INSTITUTE OF SCIENCE, NAGPUR

(An Autonomous Institute of Government of Maharashtra)

Department of Statistics

CREDIT STRUCTURE, EVALUATION SCHEME, AND SYLLABUS OF
ONE / TWO YEAR POST GRADUATION PROGRAM
IN STATISTICS (M.SC. STATISTICS)
(FACULTY OF SCIENCE & TECHNOLOGY)
BASED ON
DIRECTION 2 OF 2023 ISSUED BY INSTITUTE OF SCIENCE, NAGPUR
AS PER NEP

(TO BE IMPLEMENTED FROM ACADEMIC YEAR 2023-2024)

The structure of the course for two years, the pattern of examination, and the question papers are as specified below:

Structure of Two-Year Post Graduate Degree Program

Statistics as Major (Core) Table 1: M.Sc. Semester I

Sr No	Course Category	Course Code	Name of the course (Title of the Paper)	Level	Total Credit
1	DSC	M-ST511T	Paper 1:- Distribution Theory	6.0	4
		M-ST512T	Paper 2:- Estimation Theory		4
2	DSE	M-ST513T	Elective 1:- Sampling Theory OR		4
		M-ST513(1)T	Elective 2:- Time Series Analysis		
3	DSC /DSE	M-ST514P	Lab based on M-ST511T, M-ST512T and (M-ST513T or M-ST513(1)T)		6
4	RM	M-ST515T	Research Methodology		4
Total					22

Table 2: M.Sc. Semester II

Sr No	Course Category	Course Code	Name of the course (Title of the Paper)	Level	Total Credit
1	DSC	M-ST521T	Paper 1:- Elementary Stochastic Processes	6.0	4
		M-ST522T	Paper 2:- Testing of Hypothesis		4
2	DSE	M-ST523T	Elective 3:- Linear Models And Designs OR		4
		M-ST523(1)T	Elective 4:- Reliability Theory		
3	DSC /DSE	M-ST524P	Lab based on M-ST521T, M-ST522T and (M-ST523T or M-ST523(1)T)		6
4	OJT	M-ST525 P	Internship / Apprenticeship / Field Project (Related To DSC)		4
Total					22

Table 3: M.Sc. Semester III

Sr No	Course Category	Course Code	Name of the course (Title of the Paper)	Level	Total Credit
1	DSC	M-ST631T	Paper 1:- Decision Theory & Non Parametric Methods	6.5	4
		M-ST632T	Paper 2:- Linear &Non Linear Modelling		4
2	DSE	M-ST633T	Elective 5: - Industrial Process & Quality Control OR		4
		M-ST633(1)T	Elective 6:- Mathematical Programming		
3	DSC /DSE	M-ST634P	Lab based on M-ST631T, M-ST632T and (M-ST633T or M-ST633(1)T)		6
4	RP	M-ST635P	Research Project / Dissertation (Core)		4
Total					22

Table 4: M.Sc. Semester IV

Sr No	Course Category	Courses Code	Name of the course (Title of the Paper)	Level	Total Credit
1	DSC	M-ST641T	Paper 1:- Multivariate Analysis	6.5	4
		M-ST642T	Paper 2:- Computational Statistics		4
2	DSE	M-ST643T	Elective 7:- Industrial Statistics		4
		M-ST643(1)T	Elective 8:- Operations Research		
3	DSC /DSE	M-ST644P	Lab based on M-ST641T, M-ST642T and (M-ST643T or M-ST643(1)T)		4
4	RP	M-ST645P	Research Project / Dissertation 1 (Core)		6
					22

Total Credits:

1. Two-Year PG Degree Program: 88

Credit Specifications:

a. Theory/Tutorial Courses: One hour/credit/week (a minimum of 15 hours of teaching per credit is required in a semester.

b. Laboratory/Performance-Based Courses: A minimum of 30 hours in laboratory or Performance-based activities is required in a semester. Performance-based activities include Workshop-based activities, internships, Apprenticeships, Field-based learning, community engagement learning, etc.

c. Each semester will consist of at least 15 weeks of Academic Work equivalent to 90 actual teaching days.

Assessment

The assessment Plan will consist of Continuous Internal Evaluation (CIE) and End Semester Evaluation (ESE) for each course/subject taken together.

(A) Continuous Internal Evaluation (CIE) will be based

(a) Attendance of the student during a particular semester

(b) An assignment (min. two) based on curriculum to be assessed by the teacher concerned

(c) Subject-wise class test (min. two) or activities conducted by the teacher concerned with proper rubrics.

(d) Expected classroom activities shall consist of Group Discussions, Seminars, PowerPoint Presentations, Elocution, Debate, Role Play, Case Studies, Educational Games, etc. The teacher is expected to undertake a minimum of four of the aforesaid activities.

(e) The CIE marks will be communicated to the examination cell at the end of each semester, but before the semester end examinations / as instructed by the Examination Cell. These marks will be considered for the declaration of the results.

(f) The record of internal marks, evaluation & results should be maintained for a minimum period of three years by the respective department for verification by the competent authority.

End Semester Evaluation (ESE)

(a) Pattern of Theory Question Paper of 80 marks

1. There will be four units in each paper.
2. Maximum marks for each theory paper will be 80.
3. The question paper will consist of five questions, each of 16.
4. Four questions will be on four units with internal choice (One question on each unit).
5. Fifth question will be compulsory with questions from each of the four units having equal weightage and there will be no internal choice.

(b) Pattern of Theory Question Paper of 60 marks

1. There will be four units in each paper.
2. Maximum marks for each theory paper will be 60.
3. The question paper will consist of five questions, each of 12 marks.
4. Four questions will be on four units with internal choice (One question on each unit).
5. Fifth question will be compulsory with questions from each of the four units having equal weightage and there will be no internal choice.

(c) Pattern of Theory Question Paper of 40 marks

1. There will be four units in each paper.
2. Maximum marks for each theory paper will be 40.
3. The question paper will consist of five questions, each of 08 marks.
4. Four questions will be on four units with internal choice (One question on each unit).
5. Fifth question will be compulsory with questions from each of the four units having equal weightage and there will be no internal choice.

Standard of Passing

The scope of the course, percentage of passing in Theory and Project, and Internal Assessment will be governed as per the following rules:

(i) To pass the Bachelor of Science (B.Sc.) 1st, 2nd, 3rd, 4th, 5th, 6th, 7th, and 8th Semester Examinations, an examinee shall obtain not less than 40 % (Grade 4) marks in each theory course/paper, taking CIE & SEE together. Whereas, for practical/performance-based examinations an examinee shall obtain not less than 50 % marks in each practical, taking CIE & SEE together.

(ii) An examinee who is unsuccessful at the examination shall be eligible for admission to the subsequent examinations on payment of a fee prescribed for the examination together with the conditions of the ordinance in force from time to time.

Abbreviations Used

Continuous Internal Evaluation: (CIE) End Semester Evaluation: (ESE) Generic/Open Electives: OE, Vocational Skills & Skill Enhancement Courses: VSEC, Vocational Skill Courses: VSC, Skill Enhancement Courses: SEC, Ability Enhancement Courses: AEC, Indian Knowledge Systems: IKS, Value Education Courses: VEC, On Job Training (Internship/Apprenticeship): OJT, Field Project: FP, Community Engagement & Service: CEP, Co-curricular Courses: CC, Research Methodology: RM, Research Project: RP

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SYLLABUS

SEMESTER I

DSC I FOR STATISTICS MAJOR		
Paper Code: M-ST511T	**Title:: Distribution Theory**	
Course type- Theory	**No. of credits – 4**	**No. of contact hours – 60**

OBJECTIVES

The entire analysis in statistics is based on the probability distribution of the random variable under consideration. This course includes a study of some basic standard discrete and continuous distributions along with their properties. Besides, important concepts like truncated and mixture distributions are also introduced. The concepts and distributional properties of order statistics are also introduced in this course.

OUTCOMES

1. Students will get knowledge of some standard discrete and continuous distributions along with their properties.
2. Students also learn the applications of the random variables studied in real-life situations.
3. They will be able to test whether the given random variable follows any of the standard distributions based on which further analysis can be done.
4. Students will gain knowledge about some sampling distributions with their applications and some useful inequalities.
5. Students learn the concept of truncation and mixture distributions and also an important concept of order statistics. These concepts are useful in many areas like Actuarial Science, Telecommunication, and non-parametric density estimation

Unit No.	Content	No. of Hours
Unit - I	(A) A brief review of basic distribution theory, joint, marginal, and conditional pmf and pdfs conditional expectation. (B) Some discrete distributions are binomial, Poisson, negative binomial, geometric, uniform, multinomial, and hypergeometric distribution. Comparison between binomial and hypergeometric distributions.	**(15 Hrs)**
Unit -II	Continuous distributions- Normal, bivariate normal, exponential uniform. Functions of random variables and their distributions. Joint distribution of sample and induced sampling distribution of a statistic. Beta, Gamma, Cauchy, Log-normal, Weibull, Laplace distributions. Chi-square distribution and its properties	**(15 Hrs)**
Unit - III	t and F distributions and their properties. Markov, Holder, Jensen, Liaponov inequalities. Approximating distributions of a sample.	**(15 Hrs)**
Unit - IV	(A) Compound, truncated, and mixture distributions. Distributions of quadratic forms under normality and related distribution theory. (B) Order statistics, their distribution and their properties, joint and marginal distribution of order statistics. (C) Extreme values and their asymptotic distributions. (statement only) with applications.	**(15 Hrs)**

REFERENCES:	
1	Rohatgi V. K.: An introduction to probability theory and mathematical statistics
2	Rao C.R.: Linear statistical inference and its applications.
3	Johnson S and Kotz: Distributions in statistics Vol I, II and III.

DSC II FOR STATISTICS MAJOR		
Paper Code: M-ST512T	**Title::** Estimation Theory	
Course type- Theory	**No. of credits – 4**	**No. of contact hours – 60**

OBJECTIVES

Estimation theory is an important part of statistical Inference. The objective of this course is to train the students in obtaining point and interval estimates of the parameter based on given data.

OUTCOMES

1. The basic problem of estimation, various methods of estimation, and properties that are to be satisfied by a good point estimator.
2. Methods to improve an unbiased estimator to MVUE.
3. Concept of Fisher's Information
4. Concept of Sufficient Statistics
5. Construction of Confidence Interval

Unit No.	Content	No. of Hours
Unit - I	Problem of Point estimation, unbiased estimator, minimum variance unbiased estimator (MVUE), consistent estimators likelihood function Methods of estimation: Maximum likelihood, Minimum chi-square, method of moments. Method of scoring, Properties of maximum likelihood estimator.	**(15 Hrs)**
Unit -II	Fisher information and information matrix, Cramer Rao inequality Sufficiency Principle, Factorization theorem, minimal sufficiency, construction of minimal sufficient statistic, minimal sufficient statistic for exponential family	**(15 Hrs)**
Unit - III	Rao-Blackwell theorem, completeness, bounded completeness, Lehman Scheffe theorem, and their use. Pitman's family, Minimal sufficiency in Pitman family	**(15 Hrs)**
Unit - IV	Interval estimation: Confidence level, construction of confidence intervals using Pivots. Uniparametric case multi-parametric case (up to 2 parameters)	**(15 Hrs)**

REFERENCES:

1	E. L. Lehman: Theory of Point Estimation
2	B. K. Kale: First course on Parametric inference
3	C.R. Rao: Linear statistical inference and its applications

DSE I FOR STATISTICS MAJOR		
Paper Code: M-ST513T	**Title::** SAMPLING THEORY	
Course type- Theory	**No. of credits – 4**	**No. of contact hours – 60**

OBJECTIVES

Statisticians draw conclusions based on samples. The conclusions are close to reality only when they are based on a sample that is a proper representative of the population. This course is designed to train the students to obtain an appropriate sample in any given situation.

OUTCOMES

1. Students will get knowledge about various methods of sampling like SRSWOR, SRSWR, Stratified random sampling, Cluster sampling, systematic sampling, etc.
2. Students will gain knowledge about the efficiency of one method of sampling with respect to the other so that in any given situation, they will be able to apply an appropriate method of sampling.
3. They also learn about the ratio method of estimation and regression method of estimation when the data on the associated variable is also available along with a study variable.
4. Students also get knowledge about Warner's model of randomized response technique and two-stage sampling.

Unit No.	Content	No. of Hours
Unit - I	Basic methods of sample selection: - Simple random sampling with replacement, Simple random sampling without replacement & Sampling with replacement. Unequal probability sampling: PPS WR/WOR (including Lahiri's scheme) and related estimators of finite population mean (Hansen – Horvitz and Des-Raj estimators for general sample size and Murthy's estimators for a sample of size two.) Horvitz Thompson's estimator	**(15 Hrs)**
Unit -II	Stratified random sampling: Estimation of population mean, total, and variance, Allocation problem and estimation problem, Construction of strata and number of strata, Systematic sampling and comparison with SRS and stratified random sampling.	**(15 Hrs)**
Unit - III	Use of supplementary information for estimation:- Ratio and Regression method of estimation based on SRSWOR. Unbiased ratio estimate. Cluster sampling, equal and unequal sizes, Two-stage sampling with an equal number of second-stage units.	**(15 Hrs)**
Unit - IV	Double sampling for estimating strata sizes in ratio and regression method of estimation. Randomized response technique (Warners model, Related and Unrelated questionnaire methods.)	**(15 Hrs)**

REFERENCES:	
1	Sukhatme: Sampling theory of surveys with applications
2	Singh D and Chaudhary F. S.: Theory and analysis of sample survey designs.
3	Murthy M. N.: Sampling theory and methods
4	Des Raj and Chandak: Sampling theory

DSE II FOR STATISTICS MAJOR		
Paper Code: M-ST513(1)T	**Title::** TIME SERIES ANALYSIS	
Course type- Theory	**No. of credits – 4**	**No. of contact hours – 60**

OBJECTIVES

A time series is a series of data points indexed in time order. When this data is plotted, one can observe trends and other variations. Time series analysis is used to study the patterns of variations in data with time. These methods are useful in finance, weather forecasting, agriculture, etc. where the primary goal is forecasting. Since the observations are in the form of a sequence, the methods of modeling are different. The objective here is to introduce the concept of time series, different methods of analyzing and modeling the time series data, and their use in forecasting.

OUTCOMES

The course develops student's ability to model the time series data in various situations with the help of

1. Different methods of data smoothing to remove random variations.
2. Stationary and Nonstationary processes.
3. Estimation of the parameters of the time series model and using the models for forecasting.
4. Multivariate time series models, estimation, and forecasting.

Unit No.	Content	No. of Hours
Unit - I	Exploratory time series analysis, tests for trend and seasonality. Exponential and Moving average smoothing. Holt-Winters smoothing. Forecasting based on smoothing, adaptive smoothing. Time-series as a discrete parameter stochastic process. Auto covariance and autocorrelation functions and their properties.	**(15 Hrs)**
Unit -II	Stationary processes: General linear processes, moving average (MA), autoregressive (AR), and autoregressive moving average (ARMA). Autoregressive integrated moving average (ARIMA) models, Box – Jenkins models Stationarity and inevitability conditions. Nonstationary and seasonal time series models: Seasonal ARIMA (SARIMA) models, Transfer function models (Time series regression)	**(15 Hrs)**
Unit - III	Forecasting in time series models, Durbin-Levinson algorithm, innovation algorithm (without proof). Estimation of mean, auto covariance, and autocorrelation functions, Yule-Walker estimation, Estimation of ARIMA model parameters, maximum likelihood method, large sample theory (without proofs).Choice of AR and MA periods, FPE, AIC, BIC, residual analysis, and diagnostic checking.	**(15 Hrs)**

Unit - IV	Multivariate Time series model, VAR models, Vector ARMA models. Conditional heteroschedastic models, ARCH and GARCH, properties, examples, estimation & forecasting, extensions of ARCH & GARCH.	**(15 Hrs)**
REFERENCES:		
1	Brockwell, P.J. and Davis, R. A. (2003). Introduction to Time Series Analysis, Springer	
2	Chatfield, C. (2001). Time Series Forecasting, Chapmann&Hall, London	
3	Fuller, W. A. (1996). Introduction to Statistical Time Series, 2nd Ed. Wiley.	
4	Hamilton N. Y. (1994). Time Series Analysis.Princeton University Press.	
5	Box, G.E.P & Jenkins G.M (1976): Time Series Analysis – Forecasting & Control, Holden-Day, San Francisco.	
6	Lutkepohl, H. and Kratzing, M. (Ed.) (2004). Applied Time Series Econometrics, Cambridge University Press.	
7	Shumway, R. H.andStoffer D. S. (2010). Time Series Analysis & Its Applications, Springer.	
8	Tsay, R. S. (2010). Analysis of Financial Time Series, Wiley.	
9	Montgomery, D.C &Johnson, L.A (1977): Forecasting and Time Series Analysis, McGraw Hill	

DSC / DSE LAB FOR STATISTICS MAJOR		
Paper Code: M-ST514P	**PRACTICALS Based ON DSC I, II, and DSE**	
Course type- Practical	**No. of credits – 6**	**No. of contact hours – 180**

Practical No.	Content
Practicals on DSC I – DISTRIBUTION THEORY	
1	Fitting of truncated Binomial distribution
2	Fitting of truncated Poisson distribution
3	Drawing a random sample from a bivariate normal distribution
4	Estimation of μ and σ using random sample
Practicals on DSC II – ESTIMATION THEORY	
5	Estimation using the Minimum chi-square method
6	Problems on the method of Maximum likelihood
7	Problems on the Method of Moments
8	Problems on UMVUE
9	Problems on Confidence Intervals for mean and difference of means
10	Problems on Confidence Intervals for proportions and sample size
11	Confidence Intervals for variance and ratio of variances
Practicals on DSE I – SAMPLING THEORY	
12	Simple Random Sampling
13	Simple Random Sampling with varying Probability with Replacement
14	Ratio and Regression estimate of population mean and standard error in case of SRS
15	Des-Raj and Horvitz-Thompson estimator
16	Hartley Ross estimator
17	Cluster sampling with unequal cluster sizes
18	Problems on Two-Stage Sampling
19	Estimation of population mean and variances using Double sampling

RM FOR STATISTICS MAJOR		
Paper Code: M-ST515T	**Title::** Research Methodology	
Course type- Theory	**No. of credits – 4**	**No. of contact hours – 60**

OBJECTIVES

- To understand the role of research methodology in Engineering/Science/Pharmacy
- To understand the literature review process and formulation of a research problem
- To understand data collection methods and basic instrumentation
- To learn various statistical tools for data analysis
- To learn technical writing and communication skills required for research
- To create awareness about intellectual property rights and patents

OUTCOMES

After completion of this course, the students will be able to

1. understand the meaning and scope of doing scientific research.
2. able to think logically
3. would be able to use some of the computational algorithms and tools used in modern statistical inference problems.
4. Would be able to apply several visualization graphical methods

Unit No.	Content	No. of Hours
Unit - I	**Introduction to Research:** Definition of research, Characteristics of research, Types of research- Descriptive *vs.* Analytical, Applied *vs.* Fundamental, Quantitative *vs.* Qualitative, Conceptual *vs.* Empirical, Overview of research methodology in various areas, Introduction to problem-solving, basic research terminology such as proof, hypothesis, lemma, etc., Role of Information and Communication Technology(ICT) in research	**(15 Hrs)**
Unit -II	**Research Problem Formulation and Methods:** Literature review, sources of literature, various referencing procedures, maintaining literature data using Endnote2, Identifying the research areas from the literature review and research database, Problem Formulation, Identifying variables to be studied, determining the scope, objectives, limitations and or assumptions of the identified research problem, Justify basis for assumption, Formulate time plan for achieving targeted problem solution. Important steps in research methods: Observation and Facts, Laws and Theories, Development of Models, Developing a research plan: Exploration, Description, Diagnosis, and Experimentation.	**(15 Hrs)**

Unit -III	**Research reports and Thesis writing:** Introduction: Structure and components of scientific reports, types of reports, developing a research proposal. Thesis writing: different steps and software tools in the design and preparation of the thesis, layout, structure, and language of typical reports, Illustrations, and tables, bibliography, referencing and footnotes, Oral presentation: planning, software tools, creating and making effective presentation, use of visual aids, importance of effective communication.	**(15 Hrs)**
Unit - IV	**Research Ethics, IPR and Publishing:** Ethics: Ethical issues. IPR: intellectual property rights and patent law, techniques of writing a Patent, filing procedure, technology transfer, copyright, royalty, trade-related aspects of intellectual property rights Publishing: design of research paper, citation, acknowledgment, plagiarism tools, reproducibility, and accountability.	**(15 Hrs)**
REFERENCES:		
1	Ranjit Kumar, "Research Methodology: A Step-by-Step Guide for Beginners", SAGE Publications Ltd., 2011.	
2	Wayne Goddard, Stuart Melville, "Research Methodology: An Introduction" JUTA and Company Ltd, 2004.	
3	C.R. Kothari, "Research Methodology: Methods and Trends", New Age International,2004	
4	S.D. Sharma, "Operational Research", Kedar Nath Ram Nath & Co.,1972	
5	B.L. Wadehra, "Law Relating to Patents, Trademarks, Copyright Designs and Geographical Indications", Universal Law Publishing, 2014.	
6	Donald Cooper, Pamela Schindler, "Business Research Methods", McGraw-Hill publication, 2005.	

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SYLLABUS

SEMESTER II

DSC I FOR STATISTICS MAJOR		
Paper Code: M-ST521T	**Title::** Elementary Stochastic Processes	
Course type- Theory	**No. of credits – 4**	**No. of contact hours – 60**

OBJECTIVES

Almost all processes that we come across in real life are stochastic. The course includes some basic standard stochastic processes which help in understanding real-life situations. Many processes are observed to be Markovian in nature. A study of such processes is also included in this course. A time series is a series of data points indexed in time order. When this data is plotted, one can observe trends and other variations.

OUTCOMES

Students become well acquainted with

1. The definition of stochastic processes and their classification. Markov chain and its applications in different areas, Classification of states, and various results associated with Markov Chain.
2. Random walk model, Poisson processes & branching processes and will be able to apply them in real-life situations.

Unit No.	Content	No. of Hours
Unit - I	Definition of Stochastic Process, Classification of Stochastic processes according to state space and time domain. Examples of various Stochastic Processes. Definition of Markov Chain, Examples of Markov Chain Formulation of Markov Chain models, initial distribution, Stationary Transition Probability Matrix, Chapman Kolmogorov equation, calculation of n-step transition probabilities. Classification of states closed and irreducible classes, transient, recurrent, and null states, Periodic States, Criteria for the various types of states, Ergodic theorem.	**(15 Hrs)**
Unit -II	Algebraic treatment for finite Markov chains, Random walk, Gambler's Ruin problem, Absorbing and reflecting barriers, First Passage Probability, Expected duration of the game, Random walk in 2 and 3 dimensions.	**(15 Hrs)**
Unit - III	Discrete state-space continuous time Markov Chain, Poisson Process, Pure birth process, pure death process, Birth and death process. Continuous state space continuous-time Markov chain: Kolmogrov's equation Wiener process as a limit of random walk model, properties of Wiener process, Covariance stationary processes.	**(15 Hrs)**

Unit - IV	(A) Renewal Theory: Renewal process in discrete time, Renewal processing continuous time, Renewal equation, Elementary renewal theorem and its applications. Poisson process as a renewal process, the study of residual lifetime processes, current lifetime, and total lifetime. (B) Branching process: Galton-Watson branching process for the size of the nth generation, the relation between the generating function, probability of ultimate extinction, and distribution of population size.	**(15 Hrs)**
REFERENCES:		
1	J. Medhi: Stochastic Processes	
2	S. Karlin and H Taylor: First course in stochastic processes.	
3	W. Feller: Introduction to probability theory and its applications Vol. 1.	

DSC II FOR STATISTICS MAJOR		
Paper Code: M-ST522T	**Title::** Testing of Hypothesis	
Course type- Theory	**No. of credits – 4**	**No. of contact hours – 60**

OBJECTIVES

There are some standard statistical methods useful in testing various types of hypotheses. These methods are widely used in almost all disciplines. Sometimes we need to construct a test procedure if the situation is not as required in the standard methods. The course includes a basic lemma useful in the construction of the test. The test procedure also changes according to the nature of the null hypothesis, alternative hypothesis, the distribution of a random variable under consideration, etc. The course helps in constructing the most powerful or uniformly most powerful tests for different types of hypotheses for any given distribution. Some situations require sequential test procedures.

OUTCOMES

At the end of the course, students become well-versed with

1. A good understanding of the concept of hypotheses helps the students to differentiate between types of hypotheses like null and alternative, simple and composite, one-sided and two-sided, etc.
2. They learn about the two types of errors committed while constructing any test and the probabilities associated with them.
3. Concept of LRT and Sequential Testing

Unit No.	Content	No. of Hours
Unit - I	Test of hypothesis, concept of critical regions, test functions, two kinds of errors, size function, power function, level, MP, and UMP test in the class of size μ tests. N.P lemma, MP test for simple against a simple alternative hypothesis.	**(15 Hrs)**
Unit -II	UMP tests for simple null hypothesis against a one-sided alternative and one-sided null against a one-sided alternative in one parameter exponential family. Extension of the above results to Pitman family when only the upper or lower end depends on the parameter and to distributions with MLR property. Non-existence of UMP test for simple null against two-sided alternatives in one parameter exponential family.	**(15 Hrs)**
Unit -III	Likelihood ratio test, Asymptotic distribution of LRT statistics (without proof), Wald test, Rao's score test, Pearson's chi-square test for goodness of fit, Bartlett's test for homogeneity of variances. (without proof).	**(15 Hrs)**
Unit - IV	Sequential testing. Sequential probability ratio test. Relation among parameters Application of SPRT to Binomial, Poisson, Normal Distribution. Generalized Neyman Pearson lemma (Statement only), unbiased test, UMPUT and their existence in case of exponential family similar tests and tests with Neyman structure.	**(15 Hrs)**

REFERENCES:	
1	E. L. Lehman: Testing statistical hypothesis
2	B. K. Kale: First course on Parametric inference
3	C.R. Rao: Linear statistical inference and its applications
4	Ferguson T. S.: Mathematical statistics
5	Zacks S.: Theory of statistical inference

DSE III FOR STATISTICS MAJOR		
Paper Code: M-ST523T	**Title:: LINEAR MODELS AND DESIGNS**	
Course type- Theory	**No. of credits – 4**	**No. of contact hours – 60**

OBJECTIVES

Design of Experiments is a systematic method to determine the relationship between factors affecting a process and its output. It is useful in understanding cause-and-effect relationships. This is useful in managing inputs that will be reflected as variations in outputs. It is used in areas like agriculture, Psychology, medicine, engineering, biochemistry etc.

OUTCOMES

1. They learn basic designs like CRD, RBD, and LSD, and techniques of estimating missing values (if any) in the data.
2. Use of BIBD and its various types such as RBIBD, ARBIBD, SBIBD, and Youden square design,
3. They learn the use of factorial experiments as per the requirement of the situation where the effects of treatments are studied at two levels and their interactions.
4. Use of confounding in factorial experiments to maintain homogeneity of the block. Concept of double confounding.

Unit No.	Content	No. of Hours
Unit - I	Gauss- Markov theorem, Analysis of variance, elementary concepts (one and 2 way classified data) Review of elementary design (CRD, RBD, LSD) Missing plot technique in RBD and LSD with one and two missing values (only estimation of missing values)	**(15 Hrs)**
Unit -II	BIBD: Elementary parametric relations, Analysis. Definitions and parametric relations of SBIBD, RBIBD ARBIBD, PBIBD. Youden square design - Definition and analysis. Institute of Science, Nagpur - Syllabus for M.Sc. Statistics	**(15 Hrs)**
Unit -III	Analysis of covariance of one-way and two-way classified data., split-plot design: construction and analysis. General factorial experiments, factorial effects, best estimates and testing the significance of factorial effects, study of 23 and 24 factorial experiments in RBD.	**(15 Hrs)**
Unit - IV	Confounding in factorial experiments, complete and partial confounding. Simultaneous confounding, the double-confounding concept of generalized interaction.	**(15 Hrs)**

REFERENCES:	
1	Alok Dey (1986): Theory of block designs. Wiley Eastern
2	Das M. N. and Giri N (1997): Design and Analysis of experiments. Wiley Eastern.
3	Joshi D. D. (1987): Linear estimation and design of experiments. Wiley Eastern.
4	Montgomery. C. D. (1976): Design and analysis of experiments. Wiley, New York

DSE IV FOR STATISTICS MAJOR		
Paper Code: M-ST523(1)T	**Title:: RELIABILITY THEORY**	
Course type- Theory	**No. of credits – 4**	**No. of contact hours – 60**

OBJECTIVES

Man-made systems suffer from imperfections for several reasons. Often these imperfections lead to improper functioning resulting in failure of the system It may be the result of a defect in the system while producing it or may be because of natural component deterioration on some interacting factors. The probability of non-failure is termed reliability. Reliability models can be developed to predict the reliability of a component or a system before its implementation

OUTCOMES

At the end of the course, students become well-versed with,

1. Failure time distribution, reliability function, hazard function, etc.
2. Increasing failure rate as an effect of aging, shock models.
3. Reliability estimation in various cases.
4. Reliability growth models

Unit No.	Content	No. of Hours
Unit - I	Reliability concepts and measures, components and systems, coherent systems, reliability of coherent systems, cuts, and paths, modular compositions, bounds on system reliability, structural and reliability importance of components. Life distributions, reliability functions, hazard rate, common life distributions, exponential, Gamma, Weibull, Lognormal, etc. Estimation of parameters, confidence intervals, LR, and MLE tests for these distributions.	**(15 Hrs)**
Unit -II	Notions of aging: IFR, IFRA, NBU, DMRL, and NBUE classes and their duals, loss of memory property of the exponential distribution, closures of these classes under the formation of coherent systems, convolutions, and mixtures. Univariate shock models and life distributions Institute of Science, Nagpur - Syllabus for M.Sc. Statistics arising out of them, bivariate shock model, common bivariate exponential distributions, and their properties.	**(15 Hrs)**
Unit - III	Reliability estimation based on failure times in variously censored life tests and in tests with replacement of failed items, stress and strength reliability, and its estimation. maintenance and replacement policies, availability of repairable systems, modeling of repairable systems by a non-homogeneous Poisson process	**(15 Hrs)**

Unit - IV	Reliability growth models, probability plotting techniques, Hollander-Proschan and Deshpande tests for exponentially, tests for HPP vs. NHPP with repairable systems	**(15 Hrs)**
REFERENCES:		
1	Barlow R E and Proschan F (1985), Statistical Theory of Reliability and Life Testing	
2	Lawless J.F. (1982) Statistical Models and Methods of Life Time Data	
3	Bain L. J Engelhardt (1991), Statistical Analysis of Reliability and Life Testing Model	
4	Zacks S, Reliability Theory	
5	D C Montgomery-Design and Analysis of Experiments.	
6	R H Myers and D C Montgomery –Response Surface Methodology.	
7	J Fox: Quality through Design.	
8	J A Nelder and P McCullasn Generalized Linear Models	

DSC / DSE LAB FOR STATISTICS MAJOR		
Paper Code: M-ST524P	**PRACTICALS Based ON DSC I, II, and DSE**	
Course type- Practical	**No. of credits – 6**	**No. of contact hours – 180**

Practical No.	**Content**
Practicals on DSC I – Elementary Stochastic Processes	
1	Problems on Markov chain
2	Classification of states
3	Markov chain with absorbing barriers
4	Problems on the Poisson process
5	Determination of n-step probability
6	Tracing of the sample path
Practicals on DSC II – Testing of Hypothesis	
7	Problems on the size and power of the test
8	Problems on most powerful test
9	Construction of uniformly most powerful test
Practicals on DSE III – Linear models and Designs of experiments	
10	Analysis of missing data in RBD
11	Analysis of missing data in LSD
12	Analysis of covariance for one-way classification
13	Analysis of covariance for two-way classification
14	Analysis of BIBD
15	Analysis of Youden Square Design
16	Analysis of 2^3 and 2 factorial experiments without confounding
17	Analysis of a completely confounded factorial experiment
18	Analysis of partially confounded factorial experiment
19	Analysis of Split Plot Design

OJT **FOR STATISTICS MAJOR**		
Paper Code: M-ST525T	**Title::** INTERNSHIP / APPRENTICESHIP / FIELD PROJECT (RELATED TO DSC)	
Course type- Practical	**No. of credits – 4**	**No. of contact hours – 120**

OBJECTIVES

- Exposing students to industrial environments that cannot be replicated in a classroom.
- Providing opportunities to acquire and refine analytical and managerial skills crucial for a professional career.
- Offering hands-on experience in teamwork, thereby enhancing professional skills like communication, work ethics, conflict resolution, etc., with a lasting impact on lifelong learning and professional development.
- Establishing links between students and potential future job or research opportunities.

Methodology: 120 hours of internship in the industry (log sheet required) along with an activity report / Conduct a field survey with the analysis and report with an equal amount of work/ Any other similar activity that requires an equivalent amount of work which has to be done in other Research Institutes under the guidance of researchers or Scientists. Students can approach the industry/Research Institute directly to get the OJT-FP. There should be a supervisor from the organization/Institute from which the OJT-FP is being done apart from the internal supervisor. The completion certificate as well as the activity report should be signed by both supervisors.

REFERENCES:

1	शासन निर्णय एनईपी -2024/प्र.क्र.11 /विशि – 3 दिनांक 05.02.2024

INSTITUTE OF SCIENCE, NAGPUR

(An Autonomous Institute of Government of Maharashtra)

SYLLABUS

SEMESTER III

DSC I FOR STATISTICS MAJOR		
Paper Code: M-ST631T	**Title::** DECISION THEORY & NON PARAMETRIC METHODS	
Course type- Theory	**No. of credits – 4**	**No. of contact hours – 60**

OBJECTIVES

Decision-making is very important in all walks of life. The statistical aspect of decision-making is based on the risk involved in any decision. Some methods come out with the decision having minimum risk. The objective here is to introduce the topic to the students giving only basic knowledge of it. There are many real-life situations where the assumptions required for the application of parametric statistical methods are not satisfied. Nonparametric inference is a branch of statistics which has solutions in such situations. The course includes various non-parametric methods.

OUTCOMES

Students develop ability

● To formulate decision-making problems, methods to solve the problem by defining decision functions and risks involved, and the methods of minimizing the risk.

● How and when to apply various non-parametric methods to different types of data for testing various types of hypotheses.

●Various nonparametric tests for one sample, paired samples, and two independent samples problem.

●Concept of censoring the data, its need, and its types. Parametric and nonparametric methods of analyzing the censored data.

Unit No.	Content	No. of Hours
Unit - I	Decision problem, loss function, expected loss, decision rules (nonrandomized and randomized), decision principles (conditional Bayes, frequentist) inference, and estimation problems as decision problems, a criterion of optimal decision rules. Concepts of admissibility and completeness, Bayes rules, minimax rules, admissibility of Bayes rules. Existence of Bayes decision rules	**(15 Hrs)**
Unit -II	Definition of non-parametric test, Advantages and disadvantages of Non-parametric tests. Single sample problems : a) test of randomness b) test of goodness of fit: Empirical distribution function. Kolmogorov – Smirnov test, χ^2 test, Comparison of χ^2 test & KS test c) One sample problem of location: sign. Test, Wilcoxon's signed rank test, Wilcoxon paired sample signed rank test	**(15 Hrs)**
Unit - III	Two sample problems: different types of alternatives, sign test, Wilcoxans two-sample rank sum test, Wald-Wolfowitz run test, Mann-Whitney-Wilcoxons test, Median test, KS-two sample test. Klotz Normal score test. One sample U-statistic, Kernel and symmetric Kernel Variance of U-Statistic, two-sample U-statistic, Linear rank statistics, and their distributional properties under the null hypothesis	**(15 Hrs)**
Unit - IV	Concept of time order and random censoring, likelihood in these cases, survival function, hazard function Non-parametric Estimation of Survival function, Cox's proportional hazards model, the actuarial estimator, and Kaplan – Meier Estimator.	**(15 Hrs)**

REFERENCES:

1	Ferguson T. S.: Mathematical Statistics – A decision-theoretic approach
2	Berger J. O.: statistical decision theory and Bayesian analysis
3	Gibbons J.D.: Non-parametric Statistical inference
4	Randles and Wolfe: Introduction to the theory of nonparametric statistics

DSC II FOR STATISTICS MAJOR		
Paper Code: M-ST632T	**Title::** LINEAR &NON LINEAR MODELLING	
Course type- Theory	**No. of credits – 4**	**No. of contact hours – 60**

OBJECTIVES

Regression analysis is the most common statistical modelling approach used in data analysis and it is the basis for advanced statistical modelling. The objective of this course is to impart knowledge about the use of different useful tools in regression analysis. The relationship between variables can be of different types like linear, nonlinear, etc. The relationship is represented in terms of a model. The adequacy of any model can be checked using residual plots and residual analysis. Appropriate statistical tools are required to check for the violations of model assumptions and to deal with problems of multicollinearity etc

OUTCOMES

Students will get knowledge about

- Linear and Multiple regression.
- interpret different types of plots such as residual plots, normal probability plots, etc. To check for the violations of model assumptions using residual analysis and other statistical tests.
- To differentiate between linear and nonlinear regression under a given situation.
- Generalized Linear Models including logistic regression

Unit No.	Content	No. of Hours
Unit - I	(A) Multiple Linear regression: Model assumptions and checking for the violations of model assumption., Residual analysis – definition of residuals, standardized residuals, residual plots, statistical tests on residuals, Press statistics. Transformation of variables, Box-Cox power transformation. (B) Outliers: Detection and remedial measures, Influential observations: leverage, measures of influence, Cook's D, DFITS AND DFBETAS	**(15 Hrs)**
Unit -II	(A) Multicollinearity: Concept and definition of M.C., sources of M.C. consequences of M.C. identification of M.C. using the correlation matrix, VIF remedial measures (collecting additional data, model re-specification,), the concept of ridge regression. (B) Autocorrelation: consequences, Durbin-Watson test, Estimation of parameters in the presence of autocorrelation	**(15 Hrs)**

Unit -III	(A) Variable selection: Problem of variable selection, criteria for evaluation subset regression models (choosing subsets), coefficient of multiple determination, residual mean square, Mallow's Cp Statistics. Computational Techniques for Variable selection-Forward selection, Backward elimination, stepwise regression. (B) Non-linear regression: Difference between Linear and Non-Linear Regression Models, transformation to a linear model, Intrinsic linear and non-linear models. Parameter estimation using the Newton-Gauss method, Hypothesis testing.	**(15 Hrs)**
Unit - IV	(A) Generalized linear models: Exponential families, Definition of GLM, Link function, Estimation of parameters, and inference in GLM. (B) Logistic regression model: Link function, logit, probit, complementary log-log, estimation of parameters, odds ratio, hypothesis testing using model deviance.	**(15 Hrs)**
REFERENCES:		
1	Draper N. R. and Smith H.:Applied Regression analysis	
2	Montgomery D. C.: Linear regression analysis	

DSE V FOR STATISTICS MAJOR		
Paper Code: M-ST633T	**Title::** INDUSTRIAL PROCESS & QUALITY CONTROL	
Course type- Theory	**No. of credits – 4**	**No. of contact hours – 60**

OBJECTIVES

In industry, it is important to maintain the quality of the product. The quality of the product can be checked with the help of quality control techniques available in statistics. The course includes various methods for monitoring the quality of the product. The control charts can be used to monitor the quality of products, processes, and services in various disciplines

OUTCOMES

At the end of the course, students become well-versed with,

1. Various control charts for measurements and attributes are useful in industries.
2. EWMA, Moving average, CUSUM control charts, and multivariate control charts.
3. Concept of Six Sigma and its importance.

Unit No.	Content	No. of Hours
Unit - I	The basic concept of process monitoring General theory and review of Shewhart control charts for measurements and attributes (p, d = np, C, X, and R chart) O.C. and ARL for X control chart. General ideas on economic designing of control chart. Assumptions and costs. Duncan's model for the economic design of X chart. Moving average and exponentially weighted moving average charts. Cu-sum charts using v masks and decision intervals.	**(15 Hrs)**
Unit -II	Classification of nonconformities and their weighting modification of the c chart for Quality scores and Demerit classifications, Q chart for no. of nonconformities per (u chart), Multivariate Quality control. Hotelling's T^2	**(15 Hrs)**
Unit -III	Concept of Six Sigma. Evolution of Six Sigma Quality approach Practical approach to Six Sigma quality Basic steps involved in application of Six Sigma Define measure-Analyze improve and control approach, Barriers in implementation of Six Sigma in Indian manufacturing industries(small and medium enterprises). Impact of six sigma on a developing economy	**(15 Hrs)**
Unit - IV	Principle of acceptance sampling problem of lot acceptance. Acceptance sampling plans for attributes. Single double and sequential sampling plans and their properties Dodge Romig sampling plans for attributes (AOQL and LTPD), MIL std plans, continuous sampling plans, Dodge type	**(15 Hrs)**

REFERENCES:	
1	Montgomery D.C. (1985) Introduction to statistical quality control. Wiley
2	Montgomery D.C. (1985) Design and Analysis of Experiments Wiley
3	Grant E. L. & Leaver worth R. S. Statistical Quality control McGraHill publication
4	Amitava Mitra: fundamentals of Quality Control and Improvement

DSE VI FOR STATISTICS MAJOR		
Paper Code: M-ST523(1)T	**Title::** MATHEMATICAL PROGRAMMING	
Course type- Theory	**No. of credits – 4**	**No. of contact hours – 60**

OBJECTIVES

Optimization techniques have applications in almost all disciplines. To get an optimum solution to the problem under given constraints is always challenging. To get the best solution to such problems, different methods are depending on the problem and constraints. Various such problems and methods to solve them are part of this course

OUTCOMES

At the end of the course, students become well-versed with,

1. To formulate and solve linear programming problems (LPP). They also learn various methods to solve LPP. Application of LPP in industry, management, transportation, assignment, etc.
2. Sensitivity analysis of LPP by studying the effect of changes in coefficients of constraints on the solutions to the problem. They also learn the effect of any other changes in the constraints and, the addition of new constraints on the solution to the problem.
3. Pure and mixed integer linear programming problems and formulation of non-linear programming problems and different methods to solve them.
4. The problem is a different method of solving a two-person zero-sum game.

Unit No.	Content	No. of Hours
Unit - I	(A) L. P.: Simplex method, variants of the simplex method, duality in L. P. duality theorem, complementary slackness theorem, dual simplex method, transportation & assignment problems, method of solving transportation & assignment problems. (B) Dynamic Programming: Dynamic programming approach for solving optimization problems, forward & backward recursion formulas, minimum path problems, single additive constraint & additively separable return, single multiplicative constraint & additively separable return, single additive constraint & multiplicatively separable return	**(15 Hrs)**
Unit -II	(A) Sensitivity analysis of L. P.: Changes in R. H. S. constraint bi, changes in cost coefficient cj, changes in coefficient of constraints aij, the addition of new variables, the addition of new constraints. (B) I.L.P.P.: Pure & mixed I.L.P.P., methods for solving pure & mixed I.L.P.P. Gomory's cutting plane method.	**(15 Hrs)**
Unit - III	(A) N.L.P.P.: General N.L.P.P., convex & concave functions, text for concavity & convexity, local optimum, global optimum, basic results for local optimum & global optimum, Lagrange's methods for optimality, KT conditions (B) Q.P.P. Wolfe's & Beale's method for solving Q.P.P.	**(15 Hrs)**

Unit - IV	(A) Game theory: 2 people zero-sum game, pure & mixed strategies, saddle point of a matrix game, matrix game without saddle point, methods for solving matrix game without saddle point, 2X2, mxn, mx2, 2Xn matrix games, dominance principle, use of dominance principle in game theory, solving game problems by simplex method.	**(15 Hrs)**
REFERENCES:		
1	Gass: Linear programming	
2	Taha H. A.: Operations Research	
3	Philips, Ravindran, and Solberg: Operations research – Principles and practice	

DSC / DSE LAB FOR STATISTICS MAJOR		
Paper Code: M-ST634P	**PRACTICALS Based ON DSC I, II, and DSE**	
Course type- Practical	**No. of credits – 6**	**No. of contact hours – 180**

Practical No.	**Content**
Practicals on DSC I – DECISION THEORY & NON-PARAMETRIC METHODS	
1	Sign test
2	Wilcoxon's Signed Rank test
3	Mann-Whitney U test
4	Median test
5	Run test
6	Kolmogorov Smirnov goodness of fit test
7	Kolmogorov Smirnov two sample test
8	Problems on Bayes estimates and minimax decision rule
9	Problems on Bayes estimates and minimax decision rule using risk set
10	Problems on Bayes risks
Practicals on DSC II – LINEAR & NON-LINEAR MODELLING	
11	Problems on multiple linear regression
12	Problems on residual plots and residual analysis
13	Problems on the transformation of variables
14	Problems on outliers and influential observations
15	Problems on variable selection
16	Problems on multicollinearity
17	Fitting of non-linear regression model
18	Regression model with autocorrelated errors
19	Problems on a logistic regression model
Practicals on DSE V – INDUSTRIAL PROCESS & QUALITY CONTROL	
20	Problems on X bar and R control chart
21	Problems on OC & ARL of X bar control chart
22	Problems on the EWMA chart
23	Problems on the Moving Average control chart
24	Problems on p,d control chart (constant and variable sample size)
25	Problems on OC & ARL of p control chart
26	Problems on c,u, and U control chart
27	Problems on OC of c chart
28	Problems on single sampling inspection plan, (OC, ATI & ASN)

29	Problems on double sampling inspection plan (OC, ATI & ASN)
30	Problems on Hotelling's T^2 control chart
Practicals on DSE VI – MATHEMATICAL PROGRAMMING	
20	1) Problems on simplex method
21	2) Problems on the dual simplex method
22	3) Problems on the two-phase simplex method
23	4) Problems on Transportation
24	5) Problems on Assignment
25	6) Problems on I.P.P
26	7)Problems on NLPP
27	8)Problems on Wolfe's method
28	9)Problems on Beale's method
29	10)Problems on game theory

RP **FOR STATISTICS MAJOR**		
Paper Code: M-ST525T	**Title::** Research Project / Dissertation (Core)	
Course type- Practical	**No. of credits – 4**	**No. of contact hours – 120**

OUTCOME

After completion of this course, the students will be able to

1. read research papers

2. Formulate a statistical data analysis project involving, collection, coding, analysis (using elementary as well as advanced statistical methods), and interpretation of results

3. Prepare a presentation and report on a project

Guidelines:

1. This Research Project is an individual or group activity with a maximum of THREE students in a group.
2. As a part of this course, students should learn document preparation and Presentation. (This can be done as a part of a skill-based course as well).
3. Use real data sets for project problems, as far as possible.
4. There will be one presentation and one viva voce (each graded as per norms). In the presentation, students are expected to describe their project problem, the data they are going to analyze, and the objectives of their project. In addition to this, they should also mention their methodology. Students are expected to read at least THREE research papers that address similar kinds of problems and they should include the main contents of the papers in their first presentation as well as in the final report. In the second presentation, students should discuss the results of their analysis, findings, and new methodology they have introduced (if any). Students should make sure that they have something innovative in their project work.
5. The completed project report should be submitted to the Project Coordinator on or before the last day of the semester.
6. All project groups are expected to make the final presentation as per schedule. The project draft report as well as the final presentation will be evaluated by an external examiner (as per norms). When an external examiner is not available, the Head may appoint an external examiner from the Department with the prior permission of the Director.

INSTITUTE OF SCIENCE, NAGPUR

(An Autonomous Institute of Government of Maharashtra)

SYLLABUS

SEMESTER IV

DSC I FOR STATISTICS MAJOR		
Paper Code: M-ST641T	**Title::** MULTIVARIATE ANALYSIS	
Course type- Theory	**No. of credits – 4**	**No. of contact hours – 60**

OBJECTIVES

Multivariate Analysis is a branch of statistics where data on two or more variables are analyzed simultaneously. Most of the statistical methods in univariate analysis can be extended to the case of two or more variables. There are many situations where we need to study the effect of two or more independent variables on one variable. This is studied as an extension of simple correlation and regression in the case of one independent variable. This course consists of all such distributions, statistical methods, etc. which are multivariate analogs of corresponding univariate analysis. Many results that are derived only for multivariate cases are also included in the course.

OUTCOMES

Students develop the ability to handle multivariate data and to draw inferences from such data using the following methods.

●Concept of multiple and partial correlation and multiple regression.

●Multivariate normal distribution, estimation of parameters of the distribution and its properties. Wishart distribution and its properties.

●Hotellings T^2, its null distribution, and its applications for testing hypotheses associated with mean vector (vectors).

●Problem of classification, procedure of classification using Fisher's discriminant function. Principal component analysis is useful in dimension reduction and analysis using canonical correlation.

Unit No.	Content	No. of Hours
Unit - I	Correlation: multiple and partial correlation, Linear and multiple regression co-efficient of determination and its uses, Tests of significance of multiple and partial correlation coefficient, Multivariate normal distribution, singular and non-singular normal distribution, characteristic function, moments, marginal and conditional distributions, maximum likelihood estimators of the parameters of multivariate normal distribution	**(15 Hrs)**
Unit -II	Wishart matrix-its distribution without proof and properties, Distribution of MLEs of parameters of Multivariate Normal distribution, Distribution of sample generalized variance, Applications in testing and interval estimation, Wilks lambda [Introduction, definition, distribution (statement only)].	**(15 Hrs)**

Unit - III	Hotelling's T^2 statistic and its null distribution, Application in tests on mean vector for one and more multivariate normal populations and also on the equality of the components of a mean vector in a multivariate normal population. Application of T^2 statistic and its relationship with Mahalanobis' D^2 statistic, Confidence region for the mean vector, Applications of D^2 statistics	**(15 Hrs)**
Unit - IV	Classification and discrimination: procedures for discrimination between two multivariate normal populations. Fisher's discriminant function, tests associated with discriminant function, Sample discriminant function, Probabilities of misclassification and their estimation, and Classification into more than two multivariate populations. Principal components, Dimension reduction, Canonical variables, and Canonical correlation, definition, use, estimation, and computation.	**(15 Hrs)**
REFERENCES:		
1	Anderson T. W.: An introduction to multivariate statistical analysis	
2	Kshirsagar A. M.: Multivariate analysis	
3	Rao C. R.: Linear statistical inference and its applications	

DSC II FOR STATISTICS MAJOR		
Paper Code: M-ST642T	**Title::** COMPUTATIONAL STATISTICS	
Course type- Theory	**No. of credits – 4**	**No. of contact hours – 60**

OBJECTIVES

In many disciplines, results are established with the help of the data by fitting a suitable model. Analyzing the data plays an important role in such cases. Advanced statistical methods and different types of models can be applied to these data, even very big data. The course deals with different computational methods and algorithms necessary for the analysis of the data. The course includes different methods that are particularly useful in simulating data from various distributions and analyzing them with the help of computers.

OUTCOMES

Students get knowledge about

Visualization of data and exploratory data analysis.

●Stochastic simulation techniques like MCMC.

●Some important methods of handling missing data and incomplete data problems like EM algorithm etc.

● Jackknife, Bootstrap, and nonparametric density estimation using kernels.

Unit No.	Content	No. of Hours
Unit - I	(A) Exploratory data analysis: Components of EDA, transforming data, Clustering: Similarity measures, similarity coefficients, (B) Hierarchical clustering methods: single, complete, and average linkage methods, dendrograms. (C) Graphical Methods: Quintile plots, Box Plots, Histograms, Stem & leaf diagrams, Q-Q plots, P-P plots,	**(15 Hrs)**
Unit -II	(A) Stochastic simulation: generating random variables from discrete and continuous distributions, simulation bivariate/multivariate distributions, and simulating stochastic processes such as simple queues. Variance reduction technique: Importance sampling for integration, control variates, and antithetic variables. (B) MCMC methods: Essence of MCMC methods, Time reversible MC, Law of large numbers for MC. Metropolis-Hastings algorithm, Gibbs sampling for bivariate/ multivariate simulation, Simulated annealing for optimization, simulated annealing for M.C. (C) Simulation-based testing: simulating test statistics and power functions, permutation/randomization tests.	**(15 Hrs)**

Unit -III	(A) Resampling paradigms: Jackknife and Bootstrap: Delete one J-K, pseudo values, Bias and S.E. Efron's bootstrap, Bootstrap C.I. Bootstrap-t C.I, Bootstrap C.I. (percentile method), Bootstrap in regression, Bootstrap C.I. for linear regression parameters.	**(15 Hrs)**
Unit - IV	(A) EM algorithm: Application to missing and incomplete data problems. Mixture models. (B) Smoothing with Kernels: Density estimation, kernel density estimator for univariate data, Bandwidth selection and cross-validation, Max likelihood L CV, Least square CV.	**(15 Hrs)**
REFERENCES:		
1	Jun S. Liu: Monte Carlo Strategies in Scientific Computing, Springer series in statistics, 2001	
2	Efron B. and Tibsirani J. R.: An Introduction to Bootstrap	
3	Ross S. M.: Applied Probability models	

DSE VII FOR STATISTICS MAJOR		
Paper Code: M-ST643T	**Title::** INDUSTRIAL STATISTICS	
Course type- Theory	**No. of credits – 4**	**No. of contact hours – 60**

OBJECTIVES

The objective here is to introduce to the students a branch of statistics that helps in maintaining quality in the industry. The course contains various methods for quality maintenance.

OUTCOMES

At the end of the course, students become well-versed with,

1. Use of design of experiments for quality improvement and process Capability Analysis, various capability indices.
2. Taguchi's philosophy of quality,
3. Failure model, effect, and criticality analysis.

Unit No.	Content	No. of Hours
Unit - I	Quality Systems: ISO 9000 standards. QS 9000 standards. Total quality management (TQM): Different definitions and dimensions of quality, basic concept, Total Quality Management Models, Quality Management Tools, Six Sigma and Quality Management, What is Kaizen? - Five S of Kaizen, Role of Managers in TQM, Role of Customers in Total Quality Management, Comparison of Six Sigma and TQM, Reasons for failure of TQM, Deming's 14 point program, Continuous quality improvement, PDSA cycle, Jurantriology, Quality Gurus	**(15 Hrs)**
Unit -II	Use of Design of experiments in SPC factorial experiments, fractional factorial design. Half fraction of the 23 factorial design Basic ideas of response surface methodology. Institute of Science, Nagpur - Syllabus for M.Sc. Statistics Specification limits, Natural tolerance limits, and control limits. Process capability analysis (PCA): Process capability analysis using a Histogram, and using a control chart.	**(15 Hrs)**
Unit -III	Probability plotting capability indices Cp, Cpk, and Cpm comparison of capability indices. Estimation confidence intervals and tests of hypothesis relating to capability indices for Normally distributed characteristics. Index Cpc for non-normal data.	**(15 Hrs)**
Unit - IV	Quality at the Design stage. Quality function deployment failure mode and effect analysis.Taguchi philosophy system parameter and tolerance designs. Loss functions. Determination of manufacturing Tolerances. Signal-to-noise ratio and performance measures critique of S/N ratios.]	**(15 Hrs)**

REFERENCES:	
1	Montgomery D.C. (1985) Introduction to statistical quality control. Wiley
2	Montgomery D.C. (1985) Design and Analysis of Experiments Wiley
3	Grant E. L. & Leaver worth R. S. Statistical Quality control McGraHill publication
4	Amitava Mitra: fundamentals of Quality Control and Improvement
5	Oakland J. S. : (1989) Total quality management, Butterworth Heinemaah 14
6	K. Shridhara Bhat: Total quality management, Himalaya Publishing House
7	C. B. Michna: D. H. Besterfield Total quality management, Pearson Education.
8	Phadke M. S. (1989) Quality Engineering through Robust design. Practice Hall.
9	Logothelis N. (1992) Managing total quality, Prentice Hall of India.
10	Oakland J. S.: Statistical Process control Heinemach Professional publishing.
11	Grant E. L. & Leaver worth R. S. Statistical Quality control McGraHill publication

DSE VIII FOR STATISTICS MAJOR		
Paper Code: M-ST643(1)T	**Title::** Operations Research	
Course type- Theory	**No. of credits – 4**	**No. of contact hours – 60**

OBJECTIVES

Operations research deals with the application of advanced analytical methods which helps in making better decisions. The course includes advanced techniques that are useful in business, management, industry, project planning, etc.

OUTCOMES

Students get theoretical knowledge and the applications of the advanced techniques in O.R. in business, management, industry, project planning, etc. through topics like

- Concept of inventory problem, need of inventory types of inventory models, and types of probabilistic inventory models.
- Sequencing problems and methods to solve sequencing problems in different situations
- Concept of queues, different types of queues, and their analysis.

Unit No.	Content	No. of Hours
Unit - I	Inventory problems: Structure of inventory problem, EOQ formula, EOQ model with uniform rate of demand & having no shortages, EOQ model with different rate of demand in different cycles having no shortages, EOQ model with uniform rate of demand & finite rate of replenishment having no shortages, EOQ model with uniform rate of demand & finite rate of replenishment having shortages, EOQ model with uniform rate of demand, infinite rate of replenishment having shortages, EOQ model with single & double price breaks.	**(15 Hrs)**
Unit -II	Single-period probabilistic inventory models with i) instantaneous demand & discrete units ii) instantaneous demand& continuous units iii) Continuous demand & discrete units iv) Continuous demand & continuous units	**(15 Hrs)**
Unit - III	**Sequencing Problems**: Processing n jobs through two machines, Processing n jobs through three machines, Processing2 jobs through m machines, Processing n jobs through m machines, **Traveling salesman problem,** **Queuing Models** : (M/M/1 : FCFS/∞/∞) & its generalization , (M/M/1 : FCFs/N/∞) , (M/M/C/ : FCFS/∞/∞), (M/Ek/1 : FCFS /∞/∞/)	**(15 Hrs)**

Unit - IV	Basic steps in PERT & CPM, methods of solving PERT problem, crashing the network, updating (PERT & CPM) max. flow min. cut theorem, problems based on max. flow min. cut theorem	**(15 Hrs)**
REFERENCES:		
1	Taha H. A.: Operations Research	
2	Hiller & Liberman; Introduction to Operations research	
3	Kantiswaroop Gupta and Singh: Operations research	
4	Gross D and Harris C. M.: Fundamentals of queueing theory	

DSC / DSE LAB FOR STATISTICS MAJOR		
Paper Code: M-ST644P	**PRACTICALS Based ON DSC I, II, and DSE**	
Course type- Practical	**No. of credits – 6**	**No. of contact hours – 120**

Practical No.	**Content**
Practicals on DSC I – MULTIVARIATE ANALYSIS	
1	Problems on multiple and partial correlation and regression
2	Applications of Hotelling T^2 Statistic
3	Problems on Canonical Correlation
Practicals on DSC II – COMPUTATIONAL STATISTICS	
4	Generation of random numbers
5	Drawing of random samples from various probability distributions
6	Problems on the convolution method
7	Drawing random samples using the acceptance-rejection technique
8	Problems on the Monte Carlo technique
9	Problems on clustering
10	Problems on Jack- Knife and Bootstrap
11	Problems on Variance reduction technique
Practicals on DSE VII – INDUSTRIAL STATISTICS	
12	Problems on process capability indices
13	Process capability using Histogram
14	Process capability using pp/qq plot
15	Problems on the S/N ratio
Practicals on DSE VIII – OPERATIONS RESEARCH	
16	Problems on inventory models(Deterministic
17	Problems on inventory models(Probabilistic)
18	Problems on sequencing
19	Problems on queuing theory
20	Problems on CPM and PERT

RP **FOR STATISTICS MAJOR**		
Paper Code: M-ST645T	**Title::** Research Project / Dissertation (Core)	
Course type- Practical	**No. of credits – 6**	**No. of contact hours – 180**

OUTCOME

After completion of this course, the students will be able to

1. Formulate a statistical research problem and solve it
2. Write One/Two Research papers and publish them in a Scopus Indexed Journal
3. Prepare presentation and project report
4. Prepare Research Papers

Guidelines:

1. A Research Project is an individual or group activity with a maximum of THREE students in a group. Students will formulate a problem develop a new methodology/algorithm for solving the proposed problem and Prepare a report
2. Preparation of ONE/TWO research papers is mandatory for this project. Thus, the original contribution in the form of an algorithm or methodology is mandatory.
3. There will be one presentation and one viva voce (each graded as per norms. In the presentation, students are expected to describe their project problem, the data they are going to analyze, and the objectives of their project. In addition to this, they should also mention their methodology. Students are expected to read at least THREE research papers that address similar kinds of problems and they should include the main contents of the papers in their first presentation as well as in the final report. In the second presentation, students should discuss the results of their analysis, findings, and new methodology they have introduced (if any). Students should make sure that they have something innovative in their project work.
4. The completed project report should be submitted to the Project Coordinator on or before the last day of the semester.
5. All project groups are expected to make the final presentation as per schedule. The project draft report as well as the final presentation will be evaluated by an external examiner as per norms. When an external examiner is not available, the Head may appoint an external examiner from the Department with prior permission of the Director