DDU GORAKHPUR UNIVERSITY, GORAKHPUR
DEPARTMENT OF MATHEMATICS AND STATISTICS

National Education Policy-2020
Choice Based Credit System (CBCS)

Syllabus

for

PG Two Year Programme

In

STATISTICS

(Effective from Academic Session 2024-2025)

Title of the Program: PG (Statistics)

based on

National Education Policy-2020

In

Choice Based Credit System (CBCS)

The proposed curriculum is expected to provide the students a good overall knowledge of Statistics covering various aspects. They will not only be able to understand the important statistical techniques but also able to apply some commonly used statistical techniques to other fields. To familiarize students with computational techniques and software used in the statistical/data science arena. As a result, they can pursue their future career either in the core field or in the applied field of Statistics. Training in statistical computing will enhance their job opportunities and professional skills.

Semester Courses of PG Statistics Based on CBCS

The course of PG (Statistics) will be spread in two years – 1st and 2nd Year. Each of which will have two semester examinations and therefore will be four semester examinations.

Subject Prerequisites

To study this subject a student must had the subject(s) Mathematics in class UG.

Eligibility for Admission

For PG in Statistics following candidates are eligible.

- Eligibility for admission in this course, a student must have the major subject Mathematics/Statistics in the third year of UG Degree.

'OR'

- Eligibility for admission in this course, a student must have B.Tech. Degree in any Branch/ BCA Degree.

Program Specific Outcomes (PSOs)

PSO 1. The proposed curriculum is expected to provide the students a good overall knowledge of Statistics covering various aspects. As a result, they will not only be able to understand the important statistical techniques but also able to apply some commonly used statistical techniques to other fields.

PSO 2. To enrich the ability of critical thinking, analytical and scientific reasoning to solve problems.

PSO 3. To develop understanding of Statistics and motivating the students to use Statistical techniques as a tool in the study of other scientific domains.

PSO 4. To encourage students for research studies in Statistics and related fields.

PSO 5. To provide students a wide variety of employment options as they can adopt research as a career or take up teaching jobs or can get employment in banking or can go for any other profession.

PSO 6. To inculcate problem solving skills, thinking and creativity through presentations, assignments and project work.

PSO 7. To help students in their preparation for competitive exams.

PSO 8. To enable the students being life-long learners who are able to independently expand their Statistical expertise when needed.

Program Duration

The duration of the PG Statistics program for the candidates admitted in semester I will be of two academic years (4 semesters). There are two regular semesters in an academic year.

Examination and Assessment

As prescribed by the University (as per common ordinance for examination and assessment).

Program Structure

PG Statistics program is of minimum 92 credits spread over four semesters in Choice Based Credit System (CBCS). Overall total 23 courses are well spread over 4 semesters. These courses are divided in to five categories- Core Courses (**4 credit each**), Discipline Specific Elective (DSE) Courses (**4 credit each**), Practical (**4 credit each**), Open Minor Elective (ME) Course (**4 credit each**) and Project Work (**4 Credit each**).

Number of Courses and Credits

S.No.	Types of course	Credit per course	Total Number of course Type	Total credit for the particular type
1	Core	4+0	12	48
2	Discipline Specific Elective	4+0	4	16
3	Open Minor Elective/ Open Elective/	3+1	1	4
4	Practical	0+4	4	16
5	Dissertation/Research Project/ Project	0+4	2	8
Total				92

SEMESTER WISE BREAK-UP OF COURSES

S.No	Types of course	Semester I	Semester II	Semester III	Semester IV	Total
1	Core	4(16)	4(16)	2(8)	2(8)	48
2	Discipline Specific Elective	-----	------	2(8)	2(8)	16
3	Open Minor Elective/ Open Elective	----	1(4)	----	-----	4
4	Practical	1(4)	1(4)	1(4)	1(4)	16
5	Dissertation/ Research Project/ Project	---	---	1(4)	1(4)	8
Total		4+1(20)	4+1+1(24)	4+1+1(24)	4+1+1(24)	23(92)
		44		48		

The program emphasizes both theory and applications of statistics and is structured to provide knowledge and skills in depth necessary for the employability of students in industry, other organizations, as well as in academics. The program has some unique features such as independent projects, number of elective courses, extensive computer training of statistical computations. The independent project work is one of the important components of this program. In all semesters I, II, III & IV some courses are compulsory and others are elective. The syllabus has been framed to have a good balance of theory, methods and applications of statistics.

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FIRST SEMESTER

Course Code	Course Title	Course Type	Credits
STAT- 501N	Probability Theory	Core	**4+0**
STAT- 502N	Distribution Theory	Core	**4+0**
STAT- 503N	Demography	Core	**4+0**
STAT- 504N	Statistical Computing	Core	**4+0**
STAT- 505N	Practical (Based on theory courses)		**0+4**
Total Credits			**20**

SECOND SEMESTER

Course Code	Course Title	Course Type	Credits
STAT- 506N	Inference-I	Core	**4+0**
STAT- 507N	Theory of Sample Survey	Core	**4+0**
STAT- 508N	Multivariate Analysis	Core	**4+0**
STAT- 509N	Operations Research-I	Core	**4+0**
STAT- 510N	Practical (Based on theory courses)		**0+4**
STAT- 500N	Data Analysis	Open Minor Elective Course/ Open Elective Course	**3+1**
Total Credits			**24**
Total Credits (I +II Semesters) (including minor elective in semester II)			**44**

Note: 1. The open minor elective paper/ open elective paper must be from other PG programme (from same/ other faculty) other than core course/discipline specific course.
Note: 2. The open minor elective paper/ open elective paper is to be taken in semester-II only.

THIRD SEMESTER

Course Code	Course Title	Course Type	Credits
STAT- 511N	Inference-II	Core	**4+0**
STAT- 512N	Linear Models and Regression Analysis	Core	**4+0**
Any two of the following Discipline Specific Elective (DSE) Courses			
STAT- 513N	Operations Research-II	DSE	**4+0**
STAT- 514N	Mathematical Epidemiology	DSE	**4+0**
STAT- 515N	Design of Experiments	DSE	**4+0**
STAT- 516N	Survival Analysis	DSE	**4+0**
STAT- 517N	Statistical Decision Theory	DSE	**4+0**
STAT- 518N	Practical (Based on theory courses)		**0+4**
STAT- 519N	Project		**0+4**
Total Credits			**24**

FOURTH SEMESTER

Course Code	Course Title	Course Type	Credits
STAT- 520N	Bayesian Inference	Core	**4+0**
STAT- 521N	Computer-Intensive Statistical Methods	Core	**4+0**
Any two of the following Discipline Specific Elective (DSE) Courses			
STAT- 522N	Reliability Theory	DSE	**4+0**
STAT- 523N	Machine Learning	DSE	**4+0**
STAT- 524N	Economic Statistics and Statistical Quality Control	DSE	**4+0**
STAT- 525N	Actuarial Statistics	DSE	**4+0**
STAT- 526N	Stochastic Processes	DSE	**4+0**
STAT- 527N	Econometrics	DSE	**4+0**
STAT- 528N	Practical (Based on theory courses)		**0+4**
STAT- 529N	Dissertation/ Research Project		**0+4**
Total Credits			**24**
Total Credits (III+IV Semesters)			**48**
Total Credits (I+II+III+IV Semesters)			**92**

M.A. /M.Sc. (Statistics) First Semester
Compulsory (Core) Courses

Course Code	Course Title	Course Type	Credits
STAT- 501N	**Probability Theory**	**Core**	**4+0**

Objectives:
This course will lay the foundation of probability theory and statistical modelling of outcomes of real-life random experiments through various statistical distributions.

Unit-I
Classes of sets, field, sigma field, minimal sigma field, Borel field, sequence of sets, limits of a sequence of sets, measure, probability measure, Integration with respect to measure.
Random experiment, outcomes, sample space, events, various definitions of probability, laws of total and compound probability. Boole's inequality. Conditional probability, independence of events. Bayes Theorem.

Unit-II
Random variable, probability mass function, probability density function, cumulative distribution function. Expectation of a random variable, properties of expectation. Bivariate distributions and the joint probability distribution. Independence of random variables. Marginal and conditional distributions. Conditional expectation and its properties.

Unit-III
Moment generating function, probability generating function, cumulant generating function, characteristic function and their properties. Inversion, continuity and uniqueness theorems.

Unit-IV
Convergence in probability, almost sure convergence, convergence in distribution and their relationships. Chebyshev's inequality, weak law of large numbers (WLLN), strong law of large numbers (SLLN), central limit theorems.

Suggested Readings:

1. Rohatgi V.K. & Saleh A.K. Md.E. (2015). An Introduction to Probability and Statistics, 3rd Edition. Wiley.
2. Rao, B.L.S.P. (2010): A First Course in Probability and Statistics. World Scientific.
3. Hogg, R.V., McKean, J. & Craig, A.T. (2013). Introduction to Mathematical Statistics, 7th Ed. Pearson.
4. Mukhopadhyay, P. (2015). Mathematical Statistics. New Central Book Agency

Course Outcomes:
After completing this course, student is expected to learn the following:

- **CO 1.** Understand the concepts of random variables, sigma-fields generated by random variables.
- **CO 2.** Learn probability distributions and independence of random variables related to measurable functions.
- **CO 3.** Gain the ability to understand the concepts of different types of generating function, sequence of random variables, convergence, modes of convergence of sequence of random variables.
- **CO 4.** Learn the concepts of weak and strong laws of large numbers, and central limit theorem.

Course Code	Course Title	Course Type	Credits
STAT- 502N	Distribution Theory	Core	4+0

Objectives:

The main objective of the course is to provide the detailed knowledge of the characterization of all the useful discrete and continuous distributions.

UNIT-I

Brief review of basic distribution theory. Joint, marginal and conditional p.m.fs. and p.d. fs Discrete Probability Distributions and their properties: Bernoulli, Binomial, Poisson distribution, Hypergeometric, Geometric and Negative Binomial, and Multinomial distributions.

UNIT-II

Continuous probability distributions and their properties: Exponential, Gamma, Beta, Cauchy, Laplace, Pareto, Weibull, Normal and Log normal distributions.

UNIT-III

Central and Non-central Chi-square, t and F distributions with their properties Bivariate Normal Distribution and its properties: Marginal and conditional distributions and moment generating function.

UNIT-IV

Functions of random variables and their distributions using Jacobian of Transformation and other tools. Compound, truncated and mixture distributions. Conditional expectation.
Order statistics –their distributions and properties.

Suggested Readings:

1. Krishnamoorthy, K. (2015). Handbook of Statistical Distributions with Applications, 2nd Ed. CRC Press.
2. Rohatgi V.K. & Saleh A.K. Md.E. (2015). An Introduction to Probability and Statistics, 3rd Edition. Wiley.
3. Goon, A.M., Gupta, M.K. & Dasgupta, B. (2016). Fundamentals of Statistics, Vol. I. World Press.
4. Forbes, C., Evans, M., Hastings, N. & Peacock, B. (2010). Statistical Distributions, 4th Edition. Wiley

Course Outcomes:

After completing this course, student is expected to learn the following:

- **CO 1.** Formulate the mathematical and statistical models for real data sets arising in various fields in order to analyze in respect of various useful characteristics of the populations.
- **CO 2.** Understand how to use univariate distributions in real life problems.
- **CO 3.** Understand central and Non-central chi-square, t and F distributions.
- **CO 4.** Work with bivariate normal and multivariate normal distribution, which is a challenging problem in today's life.

Course Code	Course Title	Course Type	Credits
STAT- 503N	**Demography**	**Core**	**4+0**

Objectives :

The main objective of the course is to describe current population trends, vital rates in terms of fertility, mortality, migration and population growth, which leads to production and planning of future population.

Unit-I

Source of demographic data. Scope and application of demography. Population composition and its measures. Dependence ratio, Basic Demographic equation.

Unit-I

Measures of fertility: Crude birth rate, general fertility rate, age-specific birth rate, total fertility rate (TFR). Measurement of population growth: Gross reproduction rate (GRR) and net reproduction rate (NRR).

Unit-III

Measures of mortality: Crude, standardized and age-specific death rate, infant mortality rates. Complete life table and its main features, Construction of Abridged life table by Grevilles method, Reed and Marrel method. Uses of life table.

Unit-IV

Theory of migration, types and measures of migration, migration rates. Volume of migration and its estimation. Nuptiality analysis and Population projection.

Suggested Readings:

1. Keyfitz, N. (1977) Applied Mathematical Demography John Wiley & Sons N.Y.
2. Cox P.R. (1976): Demography, Cambridge University Press.
3. Spiegelman, M. (1980) Introduction to Demography Harvard University Press
4. R. Ramakumar (1986): Technical Demography, Wiley Eastern limited.

Course outcomes:

After the completion of the course the student shall be able to

CO 1. Identify principal course of demographic data and their strengths and weaknesses.

CO 2. Discuss the demographic significance of age sex structure and their implications on society

CO 3. Develop analytical abilities of different demographic concept in quantitative term.

CO 4. In position to identify the components of population change and their effect and influence in human society

Course Code	Course Title	Course Type	Credits
STAT- 504N	Statistical Computing	Core	4+0

Objectives:

The objective of the course is to provide the understanding of linear algebra, matrix algebra and optimization. To enhance the programming skills and working knowledge of R software. The need and scope of modern data analysis techniques.

Unit-I

Introduction to Data Science and statistical computing. Elements of modern data analysis techniques: Tools for data analysis (numerical and visual summaries): descriptive statistics with graphics, Bivarite data : correlation and regression analysis, representation of multivariate data and its visualization.

Unit-II

Exploratory data analysis: Empirical Distribution Function and its properties, quantile function,

Introduction to object-oriented programming, simple syntax, loops, functions, arrays, input/output, workspace and files, scripts and packages.

Linear Algebra : Solutions of matrix equations, generalized inverse, Idempotent matrices, Real quadratic forms, index and signature, triangular reduction of a positive definite matrix. Eigen values and vectors, algebraic and geometric multiplicity of eigen values, vector and matrix differentiation.

Unit-III

Numerical integration of one variable function. Solution of non-linear equations: Roots extraction using different methods, Newton-Raphson and other iterative procedures. Numerical optimization, Matrix computation: addition, subtraction, transpose, multiplication, inverse, eigen values, eigen vectors and Spectral decomposition of a real symmetric matrix. singular value decomposition, Solution of system of linear equations.

Unit-IV

Probability distributions: Computation of pdf, cdf, percentiles(tail areas) and relevant measures of location and dispersion of various univariate continuous probability distributions and associated graphics.

Stochastic simulation: Inverse-transform method, generation of random samples from various univariate probability distributions in R

Suggested Readings:

1. Dalgaard, P.(2008). Introductory Statistics with R. Springer, 2nd edition.

2. Gentle, J.E.(2003). Random Number Generation and Monte Carlo Methods, Springer.

3. Rubinstein, R.Y. (1981). Simulation and the Monte Carlo Method, Wiley.

4. Venables, W. N. and Ripley, B. D. (2002). Modern Applied Statistics with S, Fourth Edition, Springer, New York.

Course Outcomes:

After the completion of the course, the student shall be able to

- **CO 1.** understand linear algebra and matrix algebra.
- **CO 2.** apply the modern data analysis techniques
- **CO 3.** computation of various quantities associated with probability distributions.
- **CO 4.** use R programming with some basic notions for developing their own simple programs and visualizing graphics in R.
- **CO 5.** perform Computation using R programming.

Course Code	Course Title	Course Type	Credits
STAT- 505N	**Practical (Based on theory courses)**	**Core**	**0+4**

The practical for course code STAT- 505N is based on theory course.

PG (Statistics) Second Semester
Compulsory (Core) Courses

Course Code	Course Title	Course Type	Credits
STAT- 506N	Inference-I	Core	4+0

Objectives: The main purpose is to make an individual understand basic theoretical knowledge about fundamental principles of statistical inference.

Unit-I

Parametric models, Point estimation. Criteria of a good estimator: unbiasedness, consistency, efficiency and sufficiency. Concept of mean squared error. Fisher-Neyman factorization theorem, Family of distributions admitting sufficient Statistic. Point estimation methods: Likelihood functions, Maximum likelihood method (MLE) Examples from standard discrete and continuous models (such as Bernoulli, Poisson, Binomial, Normal, exponential, Gamma and uniform etc.)

Unit-II

Plotting Likelihood Functions for these models upto two parameters, moments and Least squares methods. Method of minimum chi-square and percentiles. Properties of maximum likelihood estimator. Successive approximation to MLE, Method of scoring and Newton-Raphson method. Cramer-Rao inequality and its attainment, Completeness and minimal sufficient statistic, Ancillary statistic, Basu theorem.

Unit-III

Uniformly minimum variance unbiased estimator (UMVUE). Rao-Blackwell and Lehmann-Scheffe theorems and their applications. Statistical Hypothesis, critical region, types of errors, level of significance, power of a test, Test function, Randomized and non-randomized tests, Most powerful test and Neyman-Pearson lemma. MP test for simple null against simple alternative hypothesis.

Unit-IV

Extension of these results to distribution with MLR property, UMP tests for simple null hypothesis against one sided alternatives and for one sided null against one sided alternatives in a one parameter exponential family. MLR family of distributions, unbiased test. Uniformly most powerful unbiased test.

Suggested Readings:

1. George Casella, Roger L. Berger, Statistical Inference, 2nd ed., Thomson Learning.
2. Mukhopadhyay P.: Mathematical Statistics, New central Book Agency (P) Ltd. Calcutta.
3. Rao, C.R.: Linear Statistical Inference and its Applications, 2nd ed, Wiley Eastern.
4. Rohatgi, V.K.: An Introduction to Probability Theory and Mathematical Statistics, Wiley Eastern.
5. Goon, Gupta & Das Gupta: An Outline of Statistical Theory, Vol. II, World Press.
6. Hogg, R.V. and Craig, A.T.: Introduction to Mathematical Statistics, McMillan.
7. Kale, B.K. : A First Course on Parametric Inference, Narosa Publishing House.
8. Lehmann, E.L. Testing Statistical Hypotheses, Student Editions.

Course Outcomes:

CO 1. Learning different estimation techniques.

CO 2. Learning properties of a good estimator.

CO 3. Learning to develop estimators for estimating population parameter.

CO 4. Learning basics of testing of hypothesis, calculation of type I and type II error.

CO 5. Learning the concept of MVBUE, MVUE, UMVUE.

CO 6. Knowledge of construction of MP test and UMP test

Course Code	Course Title	Course Type	Credits
STAT- 507N	Theory of Sample Survey	Core	4+0

Objectives:
The main objective is to provide the knowledge of concept of sample and population in statistics and also the various sampling schemes. Estimation of population parameters and their respective standard errors.

Unit-I
Basic finite population. Sampling techniques (SRSWR/SRSWOR, Stratified, Systematic) and related results on estimation of population mean/total. Allocation problem in Stratified sampling.
Ratio method of estimation, optimum properties of ratio estimator, unbiased ratio type estimators, ratio method of estimation in stratified sampling.
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Unit-II
Regression method of estimation, regression estimators, Product method of estimation. Cluster sampling with equal and unequal size clusters. Two-stage sampling: Two-stage sampling with equal number of second stage units, allocation of units at different stages.

Unit-III
Sampling with varying probabilities : PPS sampling wr/wor methods (including Lahiri's scheme) and related estimators of a finite population mean (Hansen-Hurwitz and Desraj estimators for a general sample size and Murthy's estimator for a sample of size 2);

Unit-IV
Horvitz-Thompson estimator (HTE) of a finite population total/mean; expressions for variance and its unbiased estimator; issue of non-negative variance estimation, IPPS schemes of sampling due to Midzuno-Sen. Randomized responses technique; Warner's model; related and questionnaire methods.

Suggested Readings:

1. Chaudhuri, A. and Mukerjee, R. (1988): Randomized Response: Theory and Techniques. Marcel Dekker Inc.
2. Cochran, W.G.(1984): Sampling Techniques (3rd Edition, 1977). Wiley
3. Murthy, M.N.(1977): Sampling Theory & Methods. Statistical Publishing Society, Calcutta.
4. Sukhatme et al (1984): Sampling Theory of Surveys with Applications. Iowa State University Press & IARS.
5. Singh. D. and Chaudhary, F.S. (1986): Theory and Analysis of Sample Survey Designs. New Age International
6. Mukhopadhyay, P. (1996): Inferential problems in survey sampling. New Age Internetional (P).
7. Des Raj and Chandak (1998): Sampling Theory. Narosa

Course Outcomes:
After successful completion of this course, student shall be able to

CO 1. Learn the basic concept of sampling and related terminologies.
CO 2. Understand various types of sampling schemes, with their advantages and disadvantages, and estimation of population parameters with their standard errors.
CO 3. Learn the use of auxiliary information in the ratio and regression method of estimation.
CO 4. Understand need of cluster and two stage sampling.
CO 5. Learn sampling with varying probabilities
CO 6. Understand some estimation techniques with special reference to non-response problems.

Course Code	Course Title	Course Type	Credits
STAT- 508N	Multivariate Analysis	Core	4+0

Objectives:

The main objective of the course is to simplified or reduced the dimension of data without sacrificing valuable information and make interpretation easier by canonical correlation, principal component, Hotelling T^2 and Mahalanobis D^2

Unit-I

Multivariate Normal Distribution and its properties, Marginal and Conditional Distributions, Moment Generating and Characteristics functions.

Unit-II

Sample from multivariate normal distribution, unbiased estimators of Mean vector and Dispersion matrix, Maximum Likelihood Estimation of Mean vector and Dispersion matrix.

Unit-III

Hotelling's T^2 statistic, its pdf and properties. Wishart distribution and its properties. Mahalnobis D^2. Use of T^2 and D^2 . Wilk's lambda.

Unit-IV

Canonical Correlation and variables, properties and their estimation. Principal Component of multivariate observation and its interpretation.

Suggested Readings:

1. Anderson T.W. (1983): An Introduction its multination analysis. John Wiley & Sons.
2. Kshirsagar A.M. (1972): Multivariate Analysis. Marcel Dekker.
3. Giri N.C. (1977): Multivariate Statistical Inference, Academic Press.
4. Sharma, S. (1966): Applied Multivariate Techniques John Wiley & Sons.
5. Rao, C.R. (1973) : Linear Statistical Inference and its applications, John Wiley and Sons.

Course Outcomes:

After completion of the course the student shall be able to

CO 1. Develop the interrelationships between two or more sample objects

CO 2. Analyse the interrelationship of the variables along the maen and variance and some other characteristic related to univariate analysis.

CO 3. Estimate and interpret the extent or amount of relationship among the variables.

Course Code	Course Title	Course Type	Credits
STAT- 509N	Operations Research-I	Core	4+0

Objectives:

Operations research is included in M.Sc. classes due to its wide application in our daily life. Operations research is an important course in applied mathematics because it is .very useful in Industry, banking, Defense sector, and Multinational companies etc. to optimize their performance.

Unit-I

Inventory Control: Introduction, Classification of Inventory, Economic parameter associated with inventory problems, Deterministic and Probabilistic models with without leadtime.

Unit-II

Sequencing Problems: Assumptions for sequencing problem. Processing n jobs on two machines, n jobs on three machines, 2 jobs on m machines, Problem of Replacement, Individuals and Group replacement policies.

Unit-III

Network analysis: Basic concepts and definition. Network drawing and analysis Critical path method. Labelling method. Methods based on time estimates to find critical path. Concept of slack and float. Resource levelling and time-cost trade-off analysis. Time-cost optimization procedure. Project crashing. PERT. Requirements for application of PERT technique. Practical limitations in using PERT. Differences in PERT and CPM.

Unit-IV

Non-Linear Programming: Introduction and definitions. Formulation of non-Linear programming problems, General non-linear programming problems. Kuhn-Tucker conditions, Lagrangian Method, Constrained optimization with equality constraints. Constrained optimization with inequality constraints. Saddle point problems Saddle points and NLPP. Wolfe's and Beale's method to solve Quadratic Progamming problem.

Suggested Readings:

1. S.D.Sharma: Operations Research, Kedar Nath Ram Nath & Company.
2. S.S.Rao: Optimization Theory and Applications, Wiley Eastern Ltd.,New Delhi.
3. J.K.Sharma: Operations Research–Theory and Applications, Macmillan India Ltd.
4. H.A.Taha: Operations Research–An Introduction, Macmillan Publishing Co.,Inc.,New York.
5. Kanti Swarup, P.K.Gupta, ManMohan: Operations Research, Sultan Chand and sons, New Delhi.
6. B.S. Goel, S.K.Mittal: Operations Research, Pragati Prakashan ,Meerut.
7. P.K.Gupta, D.S.Hira: Operatons Research–An Introduction, S.Chand & Company Ltd., NewDelhi.

Course Outcomes:

After the completion of the course, the student shall be able to

CO 1. apply it in different sectors of research field like game theory, job sequencing, network analysis, dynamical programming etc.

CO 2. do their research work in different interdisciplinary areas.

CO 3. get hired by most of the companies as OR technician since companies require OR experts to get maximum output out of minimum resources.

Course Code	Course Title	Course Type	Credits
STAT- 510N	**Practical (Based on theory courses)**	**Practical**	**0+4**

The practical for course code STAT- 510N is based on theory course.

Open Minor Elective Course/ Open Elective Course

Course Code	Course Title	Course Type	Credits
STAT- 500N	Data Analysis	Open Minor Elective Course	3+1

Objectives

The objective of this course is to define a variety of basic statistical terms and concepts, solve fundamental statistical problems, understanding of statistical fundamentals to interpret data.

Unit-I

Introduction to data science, Descriptive Statistics: Meaning, need and importance of statistics. Types of statistical data: primary and secondary data, Attributes and variables. Measurement and measurement scales. Collection and tabulation of data. Diagrammatic representation of frequency distribution: histogram, frequency polygon, frequency curve, ogives, stem and leaf plot, pie chart.

Measures of central tendency: Arithmetic geometric and harmonic mean, median and mode. Measures of dispersion: Mean Deviation, and Variance, Box-plot.

Unit-II

Moments, skewness and kurtosis and their measures based on quantiles and moments. Introduction to exploratory data analysis. Principle of Least Squares, fitting of Linear and Polynomial equations by the principle of Least Squares. Simple linear regression and correlation. correlation coefficient and its properties, Spearman's rank correlation.

Unit-III

Random experiments, sample spaces (finite and infinite), events, algebra of events, three basic approaches to probability, combinatorial problems. Axiomatic approach to probability. Product sample spaces. Conditional probability, Bayes' formula. Random variables (discrete and continuous). Distribution Function and its properties. Mathematical Expectation, Variance and Moments, Simple Theorems on expectation. Discrete Distributions: Bernoulli, Binomial and Poisson.

Unit-IV

Continuous Distributions: Uniform, normal and exponential. Meaning of parameters, test statistic and their sampling distributions. Need of Inferential Statistics. Testing of Hypotheses: Null and Alternative hypotheses, Types of Errors, Critical Region, Level of Significance, Power and p-values, Exact tests of hypotheses under Normal set-up for a single mean, a single variance, the equality of two means and the equality of two variances Chi square test for 2x2 contingency table.

Suggested Readings:

1. Gupta, S.C. and Kapoor, V.K. (2000). Fundamentals of Mathematical Statistics (10th ed.), S Chand & Sons.
2. Goon, A.M., Gupta, M.K. and Dasgupta, B. (2013). Fundamental of Statistics, Vol I, World Press, Kolkata.
3. Goon, A.M., Gupta, M.K. and Dasgupta, B. (2011). Fundamental of Statistics, Vol II, World Press, Kolkata.

Course Outcomes:

After completing this course, student will be able to:

- **CO 1.** Compute measures of central tendency, dispersion, skewness and kurtosis from the data.
- **CO 2.** Identify the random experiments and the underlying random variables with probability distributions.
- **CO 3.** Identify the discrete and continuous probability distributions along with their applications.

M.A./M.Sc. (Statistics) Third Semester
Compulsory (Core) Courses

Course Code	Course Title	Course Type	Credits
STAT- 511N	Inference-II	Core	4+0

Objectives:
The main objective of the course is to provide the detailed knowledge of the characterization of another inferential procedure that is interval estimation, non-parametric Inference and sequential analysis.

Unit-I
Likelihood ratio test (LRT) with its asymptotic distribution, UMP tests for monotone likelihood ratio family of distributions. Similar tests with Neyman structure, Construction of similar and UMPU tests through Neyman structure.

Unit-II
Confidence Estimation: Interval estimation for single unknown parameter, Confidence regions, Confidence bounds, Uniformly most accurate confidence intervals and uniformly most accurate unbiased confidence intervals, construction of confidence intervals using pivotal, shortest expected length confidence interval, Correspondence between testing of hypothesis and confidence Interval estimation.

Unit-III
Concept of nonparametric and distribution-free methods, probability integral transformation, empirical distribution function, kernel, one-sample and two-sample U-Statistics, test of independence, sign test, rank-order statistics, Wilcoxon signed-Rank test. Wald-Wolfowitz runs test, Kolmogorov-Smirnov two-sample test, median test, Mann-Whitney U test. Non-parametric confidence intervals for percentiles.

Unit-IV
The sequential probability ratio test (SPRT) and its application to binomial, Poisson, exponential, normal, operating characteristic (OC) function of SPRT, average sample number (ASN) function and their application, Wald's fundamental identity and its uses.

Suggested Readings:

1. George Casella, Roger L. Berger, Statistical Inference, 2nd ed., Thomson Learning.
2. Mukhopadhyay P.: Mathematical Statistics, New central Book Agency (P) Ltd. Calcutta.
3. Rao, C.R.: Linear Statistical Inference and its Applications, 2nd ed, Wiley Eastern.
4. Rohatgi, V.K.: An Introduction to Probability Theory and Mathematical Statistics, Wiley Eastern.
5. Goon, Gupta & Das Gupta: An Outline of Statistical Theory, Vol. II, World Press.
6. Hogg, R.V. and Craig, A.T.: Introduction to Mathematical Statistics, McMillan.
7. Kale, B.K. : A First Course on Parametric Inference, Narosa Publishing House.
8. Lehmann, E.L. Testing Statistical Hypotheses, Student Editions.

Course Outcomes:
After completing this course, student is expected to learn the following:
- **CO 1.** Understand the concept of likelihood ratio test with its asymptotic distribution.
- **CO 2.** Learn the method of interval estimation.
- **CO 3.** Learn the basic concepts of nonparametric techniques.
- **CO 4.** Understand the sequential probability ratio test and its application.

Course Code	Course Title	Course Type	Credits
STAT- 512N	Linear Models and Regression Analysis	Core	4+0

Objectives:
The objectives of this course are to develop theoretical foundation of linear models and understand fundamental concepts of regression analysis.

Unit-I
Gauss-Markov set-up, Normal equations and Least squares estimates, Error and estimation spaces, variances and covariances of least squares estimates, estimation of error variance, estimation with correlated observations, Least squares estimates with restriction on parameters.

Unit-II
Sum of Squares. Tests of hypotheses for one and more than one linear parametric functions, confidence intervals and regions, Simple Linear Regression: Simple linear regression model. Least squares estimation of parameters. Hypothesis testing on the slope and intercept. Interval estimation in simple linear regression. Prediction of new observations. Coefficient of determination. Estimation by maximum likelihood.

Unit-III

Multiple linear regression: Multiple linear regression models. Estimation of the model parameters. Hypothesis testing in multiple linear regression. Confidence intervals in multiple regression. Coefficient of determination and Adjusted R^2.

Model Adequacy: Checking of linearity between study and explanatory variable, Residual Analysis,

Unit-IV

Detection and treatment of outliers, Residual plots. The PRESS statistic. Outlier test based on Studentized Residual (R-student). Test for lack of fit of the regression model. Transformation and Weighting to Correct Model Inadequacies: Variance stabilizing transformations. Transformations to linearize the model. Analytical methods for selecting a transformation on study variable. Diagnostic for Leverage and Influence: Leverage, measures of influence, Cook's D

Suggested Readings:

1. Montegomery, D.C., Peck, E.A. & Vining, G.G. (2015). Introduction to Linear Regression Analysis, 5thEdition. Wiley.
2. Rao, C.R. (2009). Linear Statistical Inference and its Applications, 2nd Edition. Wiley.
3. Draper, N.R. & Smith, H. (2011). Applied Regression Analysis, 3rd Edition. Wiley.
4. Chatterjee, S. and Hadi, A.S. (2012). Regression Analysis by Example, 5th Edition. Wiley.
5. Fox, J. and Weisberg, S. (2019). An R Companion to Applied Regression, 3rd Edition. Sage Publications

Course Outcomes:
On completion of this course, students will be able to:

- **CO 1.** Understand simple and multiple linear regression models with their applications.
- **CO 2.** Learn the fitting of these models to simulated and real data sets.
- **CO 3.** Learn model adequacy using classical diagnostics, awareness of potential problems (outliers, etc.) and application of remedies to deal with them.
- **CO 4.** Understand the basic concepts of logistic, Poisson and generalized linear models.

Discipline Specific Elective (DSE) Courses

Course Code	Course Title	Course Type	Credits
STAT- 513N	**Operations Research-II**	**DSE**	**4+0**

Objectives:

The objective of Operation Research is optimization that is to do things best under given circumstances. Operation Research has many applications in different valuable sections of the real life problems.

Unit-I

Decision making in the face of Competition: Pure and mixed strategies. Existence of solution and uniqueness of value in zero-sum games. Finding solution in 2x2, 2xm, nx2 games. Nonzero-sum game. Co-operative and competitive games. Equilibrium solution and its existence in bimatrix games.

Unit-II

Advanced Inventory Theory : Models with probabilistic demand and role of probability distributions

Unit-III

Queuing Models: Specifications and effectiveness measures. Steady state solution of M/M/1 and M/M/c models with associated distributions of queue-length and waiting time. M/G/1 queue. Steady state solution of $M/E_K/1$ and $E_K/M/1$ queues.

Unit-IV

Information theory. Communication process, description of system, quantitative measure of information, Binary unit of information channel matrix, measure of uncertainty- entropy, properties of entropy functions and related theorem.

Suggested Readings:

1. Saaty T.L.(1961) : Elements of Queueing Theory with Applications, MCGraw Hill.
2. Taha H.A. (1982) : Operational Research: An Introduction, Macmillan.
3. Hadley G. and Whiten T.M. (1983): Analysis r Inventory Systems : Prentice Hall.
4. Gross D. and Harris C.M. (1974) : Fundamental of Queueing theory, John Wiley & Sons.

Course Outcomes: After the completion of the course, the students shall be able to

- **CO 1.** develop practical framework for conceiving social-economic situations among competing parties.
- **CO 2.** in position to develop Inventory models in probabilistic environment describing the behavior of demand and supply.
- **CO 3.** making optimum business decisions about resources needed to provide a service in a busy period.

Course Code	Course Title	Course Type	Credits
STAT- 514N	Mathematical Epidemiology	DSE	4+0

Objectives:
The overall objective of this course is to enable students to build mathematical models of some diseases, analyze them and make predictions about behavior of diseases. Moreover, objective of this course is to prepare the students for research in the field of mathematical epidemiology.

Unit-I
Autonomous system, phase plane, critical points, types of critical points, stability of critical points in linear systems, asymptotic stability, stability by Lyapunov's direct method, simple critical points of non-linear systems.

Unit-II
Introduction of mathematical epidemiology, need, scope and limitations of mathematical epidemiology, basic terminologies, basics of epidemic, endemic and pandemic, basic reproduction number, effective reproduction number and contact number, prevalence and incidence of a disease, SI model, SIS model with constant coefficient, SIS model with constant number of carriers.

Unit-III
Basic SIR epidemic model, threshold for SIR epidemic, basic SIR endemic model, SIR endemic model with no disease related death, SIR endemic model with disease related death, SIR model with vaccination, SIRS, SEIR and SEIRS epidemic models.

Unit-IV
Immunology and AIDS: modelling the transmission dynamics of HIV, Anderson first model, Anderson improved model, spread of Tuberculosis (TB), mathematical modelling of transmission of TB, emergence and spread of COVID-19 pandemic, mathematical modelling of COVID-19 transmission, concomitant diseases.

Suggested Readings:

1. J.N. Kapur: Mathematical Modelling, New Age International (P) Limited, New Delhi, 2007.
2. J.N. Kapur: Mathematical Models in Biology and Medicine, Affiliated East-West Press Pvt. Ltd., New Delhi, 1985.
3. J. Mazumdar: An Introduction to Mathematical Physiology and Biology, Cambridge University Press, 1999.
4. Nicholas F. Britton: Essential Mathematical Biology, Springer, 2003.

Course Outcomes:
After the completion of the course, the student shall be able to

CO 1. assess and articulate the appropriate modelling techniques for the spread of a disease in the system.
CO 2. Construct and analyze mathematical models in epidemiology and analyze it.
CO 3. make predictions of the behavior of the diseases based on the analysis of its mathematical model. analyze them and make predictions about behavior of diseases.

Course Code	Course Title	Course Type	Credits
STAT- 515N	Design of Experiments	DSE	4+0

Objectives:

This course provides the students the ability to understand the design and conduct experiments, as well as to analyze and interpret data.

UNIT-I

Principles of Design of Experiment: Randomization, Replication and Local Control, Choice of size and type of a plot using uniformity trials. Completely Randomised Design (CRD) Randomized Block Design (RBD).

UNIT-II

Concept and definition of efficiency of design, Comparison of efficiency between CRD and RBD. Latin Square Design (LSD), Lay-out, ANOVA table, Comparison of efficiencies between LSD and RBD; LSD and CRD, Missing plot techniques.

Unit-III

General factorial experiments, factorial effects; best estimates and testing the significance of factorial effects; study of 2 and 3 factorial experiments in randomized blocks; Complete and partial confounding. Fractional replication for symmetric factorials. Split plot and split block experiments.

Unit-IV

Introduction to designed experiments: General block design and its information matrix (C), criteria for connectedness, balance, and orthogonality; Intrablock analysis (estimability, best point estimates/interval estimable Linear Parametric Functions and testing of linear hypotheses); BIBD- recovery of interlock information; Analysis of covariance

Suggested Readings:

1. Aloke Dey (1986): Theory of Block Designs, Wiley Eastern.
2. Angela Dean and Daniel Voss (1999): Design and Analysis of Experiments, Springer Verlag.
3. Das, M.N. and Giri, N. (1979): Design and Analysis of Experiments, Wiley Eastern
4. Giri, N.(1986): Analysis of Variance, South Asian Publishers
5. John, P.W.M.(1971): Statistical Design and Analysis of Experiments, Macmillan
6. Joshi, D.D.(1987): Linear Estimation and Design of Experiments, Wiley Eastern
7. Montgomery, C.D.(1976): Design and Analysis of Experiments, John Wiley& Sons, New York
8. Myers, R.H. (1971): Respnes Surface Methodology, Allyn & Bacon
9. Pearce, S.C. (1984): Design of Experiments, John Wiley& Sons, New York
10. Rao, C.R. and Kleffe, J. (1988): Estimation of Variance Components and applications, North Holland.
11. Searle, S.R., Casella, G. and McCulloch, C.E.(1992): Variance Components, Wiley

Course Outcomes:

After successful completion of this course, student shall be able to

- **CO 1.** Apply Gauss-Markov set-up, Normal equations and Least squares estimates, Error and estimation spaces, variances and covariances of least squares estimates, estimation of error variance, estimation with correlated observations, least squares estimates with restriction on parameters, Sum of Squares.
- **CO 2.** Design and analyse incomplete block designs, understand the concepts of orthogonality, connectedness and balance.
- **CO 3.** Understand the concepts of balanced incomplete block designs, confounded factorial experiments.
- **CO 4.** Construct complete and partially confounded factorial designs and perform their analysis.

Course Code	Course Title	Course Type	Credits
STAT- 516N	Survival Analysis	DSE	4+0

Objectives:
The main objective is to introduce different concepts and their interpretation in survival analysis.

Unit-I
Concepts of time, order and random Censoring, likelihood in these cases. Life distributions-Exponential Gamma, Weibull, Lognormal, Pareto, log-logistic and linear failure rate. Parametric inference for these distributions.

Unit-II
Life tables, failure rate, mean residual life and their elementary properties. Ageing classes-and their properties, bathtub failure rate. Estimation of survival function-Actuarial Estimator, Kaplan-Meier Estimator,

Unit-III
Estimation under the assumption of IFR/DFR. Tests of exponentiality against non-parametric classes-Total time on test. Hollander-Proschan test. Two sample problem-Gehan test, Log rank test. Mantel-Haenszel test, Tarone -Ware tests.

Unit-IV
Model Selection : AIC and BIC criterion
Semi-parametric regression for failure rate-Cox's proportional hazards model with one and several convariates. Competing risks model.

Suggested Readings:
1. Cox, D.R., and Oakes, D.(1984). Analysis of Survival Data, Chapman and Hall, New York.
2. Elandt -Johnson, R.E., and Johnson, N.L. Survival Models and Data Analysis, John Wiley andSons.
3. Kalbfleisch, J.D., and Prentice, R.L.(1980). The Statistical Analysis of Failure Time Data, John Wiley.
4. Klein, J. P. and Moeschberger, M. L. (1997). Survival Analysis, Springer-Verlag,, NewYork.
5. Lee, E.T., and Wang, T.W.(2003). Statistical Methods for Survival Data Analysis, 3rd ed., John Wiley and Sons.

Course Outcomes:
After successful completion of this course, student shall be able to

- **CO 1.** Learn various statistical lifetime models.
- **CO 2.** Understand the concept involved in survival analysis.
- **CO 3.** Non-parametric estimation of survival data.
- **CO 4.** Learn model selection criterion.
- **CO 5.** Learn proportional hazards models.

Course Code	Course Title	Course Type	Credits
STAT- 517N	Statistical Decision Theory	DSE	4+0

Objectives:
The aim of this course is to provide a thorough theoretical grounding in Decision problems and 2-person game, utility theory, loss function, expected loss, decision rules, decision principles, inference problems as decision problems, optimal decision rules etc.

Unit-I
Decision problems and 2-person game, utility theory, loss function, expected loss, decision rules (non-randomized and randomized), decision principles (conditional Bayes and frequentist), inference problems as decision problems, optimal decision rules. Concepts of admissibility and completeness. Bayes rules, admissibility of Bayes rules.

Unit-II
Supporting and separating hyperplane theorems, minimax theorem for finite parameter space, minimax estimators of Normal and Poisson means, admissibility of minimax rules. Invariant decision rules- location parameter problems, invariance and minimaxity, admissibility of invariant rules, complete class theorem, complete and essentially complete classes in simple estimation and testing situations, estimation of a distribution function.

Unit-III
Multivariate normal distribution, exponential family of distributions, sufficient statistics, essentially complete classes of rules based on sufficient statistics, complete sufficient statistics.

Unit-IV
Sequential decision rules, Bayes and minimax sequential decision rules, invariant sequential decision problems, sequential tests of a simple hypothesis against a simple alternative. SPRT and stopping rule principle.

Suggested Readings:

1. Berger, J.O. (1985). Statistical Decision Theory and Bayesian Analysis. 2nd Ed. Springer.
2. Ferguson, T.S. (1967). Mathematical Statistics-A Decision Theoretic Approach, Academic Press.

Course Outcomes:
After successful completion of this course, student shall be able to

- **CO 1.** To analyse Decision problems and 2-person game, utility theory, loss function, expected loss, decision rules.
- **CO 2.** Concepts of admissibility and completeness. Bayes rules, admissibility of Bayes rules.
- **CO 3.** Understand how to use Multivariate normal distribution, exponential family of distributions, sufficient statistics.
- **CO 4.** Understand Sequential decision rules, Bayes and minimax sequential decision rules.
- **CO 5.** Work with sequential tests of a simple hypothesis against a simple alternative. SPRT and stopping rule principle.

Course Code	Course Title	Course Type	Credits
STAT- 518N	**Practical (Based on theory courses)**	**Core**	**0+4**

The practical for course code STAT- 518N is based on theory course.

Course Code	Course Title	Course Type	Credits
STAT- 519N	**Project**	**Core**	**0+4**

Course Objectives: The objective of course is to know introduction to Mathematical type setting on LaTeX and Programming in R/python/Mathematica/MATLAB.

Mathematical type setting on LaTeX: Sample Document, Type Style, Tables, Equation Environments, Fonts, Theorem-like Environments, Math Styles, Basic mathematical calculations such as solution of equations, differentiation, integration, graph plotting of mathematical functions, Document Classes and the Overall Structure, Titles for Documents, Sectioning Commands, Packages, Making a Bibliography, Scientific writing, Beamer. Programming in R/python/Mathematica/MATLAB. Candidate/Students should write a project based on Mathematical programs on R/ Python/ Mathemtica/ MATLAB.

Suggested Readings:

1. Eric Matthes, Python Crash Course, William Polock 2016.
2. Amos R. Omondi, Mark Ng'ang'a, and Ryan Marvin, Python Fundamentals: A Practical Guide for Learning Python, Complete with Real-world Projects for You to Explore, PAKCT Publishing (2019).
3. Michael J. C. (2015): An Introduction Using R, 2nd Edition John Wiley and Sons.
4. George Grätzer, More Math Into LaTeX, 4th Edition, Springer (2016).

Course Outcomes: After completing the course, the student shall be able to

CO 1. understand the basics of computer programming languages and LaTeX.

CO 2. understand the graph plotting of mathematical functions.

CO 3. understand some advanced computing tools and techniques.

M.A./M.Sc. (Statistics) Fourth Semester
Compulsory (Core) Courses

Course Code	Course Title	Course Type	Credits
STAT- 520N	Bayesian Inference	Core	4+0

Objectives:

The objective of this course is to provide the understanding of the fundamentals of Bayesian inference including concept of subjectivity and priors by examining some simple Bayesian models and linear regression in a Bayesian framework.

Unit-I

Subjective interpretation of probability in terms of fair odds. Evaluation of (i) subjective probability of an event using a subjectively unbiased coin (ii) subjective prior distribution of a parameter. Bayes theorem and computation of the posterior distribution.

Natural Conjugate family of priors for a model. Hyper parameters of a prior from conjugate family. Conjugate families for (i) exponential family models, (ii) models admitting sufficient statistics of fixed dimension. Enlarging the natural conjugate family by (i) enlarging hyper parameter space (ii) mixtures from conjugate family, choosing an appropriate member of conjugate prior family. Non informative, improper and invariant priors. Jeffrey's invariant prior.

Unit-II

Bayesian point estimation: as a prediction problem from posterior distribution. Bayes estimators for (i) absolute error loss (ii) squared error loss (iii) 0 – 1 loss. Generalization to convex loss functions. Evaluation of the estimate in terms of the posterior risk.

Unit-III

Bayesian interval estimation: Credible intervals. Highest posterior density regions. Interpretation of the confidence coefficient of an interval and its comparison with the interpretation of the confidence coefficient for a classical confidence interval.

Bayesian testing of Hypothesis: Specification of the appropriate form of the prior distribution for a Bayesian testing of hypothesis problem. Prior odds, Posterior odds, Bayes factor for various types of testing hypothesis problems depending upon whether the null hypothesis and the alternative hypothesis

are simple or composite. Specification of the Bayes tests in the above cases. Discussion of Lindley's paradox for testing a point hypothesis for normal mean against the two sided alternative hypothesis.

Unit-IV

Bayesian prediction problem. Large sample approximations for the posterior distribution.

Bayesian calculations for non conjugate priors: (i) Importance sampling, (ii) Obtaining a large sample of parameter values from the posterior distribution using Acceptance-Rejection methods, Markov Chain Monte Carlo methods and other computer simulation methods.

Suggested Readings:

1. Berger, J.O. : Statistical Decision Theory and Bayesian Analysis, Springer Verlag.
2. Robert C.P. and Casella, G. : Monte Carlo Statistical Methods, Springer-Verlag.
3. Leonard T. and Hsu, J.S.J. : Bayesian Methods. Cambridge University Press.
4. DeGroot M.H. : Optimal Statistical Decisions. McGraw Hill.
5. Bernando J.M. and Smith, A.F.M. : Bayesian Theory, John Wiley and Sons.
6. Robert, C.P. :The Bayesian Choice : A Decision Theoretic Motivation, Springer Verlag.

Course Outcomes:

After successful completion of this course, student shall be able to

CO 1. Treat "evidence" as value of observations and prescribe methods to deal rationally with it.

CO 2. Equip students with skills to carry out and interpret posterior and pre posterior data based modeling and analyses.

CO 3. Compute probability that the theory in question could produce the observed data.

CO 4. Examine some simple Bayesian models and linear regression in a Bayesian framework.

Course Code	Course Title	Course Type	Credits
STAT- 521N	Computer-Intensive Statistical Methods	Core	4+0

Objectives:

The main objective of this paper is to make students understand computational intensive methods for doing statistical inference.

Unit-I

Stochastic simulation: Generation of random numbers and their applications. Pseudo Random numbers, linear congruential method. Inverse-transform method, composition method, acceptance-rejection method, transform methods, sums and mixtures, Monte-Carlo technique for generation of random samples from various univariate probability distributions.

Unit-II

Simulation from multivariate normal distribution.

Monte Carlo integration: Simple Monte Carlo estimator and its standard error, variance and efficiency, variance reduction: antithetic variables and control variates, importance sampling for integration and variance in importance sampling.

Monte Carlo methods in inference**:** Monte Carlo methods for estimation, basic Monte Carlo estimation and standard error, estimation of MSE, estimating a confidence level. Simple problems on hypothesis tests.

Unit-III

Probability density estimation (univariate): Density estimation from histogram, Frequency polygon density estimate, The averaged shifted histogram, Kernal density estimation.

Bootstrap methods: resampling paradigms, estimation of bias and standard errors, Confidence intervals: The basic, standard normal, percentile and bootstrap t-intervals, Better bootstrap Confidence (BCa) intervals. Jackknife: The Jackknife estimation of bias and standard error, Jackknife after bootstrap. Bootstrapping in regression. Application: cross-validation.

Unit-IV

Markov Chain Monte Carlo(MCMC) methods : Metropolis-Hastings, Gibbs and Metropolis within Gibbs algorithms for full conditional distributions, Issues in the implementation of MCMC. Convergence diagnostics: trace, ergodic mean, autocorrelation and Brook-Gelman- Rubin(BGR) plots. Output analysis: visual and numerical summary of MCMC samples. ML estimation and asymptotic confidence intervals for exponential families.

Basic concept of Expectation-Maximization(EM) algorithm: applications to missing and incomplete data problems, mixture models.

Suggested Readings:

1. Efron, B. and Tibshirani, R.J.(1993): An Introduction to the Bootstrap, Chapman and Hall.
2. Fishman, G.S. (1996): Monte Carlo: Concepts, Algorithms, and Applications, SpringerVerlag.
3. McLachlan, G.J.,and Krishnan, T. The EM Algorithms and Extensions, John Wiley & Sons.
4. Rubinstein, R.Y. (1981): Simulation and the Monte Carlo Method, John Wiley & Sons.
5. Tanner, M.A. (1996): Tools for Statistical Inference, Third edition, Springer Verlag.
6. Venables, W. N., and Ripley, B. D. (2000): S Programming, Springer, New York.
7. Venables, W. N., and Ripley, B. D. (2002): Modern Applied Statistics with S, , Springer Verlag, New York.

Course Outcomes: After successful completion of this course, student shall be able to

CO 1. Understand the basic ideas of Random Number Generation, Resampling and Simulation Methods.

CO 2. apply computational methods, such as Monte Carlo simulations, the EM algorithm.

CO 3. use Bayesian models to formulate and solve complex statistical problems.

Discipline Specific Elective (DSE) Courses

Course Code	Course Title	Course Type	Credits
STAT- 522N	**Reliability Theory**	**DSE**	**4+0**

Objectives:
The main objective is to introduce different concepts and their interpretation in reliability analysis.

Unit-I
Reliability concepts and measures : components and systems ; coherent systems; reliability of coherent systems; cuts and paths; modular decomposition; bounds on system reliability; structural and reliability importance of components.
Life distributions; reliability function; hazard rate; common life distributions-exponential, Weibull, gamma etc. Estimation of parameters and tests in these models.

Unit-II
Notions of ageing; IFR, IFRA, NBU, DMRL, and NBUE Classes and their duals; loss of memory property of the exponential distribution; closures or these classes under formation of coherent systems, convolutions and mixtures. Univariate shock models and life distributions arising out of them; bivariate shock models;
common bivariate exponential distributions and their properties.

Unit-III
Reliability estimation based on failure times in variously censored life tests and in tests with replacement of failed items; stress-strength reliability and its estimation. Maintenance and replacement policies; availability of repairable systems; modeling of a repairable system by a non-homogeneous Poisson process.

Unit-IV
Reliability growth models; probability plotting techniques; Hollander-Proschan and Deshpande tests for exponentially; tests for HPP vs. NHPP with repairable systems. Basic ideas of accelerated life testing.

Suggested Readings:

1. Barlow R.E. and Proschan F. (1985). Statistical Theory of Reliability and Life Testing; Holt, Rinehart and Winston.
2. Lawless J.F. (1982) Statistical Models and Methods of Life Time Data; John Wiley.
3. Bain L.J. and Engelhardt (1991) Statistical Analysis of Reliability and Life Testing Models; Marcel Dekker.
4. Nelson, W (1982) Applied Life Data analysis; John Wiley.
5. Zacks S. Reliability Theory, Springer.
6. Sinha, S.K. : Reliability and Life Testing.

Course Outcomes: After successful completion of this course, student shall be able to

- **CO 1.** Learn various statistical lifetime models.
- **CO 2.** Understand various classes and their interrelations.
- **CO 3.** Non-parametric estimation in lifetime data.
- **CO 4.** Learn accelerated life testing.

Course Code	Course Title	Course Type	Credits
STAT- 523N	Machine Learning	DSE	4+0

Objectives:

- The objective is to familiarize the students with some basic learning algorithms and techniques and their applications
- The emphasis will be on machine learning algorithms and applications, with some broad explanation of the underlying principles.
- To develop the basic skills necessary to pursue research in machine learning.
- To develop the design and programming skills that will help to build intelligent, adaptive artifacts.

Unit I

Introduction to Machine Learning(ML): basic definitions. Types of learning : Supervised learning: Classification problem, Regression problem, Unsupervised learning: Dimensionality reduction, Clustering and Reinforcement learning. Steps in machine learning model development and deployment.

Unit-II

Statistical fundamentals and terminology for model building and validation, Machine learning terminology for model, building and validation, Machine learning losses, Train, validation, and test data, Machine learning model overview, hypothesis space and inductive bias, evaluation, cross-validation. Review of multivariate normal distribution. Classification problem and discriminant analysis.

Unit-III

Principle component analysis, Canonical correlation, Linear regression and Logistic Regression. Supervised Learning: K - nearest neighbourhood algorithm, Decision trees, Naïve Bayes and Bayesian learning.

Unit IV

Unsupervised Learning: Clustering, Hierarchical and k-means clustering, Distance Measures, Introduction to Random Forest and Reinforcement Learning.

Suggested Readings:

1. Alpaydin, E. (2014), Introduction to Machine Learning, 3rd Ed. MIT Press.
2. Bishop, S. (2011). Pattern Recognition and Machine Learning, Springer
3. Brett Lantz (2019). Machine Learning with R: Expert techniques for predictive modeling, Packt Publishing
4. Burger, Scott V.(2018). Introduction to machine learning with R: rigorous mathematical analysis, O'Reilly.
5. Friedman, J., Hastie,T, Tibshirani, R. (2009). Elements of Statistical Learning. Springer
6. Lewis N.D. (2017). Machine Learning made easy with R, CreateSpace Independent Publishing Platform.
7. Müller, A.C., Guido, S.(2016). Introduction to Machine Learning with Python: A Guide for Data Scientists, O'Reilly Media.
8. Murphy, K.P. (2012). Machine Learning: a Probabilistic Perspective. MIT Press.
9. Tom Mitchell(1997).Machine Learning, McGraw-Hill

Course Outcomes:

After completing the study of the discipline ―Machine Learning, the student are expected to:

CO 1. understand complexity of Machine Learning algorithms and their limitations;

CO 2. understand modern notions in data analysis oriented computing;

CO 3. be capable of confidently applying common Machine Learning algorithms in practice and implementing their own;

CO 4. be capable of performing experiments in Machine Learning using real-world data.

Course Code	Course Title	Course Type	Credits
STAT- 524N	Economic Statistics and Statistical Quality Control	DSE	4+0

Objectives:
The course aims to study various models and components of time series analysis for forecasting purposes and various methods to control the quality of a product. It also gives the study of distribution of population with respect to birth, migration, aging and death.

Unit-I
Time Series: Components of time series, Decomposition of time series- Additive and multiplicative model with their merits and demerits, Illustrations of time series, measurement of trend by method of moving averages, method of semi-averages and method of least squares (linear, quadratic and exponential). Measurement of seasonal variations by method of simple averages, method of ratio to trend.

Unit-II
A model Building strategy, Time series and Stochastic process, stationarity, Auto correlation, meaning and definition–causes of auto correlation-consequence of autocorrelation–test for auto–correlation. Study of Time Series model and their properties using correlogram, ACF and PACF. Yule-Walker equations.

Unit-III
Statistical Quality Control: Importance of statistical methods in industrial research and practice, determination of tolerance limits, causes of variations in quality: chance and assignable. General theory of control charts, process and product control, control charts for variables: X- bar and R-charts, control charts for attributes: p and c-charts.

Unit-IV
Introduction to demand analysis, theory of firms, production functions, Index number – its definition, application of index number, price relative and quantity or volume relatives, link and chain relative, problem involved in computation of index number, use of averages, simple aggregate and weighted average method. Laspeyre's, Paasche's, Fisher's and Marshall-Edgeworth index number, Criteria of an ideal index number: unit, time reversal, factor reversal and circular tests, consumer price index.

Suggested Readings:

1. Mukhopadhyay, P. (2011). Applied Statistics, 2nd Edition. Books and Allied (P.) Ltd.
2. Goon, A.M., Gupta, M.K. & Dasgupta, B. (2016). Fundamentals of Statistics, Vol. II. 9th Edition. World Press.
3. Montegomery, D.C. (2013). Statistical Quality Control: A Modern Introduction, 7th Edition. Wiley.
4. Burr, J.T. (2014). Elementary Statistical Quality Control, 2nd Edition. CRC Press.

Course Outcomes:
After completing this course, student is expected to learn the following:

CO 1. Study the components of time series and their measurement.
CO 2. Study process control and its tools-control chart for variables and attributes.
CO 3. Learn the basic measures of mortality and fertility and their application.
CO 4. Understand life tables and their uses in real life problems.

Course Code	Course Title	Course Type	Credits
STAT- 525N	Actuarial Statistics	DSE	4+0

Objectives:

Actuarial Science is the discipline that applies mathematical and statistical methods to assess risk in the insurance and finance industries. In view of the uncertainties involved, probability theory, statistics and economic theories provide the foundation for developing and analysing actuarial models.

Unit I

Future life time random variable, its distribution function and density function, concept of force of mortality, curtate future life time random variable its probability mass function, deferred probabilities, all these functions in terms of international actuarial notation. Analytical laws of mortality such as Gompertz' law and Makeham's law, Single decrement life table, select and ultimate life table.

Unit II

Concept of compound interest rate, discount factor, present value of the money, nominal rate of interest, force of interest, Assurance contracts with level and varying benefits, such as whole life insurance, term insurance endowment insurance. Means and variances of the present value random variables of the payments under these contracts under the assumption of constant force of interest, when the benefit payments are made at the end of year of death (discrete set up) or when it is paid at the epoch of death(continuous set up). Actuarial present value of the benefit, Net single premiums.

Unit III

Annuity contracts, annuity certain, discrete annuity, monthly annuity, continuous annuity, deferred annuity, present values and accumulated values of these annuities. Continuous life annuity, discrete life annuity, such as whole life annuity, temporary life annuity, n-year certain and life annuity, life annuities with mthly payments, Present value random variables for these annuity payments, their means and variances, Actuarial present value of the annuity.

Unit IV

Loss at issue random variable, various principles to decide net premiums for insurance products and annuity schemes defined in unit II and III, fully continuous premiums and fully discrete premiums, True monthly payment premiums. Extended equivalence principle to decide gross premiums, Concept of reserve, prospective & retrospective approach, Fully continuous reserve, Fully discrete reserve.

Suggested Readings:

1. Bowers, JR. N.L., Gerber, H.U., Hickman, J.C., Jones, D.A. and Nesbitt, C.J. (1997). Actuarial Mathematics, 2nd Edn., The Society of Actuaries.
2. Deshmukh S.R. (2009). Actuarial Statistics: An Introduction Using R, Universities Press.
3. Harriett, E.J. and Dani, L. L.(1999). Principles of Insurance: Life, Health, and Annuities, 2nd Edn., Life Office Management Association.
4. Neill, Alistair (1977). Life Contingencies, The Institute of Actuaries.
5. Palande, P. S., Shah, R. S. and Lunawat, M. L. (2003). Insurance in India - Changing Policies and Emerging Opportunities, Response Books.

Course Outcomes:

After successful completion of this course, student shall be able to

CO 1. modelling of individual and aggregate losses.

CO 2. fitting of distributions to claims data, deductibles and retention limits, proportional and excess-of-loss reinsurance.

CO 3. Risk models: models for individual claims and their sums.

CO 4. finding distribution of aggregate claims, compound distributions and their applications,

CO 5. finding of survival function, curate future lifetime, force of mortality.

CO 6. handling problems on joint life and last survivor status and multiple decrement model.

CO 7. mean and variance of various continuous and discrete payments for assurance and annuity contracts.

CO 8. calculation of various payments from life tables using principle of equivalence, net premiums, prospective and retrospective provisions/reserves.

Course Code	Course Title	Course Type	Credits
STAT- 526N	Stochastic Processes	DSE	4+0

Objectives:
The main objective of this course is to develop awareness for the use of stochastic models for representing random phenomena evolving in time such as inventory or queuing situations or stock prices behavior.

Unit-I
Introduction to stochastic processes (sp's).: classification of sp's according to state space and time domain. Countable state Markov chains (MC's), Chapman-Kolmogorov equations; calculation of n-step transition probability and its limit. Stationary distribution, classification of states; transient MC; random walk and gambler's ruin problem.

Unit-II
Discrete state space & continuous time MC: Kolmogorov- Feller differential equations; Poisson process, birth and death process; Applications to queue and storage problems. Wiener process as a limit of random walk; first- passage time and other problems.

Unit-III
Renewal theory: Elementary renewal theorem and applications. Statement and uses of key renewal theorem; study of residual life time process. Stationary process : weakly stationary and strongly processes. Moving and auto regressive processes.

Unit-IV
Branching process: Galton-Watson branching process, probability of ultimate extinction, distribution of population size. Martingale in discrete time, inequality, convergence and smoothing properties.

Suggested Readings:

6. Adke, S.R. and Manjunath, S.M. (1984): An Introduction to Finite Markov Processes, Wiley Eastern.
7. Bhat, B.R. (2000): Stochastic Models: Analysis and Applications, New Age International, India.
8. Cinlar, E. (1975): Introduction to Stochastic Processes, Prentice Hall.
9. Feller, W. (1968): Introduction to Probability and its Applications, Vol.1, Wiley Eastern.
10. Harris, T.E. (1963): The Theory of Branching Processes, Springer- Verlag.
11. Hoel, P.G., Port, S.C. and Stone, C.J.(1972): Introduction to Stochastic Processes, Houghton Miffin & Co.
12. Jagers, P. (1974): Branching Processes with Biological Applications, Wiley.
13. Karlin, S. and Taylor, H.M. (1975): A First Course in Stochastic Processes, Vol. 1, Academic Press.
14. Medhi, J. (1982): Stochastic Processes, Wiley Eastern.
15. Parzen, E. (1962): Stochastic Processes, Holden-Day.

Course Outcomes:
After successful completion of this course, student shall be able to

- **CO 1.** Use notions of long-time behaviour including transience, recurrence, and equilibrium in applied situations such as branching processes and random walk.
- **CO 2.** Construct transition matrices for Markov dependent behaviour and summarize process information
- **CO 3.** Use selected statistical distributions for modeling various phenomena.
- **CO 4.** Understand the principles and objectives of model building based on Markov chains, Poisson processes and Brownian motion.

Course Code	Course Title	Course Type	Credits
STAT- 527N	Econometrics	DSE	4+0

Objectives:
The main objective is to introduce branch which is an integration of mathematics, statistics, and economics used to deal with econometric models.

Unit-I
Nature of econometrics. The general linear model (GLM) and its extensions. Ordinary Least Squares (OLS) estimation and prediction. Use of dummy variables and seasonal adjustment.

Unit-II
Generalized least squares (GLS) estimation and prediction. Heteroscedastic disturbances. Pure and mixed estimation. Grouping of observation and of equation. Auto correlation, its consequences and tests. Theil BLUS procedure. Estimation and prediction. Multicollinearity problem, its implications and tools for handling the problem. Ridge regression.

Unit-III
Linear regression with stochastic regressors. Instrumental variable estimation. Errors in variables. Autoregressive linear regression. Distributed lag models. Use of principal components, canonical correlations and discriminant analysis in econometrics.
Simultaneous linear equations model, Examples, identification problem. Restrictions on structural parameters – rank and order conditions. Restrictions on variances and covariances.

Unit-IV
Estimation in simultaneous equations model. Recursive systems. 2 SLS Estimators. Limited information estimators. K-class estimators, 3 SLS estimation. Full information maximum likelihood method. Prediction and simultaneous confidence intervals. Monte Carlo studies and simulation.

Suggested Readings:

1. Apte PG (1980); Text book of Econometrics. Tata McGraw Hill.
2. Carmer, J.S. (1971) Empirical Econometrics, North Holland
3. Gujarathi, D (1979): Basic Econometrics, McGraw Hill.
4. Intrulligator, MD (1980): Econometric models-Techniques and applications, Prentice Hall of India.
5. Johnston, J. (1984) : Econometric methods. Third edition, McGraw Hill.
6. Klein, L.R. (1962) : An introduction to Econometrics, Prentice Hall India.
7. Koutsoyiannis, A. (1979) : Theory of Econometrics, Macmillan Press.
8. Malinvaud, E (1966) : Statistical methods of Econometrics, North Holland.
9. Srivastava, V.K. and Giles D.A.E. (1987) : Seemingly uncorrelated regression equations models, Marcel Dekker.
10. Theil, H. (1982) : Introduction to the theory and practice of Econometrics, John Wiley.
11. Walters, A. (1970) : An introduction to Econometrics, McMillan & Co.
12. Wetherill, G.B. (1986) : Regression analysis with applications, Chapman Hall.

Course Outcomes:
After successful completion of this course, student shall be able to

CO 1. Learn properties and problems of econometric models.
CO 2. Understand the estimation and testing of hypothesis in econometric models.
CO 3. Understand Simultaneous Equation Models.

Course Code	Course Title	Course Type	Credits
STAT- 528N	**Practical (Based on theory courses)**	**Practical**	**0+4**

The practical for course code STAT- 528N is based on theory course.

Course Code	Course Title	Course Type	Credits
STAT- 529N	**Dissertation/ Research Project**	**Project**	**0+4**

Course Objectives: The objective of course is to write a dissertation/research project on the specific topic.

Candidate/Students should write a dissertation/research project on the specific topic based on any one core/major papers or discipline specific elective/elective papers opted by the student in any semester. The students has been allotted a supervisor in this project on their topic, given by the concern faculty. The dissertation/research project should be typed in LaTex and its presentation on LaTex Beamer/Power Point.

Course Outcomes: After completing the course, the student shall be able to

CO 1. understand the basics to write a dissertation/survey on the specific topic.

CO 2. understand some advanced computing tools.

CO 3. understand some advanced research techniques.