COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

(Abstract)

Faculty of Science – Department of Statistics – M.Sc Statistics & M.Tech in Engineering Statistics – Revised course structure & Outcome Based Education Syllabus – Approved – Orders issued

CONFERENCE SECTION

No.Conf.II/2941/1/AC-Science/2020 Dated, Kochi-22, 27.10.2020

Read: Item No.1(h) of the Minutes of the meeting of the Academic Council held on 08.07.2020

ORDER

The Academic Council at its meeting held on 08.07.2020 along with the recommendations of the Standing Committee resolved to approve vide items read above the revised course structure and Outcome Based Education (OBE) syllabi of the following offered at Department of Statistics under Faculty of Science with effect from 2020 admission onwards as in appendices I & II.

1. M.Sc Statistics
2. M.Tech in Engineering Statistics

Orders are issued accordingly.

Dr.MEERA V.
REGISTRAR

To

1. Dr.K Girish Kumar, Dean, Faculty of Science & Professor, Department of Applied Chemistry, CUSAT, Kochi-22
2. Dr.N.Balakrishna, Professor, Department of Statistics & Chairman, Board of Studies in Statistics, CUSAT, Kochi-22
3. The Head, Department of Statistics, CUSAT, Kochi-22
4. The Controller of Examinations/Joint Registrar (Academic)/Assistant Registrar (Academic)
5. Academic A, C/Exam E, D, Y/Exam Confidential Sections
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M.TECH IN ENGINEERING STATISTICS

Introduction

The objective of this programme is to teach statistical methods to engineers so as to equip them to apply the recent statistical tools in the industrial sector. There is wide scope for this course as students are trained in applied statistical methods like Reliability Engineering, Industrial Experimental Design, Statistical Process Control and ISO 9000, Operation Research, Forecasting, Total Quality Management, Six Sigma Tools, Simulation and SAS/R Programming, which are essential to assess and improve the quality, reliability and productivity in industrial sector. This course is aimed at bridging the gap between theoretically trained statisticians and the professional engineers.

The course also focusses on **Analytics** which is the discovery, interpretation, and communication of meaningful patterns in data. Students are trained on the simultaneous application of statistics, computer programming and operations research to analyze data patterns which help in effective decision making. The first two semesters are devoted to classroom teaching and laboratory experiments. In the third and fourth semesters, the candidates will be sent to undertake a project work in industries of their choice. Graduates of this course are well placed in industries, software/BPO companies and academic/research organizations.

Eligibility: B.Tech or equivalent degree or AMIE in any discipline or AMII with a first class (60%) from any recognized University or institution with valid GATE score.

Program Outcomes:
On successful completion of M.Tech in Engineering Statistics program the students will be able to

P.O.1: Acquire knowledge in modern statistical, engineering and management techniques relevant for problem solving process.

P.O.2: Critically investigate the prevailing complex problem scenarios in quality, reliability and productivity in manufacturing, service and software industries and arrive at possible solutions independently by applying the acquired theoretical and practical knowledge.

P.O.3: Participate in collaborative-multidisciplinary engineering / research teams for tasks related to quality and reliability engineering in industries and help industries in product/process planning, design, improvement, controland maintenance by applying concepts ofstatistical modelling, designed experiments, reliability engineering and simulation.

P.O.4: Become data scientists/analysts/consultants by learning analytics and use of statistical packages and thus contribute to any industry which deals with data.

P.O.5: Undertake teaching/research careers in Engineering, Statistics and allied areas and be involved in the process of knowledge discovery and effective communication of the same.

Syllabus

(With Effect from 2020 Admission onwards)

Semester I

Course Code	Paper	Core/ Elective	Credits
20-458-0101	Probability	C	4
20-458-0102	Reliability and Life Testing	C	4
20-458-0103	Practical I and Viva –Voce	C	2
	Elective I, II (Any two of the following)		
20-458--0104	Statistical Inference	E	4
20-458-0105	Systems and Decision Analytics	E	4
20-458-0106	Elements of Engineering Management	E	4
20-458-0107	Total Quality Management	E	4
20-458-0108	Operations Research	E	4
20-458-0109	Manufacturing Processes and Measurements for Quality	E	4

Semester II

20-458-0201	Industrial Experimental Design	C	4
20-458-0202	Statistical Methods for Quality Assurance	C	4
20-458-0203	Practical II and Viva Voce	C	2
	Elective III, VI (Any two of the following)		
20-458-0204	Elements of Stochastic Processes	E	4
20-458-0205	Statistical Forecasting	E	4
20-458-0206	Multivariate Methods	E	4
20-458-0207	Engineering Maintainability	E	4
20-458-0208	Simulation Modelling and Analysis	E	4
20-458-0209	Business Analytics	E	4

Semester III

20-458-0301	Project Progress Evaluation	C	18

Semester IV

20-458-0401	Project Dissertation Evaluation and Viva	C	18

SEMESTER I

20-458-0101: PROBABILITY

Course Outcomes(CO)	Cognitive level
After completion of this course the student should be able to	
1. Calculate probabilities by applying probability laws and theoretical results.	Analyse
2. Distinguish probability models and function of random variables based on single & multiples random variables.	Understand
3. Evaluate and apply moments & characteristic functions and understand the concept of inequalities and probabilistic limits.	Evaluate
4. Applications of law of large numbers and central limit Theorem.	Apply

Module-I

Sample Space and Events, Axioms of Probability, Some Simple Propositions, Sample Spaces Having Equally Likely Outcomes, Probability as a continuous Set Function, Probability as a Measure of Belief, Conditional Probabilities, Bayes Formula, Independent Events, $P(. \mid F)$ is a Probability, Random Variables, Discrete Random Variables, Expected Value, Expectation of a Function of a Random Variable, Variance.

Module-II

The Poisson Random Variable, The Geometric Random Variable, The Negative Binomial Random Variable, The Hypergeometric Random Variable, The Zeta(or Zipf) distribution, Properties of the Cumulative Distributions Function. Expectation and Variance of Continuous Random Variables, The Uniform Random Variable, Normal Random Variables, Exponential Random Variables, The Gamma Distribution, The Weibull Distribution, The Cauchy Distribution, The Beta Distribution, The Distribution of a Function of a Random Variable.

Module-III

Joint Distribution Functions, Independent Random Variables, Sums of Independent Random Variables, Conditional Distributions: Discrete Case, Conditional Distributions: Continuous Case, Order Statistics, Joint Probability Distribution of Functions of Random Variables, Exchangeable Random Variables, Expectation of Sums of Random Variables, Covariance, Variance of Sums, and Correlations, Conditional Expectations, Conditional Expectation and Prediction, Moment Generating Functions, Joint Moment Generating Functions, Additional Properties of Normal Random Variables, The Multivariate Normal Distribution, The Joint Distribution of the Sample Mean and Sample Variance, General Definition of Expectation.

Module-IV

Chebyshev's Inequality and the Weak Law of Large Numbers, The Central Limit Theorem, The Strong Law of Large Numbers, Other Inequalities, Bounding the Error Probability When Approximating a Sum of Independent Bernoulli Random Variables by a Poisson.

Text Book:

1. S. Ross (2012): A First Course in Probability, 9th edition. Pearson Education.

References:

1.W. Feller, (1988): An Introduction to Probability and its Application. Vol 1 & 11, Wiley Eastern.

2. M. Fisz (1963): Probability Theory and Mathematical Statistics, John Wiley and sons, New York. 3. E. Parzen, F.A Graybill, D.C Boes (1972), Modern Probability Theory and its Applications, Wiley Eastern.

20-458-0102: RELIABILITY AND LIFE TESTING

Course Outcome (CO)	**Cognitive level**
After completion of this course the student should be able to	
1. Examine modeling using failure rates	Analyze
2. Analyze reliability in series, parallel and complex systems	Analyze
3. Analyze reliability in the context of strength and load	Analyze
4. Examine structural reliability- one member, several load	Analyze
5. Examine preventive maintenance, imperfect maintenance	Analyze
6. Analyze event tree, fault tree analysis, minimal cut sets	Analyze
7. Use of reliability testing to real data	Apply
8. Outline accelerated life testing	Analyze

Module-I

Definition of Reliability, Importance of Reliability, Pattern of failures, Factor of Safety and Reliability, Reliability Management time dependent Reliability of components and systems - Failure rate time curve, Reliability and hazard functions, Modeling of failure rates, Estimation of failure rates from empirical data, mean time before failure, Parallel and series Systems, (k,n) systems, Complex Systems, Reliability enhancement, Reliability allocation.

Module-II

Strength based Reliability and Inference- General expression for Reliability, Expression for probability of failure, Reliability when strength (S) and load (L) follow normal, Log-normal, Exponential and extreme value distribution. Distributions of S and L, Structural Reliability - one member - one Load case, single member - Several load case, Reliability analysis of parallel system.

Module-III

Maintainability and Availability - Maintainability, Preventive maintenance, Imperfect maintenance, repair - Time distributions, Unprepared failures, Optimal replacement strategy, Spare parts requirements, availability – Availability analysis development of the model, Systems with a single component, Series and parallel

systems, System safety analysis, Failure models and effects analysis, Event tree analysis, Failure tree analysis, Minimal cut-sets.

Module-IV

Reliability testing - Objectives of reliability test, Details of reliability tests, Analysis of failure time, Accelerated life testing, Sequential life testing, Statistical inference and parameter estimation, confidence intervals, plotting of reliability data.

Text Books:

1. S.S.Rao (1992): Reliability Based Design, McGraw-Hill, Chapters 1, 6, 8, 10, 12, 13, 14

References:

1. E.E.Lewis (1987): Introduction to Reliability Engineering John Wiley and Sons
2. Tobis P.A. and D.C. Trindade (1995): Applied Probability, Van Nostrand Reinhold, Second edition.
3. A.Villemeur (1992): Reliability Availability, Maintainability and Safety Assessment Vol.2, John Wiley and Sons.
4. A. Pages and M.Gondran (1986): System Reliability, Springer Verlag.

20-458-0103: PRACTICAL I AND VIVA VOCE

Course Outcome (CO)	**Cognitive level**
After completion of this course the students will be able to	
1. Understand the basic concepts of metrology and measurements	Understand
2. Analyze measured data.	Analyze
3. Illustrate data analysis using statistical software using SPSS/Minitab	Apply

Module-1- Metrology

Measurements and Calibration for quality, Gauge capability studies. Study of linear Measuring Instruments, measuring procedure, Analysis of Measured data, Capability study.

Module-II - Introduction to Minitab/ SPSS.

Topics :Importing and Formatting Data, Bar Charts, Histograms, Boxplots, Pareto Charts, Scatterplots, Tables and Chi-Square Analysis, Measures of Location and variation, t-Tests, Proportion Tests, Tests for Equal Variance, Power and Sample Size, correlation, Simple Linear and Multiple Regression, One-Way ANOVA, Multi-Variable ANOVA

References:

1. Jain, R.K., Engineering Metrology, Khanna Publishers, 2002.
2. William M. Mendenhall and Terry L. Sincich, Statistics for Engineering and The Sciences, Sixth Edition, CRC Press, 2016

20-458-0104: STATISTICAL INFERENCE

Course Outcome (CO)	Cognitive level
After completion of this course the students will be able to	
1. Illustrate the problem of statistical inference	Evaluate
2. Compute estimator of parameter or parameters of any given distribution using method of moments and method of maximum likelihood	Apply
3. Evaluate reliability estimator of various models using complete and censored samples	Evaluate
4. Evaluate MP test and UMP test corresponding to any given testing problem	Evaluate
5. Differentiate different non-parametric test procedures.	Analyze
6. Discriminate chi-square test and Kolmogorov test	Analyze
7.Differentiate least square and generalized least square procedures	Analyze
8.Relate various regression models	Evaluate

Module-I

Estimation: Formulation of the problem, Properties of estimates, Unbiased estimation, Methods of estimation, Interval estimation.

Module-II

Reliability estimation: The exponential, Gamma and Weibull models, Estimation of reliability of these models with complete and censored samples.

Module-III

Testing of hypothesis: Fundamental notions, Neyman-Pearson Lemma, Likelihood ratio test, Test based on normality. Non-parametric procedures-Chi square test of goodness of fit, Kolmogorov-Smirnov test, Sign test, Signed rank test, Median test and test for independence.

Module-IV

Regression analysis: Linear regression, Least square estimation, generalized least squres, multiple regression, testing general linear hypothesis.

Text Books:

1. E.L.Lehmann (1998) Theory of Point Estimation, John Wiley and Sons.
2. V.K.Rohatgi and A.K.L. Saleh (2001) An Introduction to Probability and Mathematical Statistics, Wiley.
3. B.K. Kale (1999) A First Course in Parametric Inference, Narosa Publishing Company.
4. Robert C.P. and Casella, G (1999) Monte Carlo Statistical Methods, Springer Verlag.

Reference Books:

1. Rao, C.R. (1973) Linear Statistical Inference and its Applications, Wiley.
2. Casella, G and Berger, R.L (2002) Statistical Inference, Second Edition, Thompson-Duxbury Press.
3. Mukhopadhay, P. (1999) Mathematical Statistics, New Central Book Agency Pvt. Ltd.

20-458-0105: SYSTEMS AND DECISION ANALYTICS

Course Outcome (CO)	**Cognitive level**
After completion of this course the students will be able to	
1. Understand the basic concepts of systems and system thinking	Understand
2. Apply diagrammatic aids to capture problem situation	Apply
3. Explain basics of hard OR approaches and soft systems methodologies	Understand
4. Use the basics tools for system studies such as system dynamics, simulations	Apply
5. Evaluate decision problems and perform utility or risk analysis	Evaluate

Module-I

Systems thinking, decision making and analytics, efficiency and effectiveness, unplanned and counterintuitive outcomes, reductionist and cause-and-effect thinking, black boxes approach, hierarchy of systems, feedback loops, control of systems, mind maps, cognitive mapping.

Module-II

Hard OR paradigm, Soft systems thinking, Checkland's soft systems methodology, causal loop diagrams, Influence diagrams and other system diagrams, problem scoping and modelling phase, the implementation phase, code of ethics. Decision making over time: planning horizon, production planning problem.

Module-III

Prescriptive Analytics: Linear Optimization: Identifying Elements for an Optimization Model - Translating Model -Solving Linear Optimization Models -Graphical Interpretation of Linear Optimization - Solving Models with General Integer Variables; Simulation and system dynamics: the structure of simulation models, computer simulation packages, basics of system dynamics.

Module-IV

Decision Analysis - Formulating Decision Problems - Decision Strategies without Outcome Probabilities Decision Strategies for a Minimize Objective - Decision Strategies for a Maximize Objective - Decisions with Conflicting Objectives- Decision Strategies with Outcome Probabilities - Average Payoff Strategy - Expected Value Strategy - Decision Trees and Monte Carlo Simulation -The Value of Information - Decisions with Sample Information- Bayes's Rule - Utility and Decision Making.

References:

1.H. G. Daellenbachand D. C. McNickle, Management Science, Decision Making Through Systems Thinking, Palgrave Macmillan, 2005
2. F.S. Hillier and J. Lieberman, Introduction to Operations Research, 7th edn.,McGraw-Hill, New York, 2001.
3. J.R. Evans and D.L Olson, Introduction to Simulation and Risk Analysis, Prentice Hall, Englewood Cliffs NJ, 1998.
4. A.M. Law and W.D Kelton, Simulation Modeling and Analysis, 3rd ed., McGraw Hill, Boston,2000.
5. J.R. Evans, Business Analytics, Pearson Education; Second edition, 2017

20-458-0106: ELEMENTS OF ENGINEERING MANAGEMENT

Course Outcome (CO)	Cognitive level
After completion of this course the students will be able to	
1. Summarize the basic business functions and see how they relate to each other to form a 'system' that leads from the idea – the concept of a product or service – to satisfying the customers for that idea.	Evaluate
2. Explain basic functions of operations management	Understand
3. Analyze Supply chain relationships and behavior	Analyze
4. Apply the basic concepts of project management	Apply
5. Explain important marketing and financial management concepts	Understand

Module-I

Principles and practices of management: definition, nature and scope, approaches and school of thought, functions of management - planning, organization, co-ordination, control, decision making, motivation, leadership and organization culture. Introduction to human resource management: elements of organizational behavior, personality and attitudes, change management, conflict management.

Module-II

Operations management: The role of the operations function, the design of products and services, site selection procedures, location models, types of production systems, process design. Inventory planning and control: ABC analysis, EOQ, Quantity discounts, Systems of stock replenishment, Material Requirements Planning, Manufacturing Resource Planning, JIT and Kanban systems, ERP.

Module-III

Supply chain planning and control: The activities of supply chain management, types of relationships in supply chains, supply chain behavior. Project management: project selection models, project organization, life cycle phases, project management functions, PERT/CPM, critical path determination, crashing and smoothing, advantages and disadvantages of PERT/CPM, introduction to project management software.

Module-IV

Marketing management: marketing concepts, consumer behavior, competitors and competition, market segmentation, market evaluation. Financial management: common types of business operations, fundamental accounting concepts, presentation of financial information, profit and loss account, the balance sheet, working capital, financial ratios, depreciation.

References:

1. J. V. Chelsom, A. C. Payne, L R. P. Reavill, Management for Engineers, Scientists and Technologists, Second Edition, John Wiley & Sons Ltd, 2005.

2. S. K. Basu, K. C. Sahu, B. Rajiv, Industrial Organization and Management, PHI, 2012

3. N. Slack , S. Chambers, R.Johnston, Operations Management, Fifth edition, Pearson Education Limited,2007

4. R. B, Chase and N. J. Aquilano, Production and Operations Management: Manufacturing and services, Eight Edition, Irwin, , 1998.

20-458-0107: TOTAL QUALITY MANAGEMENT

Course outcome (CO)	Cognitive level
After completion of this course the students will be able to	
1. Understand the basic ideas of quality and quality management	Understand
2. Evaluate various quality costs and see how quality improvement efforts could reduce costs in industries	Evaluate
3. Recognize why design for quality is important and how it can be done	Evaluate
4. Understand and use various quality management tools	Apply
5. Understand and apply tools of quality, Six Sigma, FMEA and TPM and quality management systems	Apply

Module -I

Basics of Quality and Total Quality Management – Scope and objectives - Models and frameworks for TQM- Analysis of quality costs – Economic models – Quality improvement and cost reduction. Quality planning and sales income – Life cycle costs – Control of quality – Measuring Performance – Continuous process regulation. Strategic quality management – Quality policy – Training for quality – Organization for quality – Developing quality culture – Quality circles. TQM & JIT.

Module- II

Designing for quality – Safety and manufacturability – Design review – Quality function development – Concurrent engineering – Software development – Manufacturing planning for quality – Automated manufacture – Inspection, test, and measurement.

Module-III

Supplier relationship – Supplier selection – Statistical tool for supplier selection. Marketing, Field performance and customer service – Safety and product liability – Failure mode and effect analysis – Total productive maintenance. Benchmarking: Definitions – Reasons – Planning.

Module-IV

Management tools: Forced field analysis – Nominal group techniques – Affinity diagram – Interrelationship digraph – Tree diagram – Matrix diagram – Prioritization matrices – Process decision chart – Activity network diagram: Quality system: ISO 9000/Q S9000 and ISO 14000 – Basics of Lean and Six Sigma concepts.

References:

1. Juran, J.M and Gryna, F.M : Quality Planning and Analysis for Enterprise Quality, 5th Edition, McGraw Hill, 2007.

2. Besterfield, D.H et al: Total Quality Management, 3rd Edition, Pearson Education, 2003.

Suggested Readings:

3. Evans J.R and Lindsay W.M: The Management and Control of Quality, Cengage Learning, 2008.

4. Pyzdek,T : Six sigma handbook ,3rd Edition, McGraw Hill, 2010

5. John S. Oakland: Total Quality Management and Operational Excellence, Fourth Edition, Routledge,2014

20-458-0108: OPERATIONS RESEARCH

After completion of this course the student should be able to

Course Outcome (CO)	**Cognitive level**
1. Evaluate different types of LPP using simplex method	Apply
2.Evaluate IPP using Branch-and-Bound and Cutting-Plan algorithms	Apply
3.Evaluate transportation and assignments problems	Apply
4. Use of different techniques solving network models	Analyze
5. Illustrate the methods of solving game theory problems	Apply
6. Analyze Markov chain	Analyze
7. Illustrate unconstrained and constrained problems	Apply
8. Use of non-linear programming algorithms	Apply

Module-I

Modeling with Linear programming - Graphical solution; Simplex method, Artificial starting solution, Special cases in the Simplex method; Integer Linear Programming - Branch-and-Bound algorithm, Cutting-Plan algorithm.

Module-II

Transportation model - transportation algorithm; Assignment model; Network models - Minimal spanning tree algorithm, Shortest route problem, Maximal flow model; Decision analysis and games - Decision making under certainty, Decision making under risk, Decision making under uncertainty.

Module-III

Game theory; Markov Chains - Definition of a Markov chain, Absolute and n-step transition probabilities, Classification of the states in a Markov chain, Steady-state probabilities and mean return times of Ergodic chains, First passage time, Analysis of absorbing states.

Module-IV

Classical optimization theory - Unconstrained problems, constrained problems; Non-linear programming algorithms – unconstrained algorithms, constrained algorithms.

Text Book:

1. H.A.Taha (2008): Operations Research, Eighth edition, Pearson Prentice Hall, Dorling Kindersley (India) Pvt. Ltd, Relevant sections of Chapters 2, 3, 5, 6, 9, 13, 17 and 18.

References:

1. F.S.Hiller, G.J.Liberman, B.Nag and P.Basu (1995): Introduction to Operations Research, Ninth Edition, Tata Mc Graw-Hill Education (Pvt) Ltd.
2. J.K.Sharma (2009): Operations Research Theory and Applications, Fourth Edition, MacMillan Publishers India Ltd.
3. KantiSwarup, Gupta, P.K. and Man Mohan (2001): Operations Research, Ninth Edition, Sultan Chand & Sons

20-458-0109: MANUFACTURING PROCESSES AND MEASUREMENTS FOR QUALITY

After completion of this course the students will be able to

Course Outcome (CO)	Cognitive level
1. Explain and compare processes and equipment utilized in the manufacturing environment.	Evaluate
2. Apply the concepts of inspection and quality control processes.	Apply
3. Understand and apply the concepts of measurement errors, accuracy, precision and other principles of measurement	Apply
4. Describe about various linear, angular and thread measurement instruments.	Understand

Module-I

Classification of Manufacturing Processes: General introduction, Primary and secondary process. Process for changing shapes. (Preliminary concepts), Computer integrated manufacturing: Concepts in automation, definition of automation, levels of automation, high volume discrete parts production. Basic concepts in robotics: Resolution security and repeatability. Advantages and application of robots. Computer numerical control: Basic theory of numerical control, advantages of numerical control, open and closed system.

Module-II

Introduction to quality assurance and statistical quality control – Inspection principles and practices: Inspection fundamentals – Sampling Vs 100% inspection – Automated inspection – Off-line and on-line inspection – Quantitative analysis of inspection – Coordinate measuring machines (CMM) – Flexible inspection systems.

Module-III

Introduction to Metrology, Significance of measurements, calibration, precision, accuracy, sensitivity, readability, interchangeability and selective assembly – Standard of measurements, basic standard of length, mass, force, time, frequency and temperature, error in measurements, error classification. Limits, fits and tolerances – Standard system – Selection of fits, tolerance for linear dimension. Tolerance for screw threads, gear tolerances, ISI standard for tolerance – Limit gauging – Taylor's principle of gauging – Classification of gauges. Gauge tolerance and wear allowance.

Module-IV

Linear measuring instruments – Vernier calipers – Micrometers – Mechanical, optical, electronic, hydraulic and pneumatic compactors. Angular measuring instruments – Sine bar – Angle gauges – Spirit levels – Electronic level – Clinometers – Auto collimators. Radius measurements – Surface plated and rollers fixed roller instruments – Dynamic methods – V plate instruments – Co-ordinate method – Radial arm method – Circular division by mechanical indexing. Screw thread measurements – Terminology – Errors in thread – Measurements of external and internal thread elements – Screw thread gauges.

References:

1. Kalpakjian and Schmid: Manufacturing Engineering and Technology, Fourth Ed, Pearson Education, Asia, 2000.
2. Jain, R.K., Engineering Metrology, Khanna Publishers, 2002.
3. Groover, Automation, Production system and Computer Aided Manufacturing, Prentice Hall, 2001.
4. ASTM-Handbook of Industrial Metrology, Prentice Hall of India.
5. Beckwith et al: Mechanical Measurement, Oxford and IBH Publishing, 1982.

SEMESTER II

20-458-0201: INDUSTRIAL EXPERIMENTAL DESIGN

Course Outcome (CO)	**Cognitive level**
After completion of this course the students will be able to	
1. Illustrate the statistical tool -Analysis of Variance	Apply
2. Describe the different experimental designs.	Understand
3. Describe concepts of Taguchi experiments and orthogonal array.	Understand
4. Apply design of experiments to product design, Taguchi concept of quality, Reliability enhancement techniques and accelerated life testing.	Apply

Module-I

Analysis of variance: General Linear Model, One-way analysis of variance, Two way analysis of variance, Interaction, Confidence intervals in one-way and two-way analysis of variance, Multiple treatment comparisons, Random ordering of the experimental sequence, CRD, RBD.

Module-II

Factorial experiments: Simple and main effects, Factorial applied to randomized block designs, Taguchi experiments, Generalization of orthogonal arrays, Dealing with interactions, Confounding, Other designs.

Module-III

Application of design of experiments, Product design, Managing the uncontrollable factors, Type of uncontrollable factors, Use of outer arrays for concurrent engineering, Application of design of experiments to reliability assurance.

Module-IV

Accelerated Life Testing, Environmental and operating stress, Interpreting data from accelerated tests, Developing an integrated reliability test program, Reliability improvements with design of experiments.

Text Books:

1. D.C.Montgomery (1997): Design and Analysis of Experiments, John Wiley and Sons, New York.

2. Bloyd W. Condra (1993): Reliability Improvements with Design of Experiments, Marcel Dekker.

3. R.M Bethea and R.Rhireheart (1991): Applied Engineering Statistics, Marcel Dekker.

References:

1. Alain Villemeur (1992): Reliability Availability, Maintainability and Safety Assessment Vol.2, John Wiley and Sons.

2. E.Daniel (1976): Application of Statistics to Industrial Experimentation, John Wiley and Sons.

3. T.J.Lorenzen and V.L.Anderson (1993): Design of Experiment, Marcel Dekker.

20-458-0202: STATISTICAL METHODS FOR QUALITY ASSURANCE

Course Outcomes(CO)	**Cognitive level**
After completion of this course the student should be able to	
1. Understand the basic concepts of quality and quality assurance	Understand
2. Understand the theory and application of acceptance sampling for attributes, variables	Understand
3. Illustrate the applications of various types of control charts.	Apply
4. Examine the basics of management aspects of quality improvement , TQM and ISO 9000.	Analyze

Module-I

The concept of quality, need for quality assurances, Acceptance Sampling for attributes, Design and analyzing of single, double, multiple and sequential sampling plans, measurement of the performance of the sampling plans, AOQ, AOQ, AOQL, ASN and ATI.

Module-II

Acceptance sampling by variables, Sampling plans with a single specification limit with known and unknown variance, Sampling plan with double specification limits, Comparison of sampling plans by variables and attributes,Continuous Sampling Plans

Module-III

Control charts, basic ideas, design and uses, shewhart: control chart for attributes and variables, modified control, process capability studies, control charts with memory, CUSUM charts, Six Sigma limits.

Module-IV

Management aspects of quality Improvement - Quality Philosophy and Management Strategies- The Link Between Quality and Productivity- Quality Costs- Legal Aspects of Quality -Implementing Quality Improvement - Introduction to Total Quality Management and ISO 9000.

References:

1. Montgomery, D.C. (2013). Introduction to Statistical Quality Control, 7th Edition, Wiley.
2. AmitavaMitra. (2016). Fundamentals of Quality Control and Improvement, 4th edition– Pearson Education Asia.
3. Mittag, H.J. &Rinne, H. (1993) Statistical Methods for Quality Assurance, Chapman & Hall, Chapters 1, 3 and 4.
4. David Hoyle.(2017). ISO 9000 Quality Systems Handbook, Routledge; 6 edition.
5. Duncan, A.J. (1986) Quality Control and Industrial Statistics. 5th Edition, Irwin, Homewood.
6. Grant, E.L. and Leavenworth, R.S. (1996) Statistical Quality Control. 7th Edition, McGraw-Hill, New York.
7. Schilling, E.G. (1982) Acceptance Sampling in Quality Control, Marcel Dekker.

20-458-0203: PRACTICAL II AND VIVA VOCE

After completion of this course the students will be able to

Course Outcome (CO)	**Cognitive level**
1. Use R as a scientific computing environment	Apply
2.Identify the use of R packages to meet the given scientific objective	Analyze
3. Write an efficient programs using R to perform routine and specialized data manipulation /management and analysis tasks	Evaluate

Module-I

The R Language - Getting R – Using R as a calculating environment -Arithmetic - Variables - Functions - Vectors - Missing data - Expressions and assignments -Logical expressions - Matrices -The workspace. Basic programming - Branching with if- Looping with for- Looping with while - Vector-based programming - Factors - Data frames -Lists

Module-II

Bar Charts, Histograms, Boxplots, Pareto Charts, Scatterplots, Tables and Chi-Square Analysis, Measures of Location and variation, t-Tests, Proportion Tests, Tests for Equal Variance, Power and Sample Size, correlation, Simple Linear and Multiple Regression, One-Way ANOVA, Multi-Variable ANOVA.

References:

1. M.J.Crawley (2013): The R Book, Wiley.

2. S.G.Purohit, S.D.Gore and S.D.Desmukh (2008): Statistics using R, Narosa Publishing Company.

20-458-0204: ELEMENTS OF STOCHASTIC PROCESSES

Course Outcomes (CO)	**Cognitive level**
After completion of this course the student should be able to	
1. Understand the classifications of random processes and concepts such as strict stationarity, wide-sense stationary and ergodicity.	Understand
2. Classify the states of a Markov chain and apply ergodic theorem for finding limiting distributions on states	Apply
3. Understand and apply Poisson, birth-death and renewal processes.	Understand
4. Describe and use the recurrence relation for generation sizes in a Branching Process and determine the probability of ultimate extinction.	Analyze
5. Describe and analyze basic Markov and non- Markov queuing models and situations to which they may be applied	Analyze

Module-I
Different types of stochastic processes, Markov chain, transition probability matrix, classification, recurrence, stationary distribution, Chapman- Kolmogorov equation, random walk.

Module-II
Continuous time stochastic processes, Poison Process, birth process, birth-death process, Kolmogorov's differential equation, limit theorems, Branching processes.

Module-III
Renewal theory, excess life and current life, limit theorems, applications, delayed Renewal process, stationary renewal process, regenerative phenomena; central limit theorem.

Module-IV
Queuing models, steady state and waiting time distributions of Markovian models, Non- Markovian queues, time reversibility, network queues.

References:

1. Sheldon M Ross (1996): Stochastic Processes, Second Edition, John Wiley New York.
2. S.Karlin and H.M.Taylor (1975): A first course in Stochastic processes, Academic Press, New York.
3. J.Medhi (2009): Stochatic Processes, Third Edition, New Age International, India.
4. W. Feller (1988): An Introduction to Probability and its Application, Vol 1 & 11, Wiley Eastern.

20-458-0205: STATISTICAL FORECASTING METHODS

Course Outcome(CO)	**Cognitive level**
After completion of this course the students will be able to	
1. Choose a suitable model for the given time series.	Evaluate
2. Define forecasts under various optimization criteria such as MMSE, MAP,MAPE, etc.	Remember
3. Prediction by suitable smoothing methods.	Evaluate
4. Compute forecasts using regression and time series models.	Apply
5. Evaluate the forecasts using suitable measures.	Evaluate
6. Prediction using logistic regression, intervention models and neural networks	Evaluate
7.Interpret the model performance based on residuals.	Evaluate
8. Choose forecast methods for a given data.	Evaluate

Module-I

Need for forecasting, Basic forecasting tools, Time series and cross-sectional data, Graphical and numerical summaries, Measuring forecast accuracy, Transformations and adjustments. Time series decomposition: principle of decomposition, moving averages. Exponential smoothing: single, double, Holt's and Holt – Winters' smoothing methods.

Module-II

Simple regression: model and properties, Inference and forecasting with simple regression. Multiple linear regression: Method of analysis and examples. Variable selection methods, Multicollinearity, multiple linear regression and forecasting, Regression with correlated errors, Durbin – Watson test.

Module-III

Box-Jenkins Methodology for forecasting: Tests for independence and stationarity, methods of removing non-stationary, ARMA and ARIMA models for time series: Identification, estimation and diagnosis methods. Forecasting with ARIMA models.

Module-IV

Modelling and forecasting of Regression models with ARIMA errors: Dynamic regression models, Intervention analysis, non-linear models: logistic regression, Neural network forecasting.

References:

1. S. Makridakis, S.C.Wheelwright and R.J. Hyndman (2005): Forecasting Methods and Applications. 3rd Edition. John Wiley and Sons, New York.
2. B. Abraham and J. Ledolter (2006): Introduction to Regression Modeling . Thomson, Canada
3. B. Abraham and J. Ledolter (1983). Statistical Methods for Forecasing. Wiley, New York.
4. D.C.Montgomery, E.A. Peck and G.G. Vining (2003): Introduction to Linear Regression Analysis. Wiley

20-458-0206: MULTIVARIATE METHODS

Course Outcome (CO)	**Cognitive level**
After completion of this course the student should be able to	
1.Describe multivariate data and its preliminary analysis	Understand
2. Practice multivariate normal distributions	Apply
3.Examine properties of principal component analysis	Analyze
4.Apply Principal Component Analysis to real data	Apply
5.Explain factor model and properties	Understand
6. Apply factor analysis to real data	Apply
7.Illustrate discriminant analysis to real data	Apply
8.Illustrate different clustering methods	Apply

Module-I

Multivariate Data, Types and preliminary methods of analysis, Multivariate normal distributions: Definition Mean vectors, Variance - Matrices, Correlations, Bivariate Normal Distributions, Multivariate outliers, Multivariate Summary Statistics, Assessing Multivariate Normality Covariance.

Module-II

Principles Components Analysis: Objectives of Principal Components Analysis, Principal Components Analysis on the Variance, Estimation of Principal Components, PCA on the Correlation Matrix, Determining the Number of

Module-III

Factor Analysis: Objectives of factor Analysis, factor Analysis Model, Factor Analysis Equations, Solving the Factor Analysis Equations, Choosing the Appropriate Number of Factors, Computer Solutions of the Factor Analysis Equations, Rotating Factors, Oblique Rotation Methods, Factor Scores.

Modole- IV

Discriminant Analysis: Discrimination for Two Multivariate Normal Populations, Cost Functions and prior Probabilities (Two Populations), A General Discriminant Rule (Two populations), Discriminant Rules (More than Two populations), Variable Selection Procedures, Canonical Discriminant Functions, Nearest Neighbour Discriminant Analysis, Classifications Trees. Cluster Analysis: Measures of Similarity and Dissimilarity, Graphical aids in Clustering, Clustering Methods, Multidimensional Scaling.

References:

1. D.E. Johnson (1998): Applied Multivariate Methods for Data Analysis. Duxbury, USA.
2. A.C. Rencher (1995): Methods of Multivariate Analysis, John Wiley, New York.
3. M.S. Srivastava (2002): Methods of Multivariate Statistics, John Wiley, New York.

20-458-0207: ENGINEERING MAINTAINABILITY

Course Outcome (CO)	**Cognitive level**
After completion of this course the student should be able to	
1. Understand the importance, purpose, and results of maintainability efforts	Evaluate
2. Use maintainability data to estimate item availability or Unavailability	Apply
3. Analyse how reduced downtime for the product and consequently an increase in its operational readiness or availability	Evaluate
4. Apply various maintainability tools in practical situations	Apply
5. Apply human factor principles in maintainability considerations	Apply
6. Understand and evaluate RCM applications	Evaluate

Module-1

Maintainability – Purpose and Importance – Terms and definitions – Maintainability Management – Product Life Cycle – Maintainability organizational structures – Program plan – Design reviews. Maintainability measures – Functions and models – System effectiveness – Availability and dependability models.

Module-II

Maintainability tools – Failure Mode, Effects and criticality analysis – Cause and effect diagrams, TQM - Maintainability allocation. Maintainability Design considerations – Standardizations – Interchangeability – Modularization – Simplification – General maintainability design considerations.

Module-III

Human factor consideration – Auditory and visual warning – Environmental factors – Safety considerations Electrical, Mechanical and other hazards – Safety checklists. Cost considerations – Costs associated with maintainability - Maintenance cost estimation models.

Module-IV

Reliability centered maintenance – The RCM Process – RCM implementation- review groups – Methods of monitoring equipment condition – RCM applications. Maintainability Testing, Demonstration and Data Maintenance models and Warranties.

References:

1. Dhillon B.S., "Engineering Maintainability", Prentice Hall of India, 2000.
2. Kececioghu D, "Maintainability, Availability and Operational Reading Engineering" Prentice Hall, New Jercy, 1995.
3. Elsayed E A., "Reliability Engineering" Addision Western Massachrselts, 1996.
4. Manbray,J, "Reliability – Centered Maintenance", Industrial Press, Inc, New York, 1999

20-458-0208: SIMULATION MODELLING AND ANALYSIS

After completion of this course the student should be able to

Course outcome (CO)	**Cognitive level**
1. Understand how simulation works, application areas and the types of software that are available for simulation modelling	Understand
2. Develop a conceptual model for a given problem	Evaluate
3. Describe general modelling principles of simulation of manufacturing systems	Understand
4. Evaluate model's models validation using appropriate methods	Evaluate
5. Perform output analysis and show how to express results of simulation models	Analyze

Module-I

Simulation: Definition, areas of application, System: discrete and continuous Systems, Model of System, Steps in a simulation study. General principles of discrete event–Simulation, Event scheduling/time advance algorithms, World views, Simulation examples: single channel queues newspaper selling problem, reliability problem, Lead-time demand.

Module-II

Random number generation, Properties of random numbers, Techniques of generation of pseudo–random numbers, Test for random numbers, Random variate generation: Inverse transform technique, Convolution method, Acceptance–rejection technique.

Queuing Models, Long run measures of performance, Steady state models M/G/1, M/M/1/N/∞, M/M/C/∞/∞, M/M/C/K/K.

Module-III

Simulation of manufacturing and material handling systems: Modeling of manufacturing system, Material handling systems, Goals and performance measurement, Modeling of down times and failures, Trace driven models; Features of Simulation languages: Promodel – Extend - Auto Mod – Taylor II – Witness, Simul8– AIM – Arena.

Module-IV

Input modeling, Verification, Calibration and validation, Face validity, Validation of model assumption, Validating input-output. Analysis of simulation data: Output analysis for terminating simulations, Output analysis for steady state simulations.

Text Book:

Jerry Banks et.al. : Discrete – Event System Simulation, Fifth Edition, Prentice Hall, 2009.

Suggested Readings:

1. Law, A. M: Simulation Modeling and Analysis, Fourth edition, McGraw Hill New York, 2007.

2. Gordon, G : System Simulation, Second Edition, Prentice Hall, 1978

3.Robinson S: Simulation: The Practice of Model Development and Use, Red Globe Press; Second edition, 2014

20-458-0209: BUSINESS ANALYTICS

After completion of this course the student should be able to

Course Outcome (CO)	**Cognitive level**
1. Understand and explore problems in business	Understand
2. Summarize the evolution of business analytics and explain the concepts of business intelligence, operations research and management science, and decision support systems	Evaluate
3. Apply the appropriate forecasting technique to given problem	Apply
4. Apply k-Nearest Neighbors, discriminant analysis, and logistic regression for classification	Apply
5. Apply least square regression, verify assumptions	Apply

Module-I

Business Analytics Evolution of Business Analytics Impacts and Challenges - Big Data - Metrics and Data Classification - Data Reliability and Validity - Models in Business Analytics - Decision Models - Model Assumptions - Uncertainty and Risk - Prescriptive Decision Models -Problem Solving with Analytics - Recognizing a Problem - Defining the Problem - Structuring the Problem - Analyzing the Problem - Interpreting Results and implementation.

Module-II

Predictive Analytics: Modeling Relationships and Trends in Data - Least-Squares Regression - Regression as Analysis of Variance - Testing Hypotheses for Regression Coefficients - Confidence Intervals for Regression Coefficients -Residual Analysis and Regression Assumptions -Checking Assumptions - Multiple Linear Regression - Building Good Regression Models - Regression with Categorical Independent Variables

Module-III

Forecasting Techniques -Qualitative and Judgmental Forecasting - Forecasting Models for Stationary Time Series -Moving Average Models - Error Metrics and Forecast Accuracy - Exponential Smoothing Models Regression-Based Forecasting for Time Series with a Linear Trend -Forecasting Time Series with Seasonality -Regression-Based Seasonal Forecasting Models - Holt-Winters Forecasting for Seasonal Time Series - Holt-Winters Models for Forecasting Time Series with Seasonality and Trend - selecting Appropriate Time-Series-Based Forecasting Models - Regression Forecasting with Causal Variables .

Module-IV

Introduction to Data Mining - The Scope of Data Mining -Data Exploration and Reduction - Sampling - Data Visualization - Dirty Data - Cluster Analysis -Classification - Measuring Classification Performance - Using Training and Validation Data - Classifying New Data - k-Nearest Neighbors (k-NN) - Discriminant Analysis - Logistic Regression - Association Rule Mining - Cause-and-Effect Modeling

References:

1. GalitShmueli et al, Data Mining For Business Analytics: Concepts, Techniques, and Applications in R, John Wiley & Son ,2018
2. J.R. Evans, Business Analytics, Pearson Education; Second edition, 2017
3. Jeffrey D Camm, Essentials of Business Analytics; South Western, 2015
4. S. Christian Albright and Wayne L. Winston, Business Analytics: Data Analysis & Decision Making, Cengage Learning; Sixth Edition, 2017