. An Introduction to Neural Networks: By K. Gurney, UCL Press.
8. Neural Network Fundamentals, 1996: By N.K. Bose, P. Liung:, McGraw Hill Inc.,
9. Neural Networks, 1994: By Haykin Simon, Macmilan, U.K
10. Neural networks for pattern recognition, 1995: By Bishop, C., Oxford Univ. press
11. Neural networks for statistical modeling: By Murray Smith.
12. Neuro-Fuzzy PR-Methods in Soft Computing: By Sankar K.Pal and Sushmita Mitra, John Wiley & Sons

SIX SIGMA

I. Overview : Six Sigma and the organization [18]

A. Six Sigma and organizational goals

1. Value of six sigma

   Recognize why organizations use six sigma, how they apply its philosophy and goals, and the origins of six sigma. Describe how process inputs, outputs, and feedback impact the larger organization.

2. Organizational drivers and metrics

   Recognize key drivers for business (profit, market share, customer satisfaction, efficiency, product differentiation) and how key metrics and scorecards are developed and impact the entire organization.

3. Organizational goals and six sigma projects

Describe the project selection process including the advantages of six sigma improvement methodology (DMAIC) as opposed to other quality management methodologies like TQM etc., and confirm that the project supports and is linked to organizational goals.

B. Lean principles in the organization

1. Lean concepts and tools

   Define and describe concepts such as value chain, flow, pull, perfection etc. and tools commonly used to eliminate waste, including kaizen, 5S, error-proofing, value-stream mapping etc.

2. Value-added and non-value-added activities

C. Design for Six Sigma (DFSS) in the organization

1. Quality function deployment (QFD)

   Describe how QFD fits into the overall DFSS process.

2. Design and process FMEA

3. Road maps for DFSS

   Describe and distinguish between DMADV (define, measure, analyze, design, verify) and IDOV (identify, design, optimize, verify), identify how they relate to DMAIC and how they help close the loop on improving the end product/process during the design (DFSS) phase.

II. Six Sigma – Define [5]

A. Process Management for Projects

1. Process elements (SIPOC diagram, detailed process flow chart etc.)
2. Owners and stakeholders
3. Identify and classify internal & external customers as applicable to a particular project, and show how projects impact customers.
4. Collect customer data
5. Analyze customer data
6. Translate customer requirements

   Assist in translating customer feedback into project goals and objectives, including critical to quality (CTQ) attributes and requirements statements. Use voice of the customer analysis tools such as quality function deployment (QFD) to translate customer requirements into performance measures.

B. Project management basics

1. Project charter and problem statement
2. Project scope.
3. Project metrics (e.g. primary metrics like quality, cycle time, cost and establish key project metrics that relate to the VOC.)
4. Project planning tools (Gantt chart, prioritization matrices etc.)
5. Project documentation for phase reviews, management reviews etc.

6. Project risk analysis including resources, financials, impact on customers & other stakeholders etc.
7. Project closure.

C. Team Dynamics and Performance

Define the qualifications, roles and responsibilities of teams including Champion, MBB, BB, GB, Process Owner etc., utilities of brainstorming & related tools & techniques.

III. Six Sigma – Measure [15]

1. Gage R & R studies for variables
2. Kappa index for attributes
3. Six Sigma Metrics for finding long-term, short-term, normalized sigma levels of a process based on throughput yield, rolled throughput yield, TDPU, normalized yield, and DPU_{NORM}.

IV. Six Sigma – Analyze [3]

An overview of statistical tools that can be used for root cause analysis.

V. Six Sigma – Improve [4]

1. Innovation – prioritization approach.
2. Piloting solution
3. Validating solutions through Box plots, F-test, t-test, FMEA, Sigma level calculation etc.

VI. Six Sigma – Control [5]

Developing a control plan to document and hold the gains and assist in implementing controls and monitoring systems through selection and application of different control charts.

References:

1) The Six Sigma Handbook: A Complete Guide for Green Belts, Black Belts, and Managers at All Levels by Thomas Pyzdek and Paul A. Keller
2) Six Sigma – The Breakthrough Management Strategy Revolutionazing the World's Top Corporations by Mikel Harry and Richard Schroeder
3) Statistical and Managerial Techniques for Six Sigma Methodology – Theory and Application by Stefano Barone and Eva Lo Franco
4) Practitioner's Guide to Statistics and Lean Six Sigma for Process Improvements by Mikel Harry, Prem S. Mann, Ofelia C. De Hodgins, Richard L. Hulbert, Christopher J. Lacke
5) Lean Six Sigma – Process Improvement Tools and Techniques by Donna C. S. Summers

SOFTWARE ENGINEERING

1. Introduction (4)

Programming in the small vs. programming in the large; software project failures and importance of software quality and timely availability; engineering approach to software development; role of software engineering towards successful execution of large software projects; emergence of software engineering as a discipline.

2. **Software Project Management (6)**

   Basic concepts of life cycle models – different models and milestones; software project planning – identification of activities and resources; concepts of feasibility study; techniques for estimation of schedule and effort; software cost estimation models and concepts of software engineering economics; techniques of software project control and reporting; introduction to measurement of software size; introduction to the concepts of risk and its mitigation; configuration management.

3. **Software quality and reliability (8)**

   Internal and external qualities; process and product quality; principles to achieve software quality; introduction to different software quality models like McCall, Boehm, FURPS / FURPS+, Dromey, ISO – 9126; introduction to Capability Maturity Models (CMM and CMMI); introduction to software reliability, reliability models and estimation.

4. **Software Requirements Analysis, Design and Construction (10)**

   Introduction to Software Requirements Specifications (SRS) and requirement elicitation techniques; techniques for requirement modeling – decision tables, event tables, state transition tables, Petri nets; requirements documentation through use cases; introduction to UML, introduction to software metrics and metrics based control methods; measures of code and design quality.

5. **Object Oriented Analysis, Design and Construction (8)**

   Concepts -- the principles of abstraction, modularity, specification, encapsulation and information hiding; concepts of abstract data type; Class Responsibility Collaborator (CRC) model; quality of design; design measurements; concepts of design patterns; Refactoring; object oriented construction principles; object oriented metrics.

6. **Software testing (8)**

   Introduction to faults and failures; basic testing concepts; concepts of verification and validation; black box and white box tests; white box test coverage – code coverage, condition coverage, branch coverage; basic concepts of black-box tests – equivalence classes, boundary value tests, usage of state tables~~,~~ testing use cases; transaction based testing; testing for non-functional requirements – volume, performance and efficiency; concepts of inspection.

7. **Any other topics may be included by the course teacher.**

8. **Project and assignments**

The above syllabus is only a guideline for the course. Some topics may be included or excluded from the above course syllabus.

Note: Computer programming skills is a must for this course.

References:

1. Software Engineering –Ian Sommerville
2. Fundamentals of Software Engineering –Carlo Ghezzi, Jazayeri Mehdi, Mandrioli Dino

3. An Integrated Approach to Software Engineering –P Jalote
4. Software Requirements and Specification: A Lexicon of Practice, Principles and Prejudices –Michael Jackson
5. The Unified Development Process –Ivar Jacobson, Grady Booch, James Rumbaugh
6. Design Patterns: Elements of Object-Oriented Reusable Software –Erich Gamma, Richard Helm, Ralph Johnson, John Vlissides
7. Software Metrics: A Rigorous and Practical Approach –Norman E Fenton, Shari Lawrence Pfleeger
8. Software Engineering: Theory and Practice --Shari Lawrence Pfleeger and Joanne M. Atlee
9. Object-Oriented Software Construction --Bertrand Meyer
10. Object Oriented Software Engineering: A Use Case Driven Approach --Ivar Jacobson
11. Touch of Class: Learning to Program Well with Objects and Contracts --Bertrand Meyer
12. UML Distilled: A Brief Guide to the Standard Object Modeling Language --Martin Fowler

DATA BASE MANAGEMENT SYSTEMS

1. **Introduction (4)**
   Purpose of Database systems, Data abstraction and Modelling, Instances and schemes, Database manager, Database users and their interactions, Data Definition and manipulation language, Data Dictionary, Overall system structure, Database models (relational, hierarchical, network, object oriented, object-relational)

2. **Entity relationship model (4)**
   Entities and entity sets, Relationship and relationship sets, Mapping constraints, E-R diagram, Primary keys, Strong and weak entities, Reducing E-R diagram to tables, Generalization and Specialization, Aggregation.

3. **Files and Data-structure Revisited (3)**
   Sequential file organization, buffer management, mapping tables, ISAM file, Use of B-tree and B+ tree for indexing, Hashing and Hash functions.

4. **Relational Model (5)**
   Structure of relational database, operations on relation Relational Algebra, Tuple and Domain relational calculus, Salient features of query language.

5. **Normalization in Relational System (5)**
   Pitfalls in RDBMs, Importance of normalization, Functional and multi-valued dependencies, 1NF to 4NF, Limitations of RDBMS.

6. **Description of an actual RDBMS and its Query language (2)**
   Involves extensive practice in computer centre to get an idea of an actual implementation.

7. **Query Optimization (5)**
   Importance of query processing, Equivalence of queries, Cost estimation for processing a query, general strategies, bi-relational and multi-relational join algorithms, algebraic manipulations, database tuning.

8. **Failure and Crash recovery in DBMS (2)**
   Failure classification, transactions, log maintenance, check point implementation.

9. **Security and Integrity (2)**
   Security and Integrity violations and constraints, Authorization and views, Encryption, Example of an actual implementation.

10. **Project (18)**

11. **Programming Assignments**

References:

1. Database System Concepts – Silberschatz Abraham, Korth Henry F, Sudarshan S
2. Database Systems, The Complete Book - H.G.Molina, J.D.Ullman and J.Widom, Pearson Education
3. Fundamentals of Database System – Ramez Elmasri & Shamkant B Navathe
4. Database Management Systems – Raghu Ramakrishnan and Johannes Gehrke

SEMESTER-IV

A ten-week Summer Internship starts immediately after Semester II examination. The summer internship will carry 100 marks which will be carried forward in Semester IV. In semester IV every student shall opt for either project or dissertation or a combination of project and dissertation under a supervisor who will be a faculty of the institute. This project and/or dissertation will carry 400 marks and time duration will be 6 months.

If a student opts for a combination of project and dissertation then the distribution of marks for project and dissertation will be either (0+400) or (100 + 300) or (200+200) or (300+100) or (400+0). The total time frame of six months will also be divided in the same ratio between project and dissertation, that is, (0+6) months, (1½ + 4½) months, (3+3) months], (4½ +1½) months and (6+0) months respectively, with at least 4 contact hours per week.[1]

[1] Decided in the 69th meeting of the Academic Council of the Institute, held on March 27 and April 4, 2019.