Central University of Punjab, Bathinda

M.Sc. STATISTICS

Batch: 2025-2026

Department of Mathematics and Statistics
School of Basic Sciences

M.Sc. (Statistics) Programme

Graduate Attributes:

Students will be able to develop a broad understanding of recent Statistical theories, tools and techniques. Students will apply different Statistical techniques in various fields and will independently plan and carry out research in different areas of Statistics. They will compete at regional/national/international level for research/jobs in the area of statistics.

M.Sc. Statistics (2 years):

- Two semesters of course work and two semesters of research work.

The Programme will have the following credit distribution:

Curriculum Components	Two Year M.Sc. Statistics Minimum Credits			
	Course Level	Course Work	Research Thesis	Total Credits
1st Year Sem 1	400	20	–	44
1st Year Sem 2	500	24	–	
2nd Year Sem 3	–	–	20	40
2nd Year Sem 4	–	–	20	

M.Sc. Statistics (Semester-I)

Course Code	Course Title	Course Type	Credit Hours			Course Credits
			L	T	P	
MSTA.516	Mathematical Statistics	DSC	3	0	0	3
MSTA.517	Sampling Theory	DSC	3	0	0	3
MSTA.518	Stochastic Processes	DSC	3	0	0	3
MSTA.519	Quality Control and Time Series	DSC	3	0	0	3
MMAT.520	Real Analysis	SEC	3	0	0	3
	Skill Enhancement/ Practicals					
MSTA.401	Basics of R Programming	SEC	0	0	2	1
MMAT.401	Introduction of Mathematica and MATLAB	SEC	0	0	2	1
MMAT.403	Linear Algebra	DSC	3	0	0	3
	Remedial Classes		0	2*	0	0
Total			**18**	**2***	**4**	**20**

DSC – Discipline Specific Core, DEC – Discipline Elective Course, SEC– Skill Enhancement Course

M.Sc. Statistics (Semester II)

Course Code	Course Title	Course Type	L	T	P	Cr
MSTA.524	Statistical Inference	Core	3	0	0	3
MSTA.525	Multivariate Analysis	Core	3	0	0	3
MSTA.526	Design and Analysis of Experiment	Core	3	0	0	3
Skill Enhancement (Practicals/Skill Courses)						
MMAT.405	Basics of Latex	Practical	0	0	2	1
MSTA.402	Basics of Python	Practical	0	0	2	1
MMAT.404	Numerical Analysis	SEC	3	0	0	3
Ability Enhancement Course						
MMAT.407	Complex Analysis	AEC	3	0	0	3
Discipline Elective Course (any one of the following):						
MSTA.520	Econometrics	DEC	3	0	0	3
MSTA.521	Statistical Methods for Insurance		3	0	0	3
MSTA.522	Extreme Value Theory		3	0	0	3
MSTA.523	Actuarial Statistics		3	0	0	3
Interdisciplinary Course						
MSTA.506	Basic Statistics	IDC	2	0	0	2
***Value-added Course** (choose a Course from the Value-Added Courses offered in the University)*						
MMAT.511	Linear Programming	VAC	2	0	0	2
MMAT.513	Vedic Mathematics and Data Science		2	0	0	2
Total Credits			**22**	**0**	**4**	**24**

*MOOCs May be taken up 40% of the total credits (excluding dissertation credits). MOOC may be taken in lieu of any course but content of that course should match a minimum 70%. Mapping is to be done by the respective department and students may be informed accordingly.

M.Sc. Statistics (Semester III)

Course Code	Course Title	Course Type	Credit Hours			Course Credits
			L	T	P	
MSTA.599-1	Dissertation Part- I	Skill Based	0	0	40	20

Students will have an option to carry out dissertation work in industry, national institutes or Universities in the top 100 NIRF ranking.

Group dissertation may be opted, with a group consisting of a maximum of four students. These students may work using a single approach or multidisciplinary approach. Research projects can be taken up in collaboration with industry or in a group from within the discipline or across the discipline.

M.Sc. Statistics (Semester IV)

Course Code	Course Title	Course Type	Credit Hours			Course Credits
			L	T	P	
MSTA.599-2	Dissertation Part- II	Skill Based	0	0	40	20

Students will have an option to carry out dissertation work in industry, national institutes or Universities in the top 100 NIRF ranking.

Group dissertation may be opted, with a group consisting of a maximum of four students. These students may work using a single approach or multidisciplinary approach. Research projects can be taken up in collaboration with industry or in a group from within the discipline or across the discipline.

Total Credits for the course: 84

Examination pattern and evaluation Criteria for Core, Discipline Elective, Compulsory Foundation Courses:

Formative Evaluation: Internal assessment shall be 25 marks using any two or more of the given methods: tests, assignments, term paper, presentations etc. The Mid-semester test (MST) shall be descriptive type of 25 marks including short answer and essay type except for some courses as given in the table below. Each answer shall carry a maximum weightage of five marks in MST. The teachers shall have the flexibility to decide on the number of questions and distribution of marks following above guidelines.

Summative Evaluation: The End semester examination (ESE) shall be 50 marks with upto 100% descriptive type and upto 30% objective type shall be conducted at the end of the semester. The objective type shall include a few words (very short) answers, fill-in the blanks, MCQs', and matching. Each answer shall carry weightage of upto two marks depending on the level of difficulty. The descriptive type shall include short answer and essay type questions. Each answer shall carry a maximum weightage of ten marks in ESE. The teachers shall have the flexibility to decide on the number of questions and distribution of marks following above guidelines. Questions for exams and tests shall be designed to assess course learning outcomes along with focus on knowledge, understanding, application, analysis, synthesis, and evaluation.

Evaluation Criteria for IDC, VAC and entrepreneurship, innovation and skill development courses.

The evaluation for IDC, VAC and entrepreneurship, innovation and skill development courses (<2 credits) shall include MST (50 marks) and ESE (50 marks). The pattern of examination for both MST and ESE shall be the same as given in the table (Annexure II).

Evaluation of dissertation proposal and presentation in the third semester shall include 50% weightage by supervisor and 50% by HoD and senior-most faculty of the department. The evaluation of dissertation in the fourth semester shall include 50 marks for continuous evaluation by the supervisor for regularity in work, mid-term evaluation, report of dissertation, presentation, and final viva-voce; 50 marks (50% weightage) by an external expert shall be based on report of dissertation (25 marks), presentation (10 marks), novelty/originality (5 marks) and final viva-voce (10 marks). The external expert may attend final viva-voce through offline or online mode.

Dissertation:

A. Third semester (Based on Dissertation proposal and presentation)

a. Supervisor [50% weightage]

b. HoD and Senior most faculty [50% weightage]

B. Fourth semester (Based on Dissertation)

a. Continuous assessment, report, presentations, viva voce: Supervisor [50% weightage]

b. Report of dissertation (25 marks), presentation (10 marks), novelty/originality (5 marks) and final viva-voce (10 marks): External expert [Total 50% weightage].

Evaluation Criteria for Practical classes

A. Practical file: [15 Marks]

B. Practical Exam: [70 Marks]

C. Viva-Voce Examination: [15 Marks]

Semester I

Course Title: Mathematical Statistics
Course Code: MSTA.516
Course Type: Core
Total Lectures: 45

L	T	P	Credits
3	0	0	3

Learning outcomes:

The students will be able to -

CLO1: Define the sample space and concept of random variables (discrete and continuous).
CLO2: Explore the concept of Expectations, Moment generating function andcharacteristic functions with examples.
CLO3: Illustrate various properties of Discrete and continuous Distributions. **CLO4:** Explain concepts of sampling distribution and its standard error, Chi-square, t and F distribution.

Units/Hours	Contents	Mapping with CLO
I 11 Hours	Concept of random variables (discrete and continuous). Distribution Function and its properties, mean and variance. Bivariate random variables and their joint, marginal and conditional p.m.fs. and p.d.fs. Independence of random variables. **Activity:** Students will try to work on various examples related to the concepts of p.m.fs. and p.d.fs of random variables.	CLO1
II 12 Hours	Expectation, Conditional expectation, Moments, Moment generating function and its properties, Tchebyshey's inequalities, Markov's inequality, Jensen's inequality, Characteristic function and its elementary properties, weak and strong laws of large numbers, Central Limit theorems (i.i.d. case). **Activity:** Students will explore the use of expectations and its properties in various concepts of statistics. They will also solve problems based on moment generating functions, characteristic functions and weak & strong law of large numbers.	CLO2

III 11 Hours	Discrete Distributions: Bernoulli, Binomial, Poisson, hyper-geometric, geometric, negative binomial. Continuous Distributions: Uniform, normal, exponential, gamma, Beta. **Activity:** Students will explore the use of these discrete and continuous distributions in real life problems.	CLO3
IV 11 Hours	Chi-square, t and F distributions and their applications. Elementary concepts in testing of statistical hypotheses, Tests of significance: tests based on normal distribution, Chi-square, t and F statistic. **Activity:** Students will do the examples applying the tests based on normal distribution, Chi-square, t and F statistics.	CLO4

TRANSACTION MODE: Lecture/Demonstration/Project Method/ Co Operative learning/Seminar/Group discussion/Team teaching /Tutorial/Problem solving/E-team teaching/Self-learning.

Suggested Readings:

1. E. J. Dudewicz and S. N. Mishra, *Modern Mathematical Statistics*, Wiley International Student Edition, 1988.
2. I. Miller and M. Miller, *Mathematical Statistics,* 6th Edition, Oxford & IBHPub., 1999.
3. P. Billingsley, *Probability and Measure*,4th Edition, John Wiley & Sons, 2012.
4. P.L. Meyer, *Introductory probability and statistical applications*, Addison-Wesley Publishing Company, Inc., 1972.
5. S. M. Ross, *Introduction to Probability Models*, 11th Edition, 2014.
6. V. K. Rohtagi and A. K. M. E. Saleh, *An Introduction to Probability Theory and Mathematical Statistics*, Wiley Eastern, 2010.

Course Title: Sampling Theory
Course Code: MSTA.517
Course type: Core
Total Hours: 45

L	T	P	Credits
3	0	0	3

Learning outcomes: The students will be able to

CLO1: Explain various sampling techniques.
CLO2: Classify among SRSWOR, SRSWR, stratified, etc.
CLO3: Make use of Two-stage sampling and double sampling techniques.
CLO4: Understand PPS WR/WOR methods as well as Yates, Grundy and Desraj estimators
CLO5: Discuss Sampling and Non-sampling errors with special reference to non- response problems.

Units/ Hours	Contents	Mapping with CLO
I 11 Hours	Introduction to usual notations used in sampling. Basic finite population sampling techniques: SRSWOR, SRSWR, stratified, systematic and related results on estimation of population mean/ total. Relative precision of different sampling techniques. Allocation problem in stratified sampling. **Activity**: Students will solve problems related to different types of sampling techniques for estimation of population parameters.	CLO1 CLO2
II 12 Hours	Ratio and regression estimators based on the SRSWOR method of sampling. Two-stage sampling with equal size of first stage units. Double sampling for ratio and regression methods of estimation. Cluster sampling - equal clusters. **Activity:** Students will solve problems related to ratio regression, two stage sampling method and clustering	CLO3
III 12 Hours	PPS WR/WOR methods [cumulative total, Lahiri's schemes] and related estimators of a finite population mean: [Thompson-Horwitz, Yates and Grundy estimator, Desraj estimators for a general sample size and Murthy's estimator for a sample of size 2]. **Activity:** Students will solve problems related to the PPS method using different estimators.	CLO4

IV 10 Hours	Sampling and non-sampling errors with special reference to non- response problems. National sample surveys office (NSSO) and role of various statistical organizations in national development. **Activity:** Students will get an understanding about different statistical organizations and their roles.	CLO5

Transaction mode: Lecture/Cooperative learning/Practical/Group discussion/Team teaching /Tutorial/Problem solving/Self-learning.

Suggested Readings:

1. A. Chaudhuri, *Essentials of Survey Sampling*, Prentice Hall of India, 2010.
2. A. Chaudhari and H. Stenger, *Survey Sampling Theory and Methods*, 2nd Edition, Chapman and Hall, 2005.
3. C. Wu and M.E. Thompson, *Sampling Theory and Practice*, Springer, 2020.
4. D. Raj and P. Chandak, *Sampling Theory*, Narosa, 1988.
5. D. Singh and F.S. Chaudhary, *Theory and Analysis Of Sample Survey Designs*, John Wiley & Sons, 1986.
6. P. Mukhopadyay, *Theory and Methods of Survey Sampling*, 2nd Edition, Prentice Hall of India, 2008.
7. A. Chaudhuri, *Essentials of Survey Sampling*, Prentice Hall of India, 2010.
8. A. Chaudhari and H. Stenger, *Survey Sampling Theory and Methods*, 2nd Edition, Chapman and Hall, 2005.
9. C. Wu and M.E. Thompson, *Sampling Theory and Practice*, Springer, 2020.
10. D. Raj and P. Chandak, *Sampling Theory*, Narosa, 1988.
11. D. Singh and F.S. Chaudhary, *Theory and Analysis Of Sample Survey Designs*, John Wiley & Sons, 1986.
12. P. Mukhopadyay, *Theory and Methods of Survey Sampling*, 2nd Edition, Prentice Hall of India, 2008.
13. P.V. Sukhatme and P.V. Sukhatme, *Sampling Theory of Surveys with Applications*, Asia Publishing House, New edition, 1970.
14. S. K. Thompson, *Sampling*, John Wiley and Sons, New York, 2002.
15. W. G. Cochran, *Sampling Techniques*, John Wiley & Sons, New York, 1977.

Course Title: Stochastic Processes

Course Code: MSTA.518
Course Type: Core
Total Hours: 45

L	T	P	Credits
3	0	0	3

Learning Outcomes: The students will be able to
CLO1: Explain Stochastic Processes.
CL02: Classify among various forms of stochastic processes.
CL03: Make use of Chapman Kolmogorov equations.
CL04: Justify Simple Birth, Birth Death Processes.
CL05: Discuss Wiener Processes.

Units/Hours	Contents	Mapping with CLO
I 12 Hours	Introduction to Stochastic Processes. Classification of stochastic processes according to state space and time domain into discrete/continuous time, discrete/continuous state spaces, elementary problems, Random Walk and Gambler's ruin problems, Counting process. Applications of stochastic processes. Stationarity of stochastic processes, Weakly stationary and strongly stationary processes. **Activity:** Students will classify among various forms of stochastic processes. They will solve real life problems using the properties of stochastic processes.	CLO1 CLO2
II 13 Hours	Markov chains: Definition and examples of Markov Chain, Transition probability matrix, classification of states, communicating classes, recurrence: non-recurrence, Irreducibility, Stationary distribution and its interpretation. Chapman- Kolmogorov equations, n-step transition probability matrices and their limits, stationary distribution. **Activity:** Students will solve problems related to Markov chains and derive the stationarity of the distribution.	CLO3
III 10 Hours	Statistical Inference for Markov Chains: Estimation of transition probabilities. Discrete state space continuous time Markov Processes: Poisson process, Simple Birth Process, Simple Death Process, Simple Birth- Death process. **Activity:** Students will explore about the various forms of stochastic processes and estimate their transition probabilities.	CLO4
IV 10 Hours	Continuous State Continuous Time Markov Processes: Brownian motion process, Wiener Process and its properties. **Activity**: Students will solve problems related to continuous state and continuous time stochastic processes.	CLO5

Transaction mode: Lecture/Co Operative learning/ Practical/ Group discussion/Team teaching Problem solving/Self-learning.

Suggested Readings:

1. B. R. Bhat, *Stochastic Models: Analysis and Applications*, New Age International India, 2000.
2. J. Medhi, *Stochastic Processes*, 3rd Ed, Wiley Eastern Ltd., 2012.
3. N. T. Bailey, *The Elements of Stochastic Processes*, John Wiley & Sons, Inc., New York, 1965.
4. S. M. Ross, *Stochastic Processes,* Wiley Publications, 1996.
5. S. Karlin and H. M. Taylor, *A First Course in Stochastic Processes*, Vol. 1, Academic Press, 1975.

Course Title: Quality Control and Time Series Course
Code: MSTA.519
Course Type: Core
Total Hours: 45

L	T	P	Credits
3	0	0	3

Learning outcomes: The students will be able to

CLO1: Understand the concept of quality technology and assurance, productivity

CLO2: Explain $\bar{X}$ and R charts, analysis of pattern on control charts, control chart for attributes - np, p, c and u charts

CLO3: Explain CUSUM, Group control charts, O. C. curve and ARL of control charts.

CLO4: Discuss Dodge's continuous sampling inspection plans.

CLO5: Get in-depth understanding of Time Series models

Units/Hours	Contents	Mapping with CLO
I 11 Hours	The meaning of quality, quality assurance, technology and productivity. Statistical methods for quality control and improvement. Chance and assignable causes of quality variation, general theory of control charts, control charts for variables: $\bar{X}$ and R charts, analysis of pattern on control charts, control chart for attributes- np, p, c and u charts. **Activity**: Students will understand about quality of the product. They will construct various charts to detect pattern in the production process.	CLO1 CL02
II 11 Hours	Multiple stream processes: Group control charts. Specification limits and tolerance limits, O.C and ARL of control charts, CUSUM charts. **Activity**: Students will explore various multiple stream processes and solve problems related to them.	CLO3
III 12 Hours	Review of sampling inspection techniques, single, double, multiple and sequential sampling plans and their properties, methods for estimating (n, c) using large sample techniques, Dodge's continuous sampling inspection plans. **Activity:** Students will use various sampling inspection techniques to make an inference about the acceptance or rejection of the lot of final products.	CLO4

IV 11 Hours	Time series as discrete parameter stochastic process. Auto covariance and auto correlation functions and their properties. Moving average (MA), Auto regressive (AR), ARMA and ARIMA models. Box-Jenkins models. Choice of AR and MA periods. Estimation of ARIMA model parameters, correlogram analysis. **Activity**: Students will understand various time series models and solve problems to understand their applications.	CLO5

Transaction mode: Lecture/Co Operative learning/ Practical/ Group discussion/Team teaching /Tutorial/Problem solving/Self-learning.

Suggested Readings:

1. D. C. Montgomery and L. A. Johnson, *Forecasting and Time Series Analysis*, Mc Graw Hill, New York, 1976.
2. D. C. Montgomery, *Introduction to Statistical Quality Control*, 8th Edition., John Wiley & Sons, 2019.
3. G. B. Wetherill, *Sampling Inspection and Quality Control*, Halsted Press, 1977.
4. P. J. Brockwell and A. Daris Richard, *Introduction to Time Series And Forecasting*, 2nd Edition. Springer-Verlag, New York, Inc. (Springer Texts in Statistics), 2002.
5. S. Biswas, *Statistics of Quality Control, Sampling Inspection and Reliability*, New Age International Publishers Eastern Ltd, 1996.

Course Title: Real Analysis
Course Code: MMAT.520
Course type: Skill Based

L	T	P	Credits
3	0	0	3

Total Hours: 45

Learning outcomes:
The students will be able to
CLO1: Apply the knowledge of set theory and metric spaces with properties.
CLO2: Illustrate various properties of compact sets and connected sets.
CLO3: Explain concepts of convergent sequences and continuity in metric spaces.
CLO4: Apply the knowledge of Riemann Stieltjes Integrals.
CLO5: Discuss the problem of interchange of limit processes for sequences of functions and pointwise/Uniform convergence of sequence of functions.

Units/Hours	Contents	Mapping with CLO
I 12 Hours	**Metric spaces:** Definition and examples, Open and closed sets, Compact sets, Elementary properties of compact sets, k- cells, Compactness of k-cells, Compact subsets of Euclidean space, Bolzano Weierstrass theorem, Heine Borel theorem, Perfect sets, Cantor set, separated sets, connected sets in a metric space, Connected subsets of real line. **Activity:** Students will solve some problems which will be based on concepts of compact sets and connected sets	CLO1 CL02
II 11 Hours	**Sequences in Metric spaces:** Convergent sequences, Subsequences, Cauchy sequences, Complete metric space with examples, Cantor's intersection theorem (Statement only), Category of a set and Baire's category theorem. Banach contraction principle. **Activity:** Students will solve some problems which will be based on application of sequences, category theorem and Banach contraction theorem.	CLO3
III 12 Hours	**Continuity:** Limits of functions (in Metric spaces), Continuous functions, Continuity and compactness, Continuity and connectedness, Discontinuities, Uniform continuity. **Riemann Stieltje's Integral:** Definition and existence of Riemann Stieltje's integral, Properties of integral. Integration and Differentiation. Fundamental Theorem of Calculus, 1st and 2nd Mean Value Theorems of Riemann Stieltje's integral. **Activity:** Students will do examples/exercises related to continuity and its characterizations. Students will explore how Riemann Stieltje's integral is a generalization of Riemann integral.	CLO4

IV 10 Hours	**Sequences and series of functions:** Problem of interchange of limit processes for sequences of functions, Uniform convergence, Uniform convergence and continuity, Uniform convergence and integration, Uniform convergence and differentiation. **Activity:** Students will explore how uniform convergence is related to integration and differentiation.	CLO5

TRANSACTION MODE: Lecture/Demonstration/Project Method/ Co Operative learning/ Seminar/Group discussion/Team teaching /Tutorial/Problem solving/E-team teaching/Self-learning.

Suggested Readings:

1. T. M. Apostol, *Mathematical Analysis*, 2nd Edition, Addition –Wesley, USA, 2002.
2. A. Kumar and S. Kumaresan, *A Basic Course in Real Analysis*, Narosa, Publishing House, New Delhi, 2014.
3. W. Rudin, *Principles of Mathematical Analysis,* 3rd Edition, McGraw Hill, Kogakusha, International student Edition, 1976.
4. E. C. Titchmarsh, *The Theory of functions,* Oxford University Press, Oxford, 2002.
5. S. P. S. Kainth, A Comprehensive Textbook on Metric Spaces, Springer Verlag, Singapore, 2023.

Course Title: Basics of R Programming (Practical)
Course Code: MSTA.401
Course Type: Skill Based
Total Hours: 30

L	T	P	Credits
0	0	2	1

Learning Outcome.
The students will be able to

- Explain various mathematical operators
- Illustrate mathematical function in R
- Discuss methods to handle dataset in R

Laboratory Work. Program related to R programming.

1. Learn the basic procedure for installation of the R software.
2. Use mathematical operators, relational operators.
3. Understand if-else function, nested loop
4. Understand for loop, while loops, break nest statement
5. Understand mathematical functions in R, random numbers in R
6. Apply Matrix operations in R
7. Apply List operators
8. Implement the concept of usage of various packages in R.
9. Develop skills to handle dataset in R.
10. Develop skills to construct graphical display, histogram, boxplot.

Transaction mode: Lecture/Co Operative learning/ Practical/ Group discussion/Team teaching /Tutorial/Problem solving/Self-learning.

Suggested Reading

1. J. P. Lander, *R for Everyone, Advanced Analytics and Graphics,* Ist Edition, Pearson Education, 2014.
2. M. Gardener, *Beginning R: The Statistical Programming Language*, Wiley, 2013.

Course Title: Introduction of Mathematica and MATLAB
Course Code: MMAT.401
Course Type: Skill Based
Total Hours: 30

L	T	P	Credits
0	0	2	1

To be performed using Computer with aid of MATLAB/MATHEMATICA/MAPLE or any other such software

1. Plotting the graphs of the functions, exp(ax+b), log(ax+b), 1⁄ax+b, sin(ax+b), cos (ax+b) and |ax+b| to illustrate the effect of a and b on the graph.
2. Plotting the graphs of the polynomial of degree 4 and 5.
3. Sketching parametric curves (E.g. Trochoid, cycloid, hypocycloid).
4. Obtaining the surface of the revolution of curves.
5. Tracing of conics in Cartesian coordinates/polar coordinates.
6. Sketching ellipsoid, hyperboloid of one and two sheets (using Cartesian coordinates).
7. Construction of matrices and arithmetic operations among the matrices.

Transaction mode: Lecture/Co Operative learning/ Practical/ Group discussion/Team teaching /Tutorial/Problem solving/Self-learning.

Suggested Readings:

1. Peter I. Kattan, MATLAB for Beginners: A Gentle Approach, Publisher: Petra Books, 2008.
2. H.Anton, I.Bivensand S.Davis, Calculus,10th Ed., John Wiley and Sons (Asia) P.Ltd., Singapore, 2002.
3. Shanti Narayan, P. K. Mittal, Differential Calculus, S. Chand, 2014.
4. Shanti Narayan, P. K. Mittal, Integral Calculus, S. Chand, 2014.
5. James Stewart, Single Variable Calculus, Early Transcendentals, Cengage Learning, 2016.
6. G.B. Thomas and R.L. Finney, Calculus, 9th Ed., Pearson Education, Delhi, 2005.

Course Title: Linear Algebra
Course Code: MMAT.403
Course Type: Core
Total Hours: 45

L	T	P	Credits
3	0	0	3

Learning outcomes:
The students will be able to

CLO1: Review the basic notions in linear algebra that are often used in mathematics and other sciences
CLO2: Define Vector spaces, Subspaces and related results.
CLO3: Define Linear transformations and characteristic polynomials with examples.
CLO4: Illustrate various properties of canonical forms.
CLO5: Study of inner product spaces.
CLO6: Explain concepts of the Gram-Schmidt orthogonalization process and its application in construction of orthonormal basis.

Unit/Hours	Content	Mapping with CLO
I 11 Hours	**Linear Transformations:** Linear transformations, Algebra of linear transformations, Isomorphism, **Matrix representation:** Matrix representation of a linear transformation. Change of basis, Rank and nullity of a linear transformation. **Activity:** Students will try to find the applications of linear transformations and matrices	CLO1 CLO2
II 11 Hours	Inner product spaces. Norms and distances, Orthonormal basis, Orthogonality, Schwarz inequality, The Gram-Schmidt orthogonalization process. Orthogonal and positive definite matrices. **Activity:** Students will try to find the applications of Gram-Schmidt orthogonalization process	CLO5 CLO6
III 12 Hours	Annihilating Polynomials: Characteristic polynomial and minimal polynomial of a linear transformation, Characteristic values and Characteristic vectors of a linear transformation, Cayley Hamilton theorem. **Activity:** Students will try to find the applications of Cayley Hamilton theorem.	CLO3
IV 11 Hours	Diagonalizing matrices, Diagonalizing real symmetric matrices, Characteristic polynomials and minimal polynomials of block matrices, Canonical forms: Jordan canonical forms, rational canonical forms. Quotient spaces, Bilinear forms, Symmetric and skew- Symmetric bilinear forms, Sylvester's theorem, quadratic forms, Hermitian forms. **Activity:** Students will try to find the applications of Characteristic polynomials and minimal polynomials of block matrices.	CLO4

TRANSACTION MODE: Lecture/Demonstration/Project Method/ Co Operative learning/ Seminar/Group discussion/Team teaching /Tutorial/Problem solving/E-team teaching/Self-learning.

Suggested Readings:

1. J. Gilbert and L. Gilbert, *Linear Algebra and Matrix Theory,* Cengage Learning, 2004.
2. K. Hoffman and R. Kunze: *Linear Algebra,* Pearson Education (Asia) Pvt. Ltd/ Prentice Hall of India, 2018.
3. V. Bist and V. Sahai, *Linear Algebra,* Narosa, Delhi, 2002.
4. S Lang, *Linear Algebra*, Undergraduate texts in mathematics, Springer, 1989.

Semester II

Course Title: Statistical Inference

Course Code: MSTA.524
Course Type: Core
Total Hours: 45

L	T	P	Credits
3	0	0	3

Learning outcomes: The students will be able to
CLO1: Learn different estimation techniques.
CLO2: Identify a good estimator.
CLO3: Learn the concept of MVUE and UMVUE.
CLO4: Establish various properties of likelihood estimators.
CLO5: Understand the concept of statistical inference under Bayesian framework.

Units/ Hours	Contents	Mapping with CLO
I 12 Hours	Statistic and its sampling distributions, Concept of mean squared errors. Basic concepts of point estimation: Unbiasedness, consistency and efficiency of estimators. Examples from some standard discrete and continuous distributions. Sufficiency and minimal sufficiency, Exponential family of distributions, Factorization criteria, Completeness. **Activity:** Students will explore the basic concept of parametric estimation. They will learn how to extract a good estimator among the huge class of estimators.	CLO1 CL02
II 12 Hours	Minimum and uniformly minimum variance unbiased estimation, Rao-Blackwell and Lehmann-Scheffe theorems. Ancillary statistic, Basu's theorem and its applications. Fisher information measure, Cramer-Rao inequality, Chapman-Robin inequality, Bhattacharya bounds. **Activity:** Students will learn the concept of Fisher information measure and will construct some important lower bounds for variance	CLO3
III 11 Hours	Methods of estimation: Method of moments, Maximum likelihood estimators, Properties of maximum likelihood estimators, Least square estimation, Minimum chi- square method. **Activity:** Students will explore various methods of parameter estimation and will establish its statistical properties.	CLO4

IV 10 Hours	Introduction to Bayesian Statistics and its applications: Loss function, Prior distribution, Bayes' theorem, Posterior distribution, Bayes' risk, Bayes' principle, Bayesian estimation, Properties of Bayesian estimator. **Activity**: Students will learn basic concepts of Bayes' estimation.	CLO5

Transaction mode: Lecture/Co Operative learning/ Practical/ Group discussion/Team teaching/Tutorial / Problem solving/Self-learning.

Suggested Readings:

1. A. K. M. E. Saleh and V. K. Rohatgi, *An Introduction to Probability and Statistics*, 3rd Edition, Wiley, 2015.
2. B. K. Kale, *A First Course on Parametric Inference*, Narosa Publishing House, 2005.
3. C. R. Rao, *Linear Statistical Inference and its Applications*, 2nd Edition, Wiley, 2009.
4. E. J. Dudewicz and S. N. Mishra, *Modern Mathematical Statistics*, Wiley International Student Edition, 1988.
5. E. L. Lehmann, *Theory of Point, Estimation*, Student Edition, John Wiley & Sons, 1986.
6. G. Casella and R. L. Berger, *Statistical Inference*, 2nd Edition, Duxbury Thomson Learning, 2021.

Course Title: Multivariate Analysis
Course Code: MSTA.525
Course Type: Core
Total Hours: 45

L	T	P	Credits
3	0	0	3

Learning Outcomes:

The students will be able to

CLO1: Learn various important properties of multivariate normal distribution.

CLO2: Analyze multivariate data.

CLO3: Understand multivariate hypothesis tests and infer appropriate conclusions.

CLO4: Use the Wishart distribution in real applications.

CLO5: Explore the principles of data reduction technique

Units/ Hours	Contents	Mapping with CLO
I 11 Hours	Multivariate normal distribution: Definition, conditional & marginal distributions, characteristic function. Maximum likelihood estimators of parameters. Distributions of sample mean vector and variance-covariance matrix and their independence. Null distribution of partial and multiple correlation coefficients. Application in testing and interval estimation. **Activity:** Students will explore the concept of multivariate normal distribution and will obtain its MLEs. Students will also apply multivariate normal population in testing and interval estimation.	CLO1 CLO2

II 11 Hours	Hotelling's T^2, its distribution and applications. One sample, two sample and application in tests on mean equality of the components of a mean vector in a multivariate normal population. Mahalanobis D^2 and its sampling distribution. **Activity:** Students will learn the generalization of Student's t-distribution and will use it in one sample and two sample problems.	CLO3
III 11 Hours	Wishart distribution and its properties. Distribution of sample generalized variance. Classification and discriminant procedure for discriminating between two multivariate normal populations, Sample discriminant function and related tests. Probabilities of misclassification and their estimation. **Activity:** Students will learn about classification and discriminant procedure for discriminating between two multivariate normal populations.	CLO4
IV 11 Hours	Generalized variance, Wilk's criterion and Multivariate Analysis of Variance [MANOVA] of one-way classified data. Testing independence of sets of variates and equality of covariance matrices. Principle components, dimension reduction, canonical variables and canonical correlation: definition, use, estimation and computation. **Activity:** Students will explore the concept of data reduction and also learn about canonical correlation.	CLO5

Transaction mode: Lecture/Demonstration/ Co Operative learning/ programming/Practical/Group discussion/Team teaching/Experimentation/Tutorial/Problem solving/Self-learning.

Suggested Readings:

1. A. M. Kshirsagar, *Multivariate Analysis*, Illustrated Edition, Marcel Dekker, 1972.
2. N. C. Giri, *Multivariate Statistical Inference*. 1st Edition, Academic Press, 2004.
3. R. A. Johnson and D. Wichern, *Applied Multivariate Statistical Analysis*, 7th Edition, Pearson, 2013.
4. T. W. Anderson, *An Introduction to Multivariate Statistical Analysis*, 6th Edition, John Wiley & Sons, 2015.
5. W. K. Hardly and L. Simor, *Applied Multivariate Statistical Analysis*, 4th Edition,Springer-Verlag Berlin Heidelberg, 2015.
6. A. M. Kshirsagar, *Multivariate Analysis*, Illustrated Edition, Marcel Dekker, 1972.
7. N. C. Giri, *Multivariate Statistical Inference*. 1st Edition, Academic Press, 2004.
8. R. A. Johnson and D. Wichern, *Applied Multivariate Statistical Analysis*, 7th Edition, Pearson, 2013.
9. T. W. Anderson, *An Introduction to Multivariate Statistical Analysis*, 6th Edition, John Wiley & Sons, 2015.
10. W. K. Hardly and L. Simor, *Applied Multivariate Statistical Analysis*, 4th Edition,Springer-Verlag Berlin Heidelberg, 2015.

Course Title: Design and Analysis of Experiment

Course Code: MSTA.526

Course Type: Core

Total Hours: 45

L	T	P	Credits
3	0	0	3

Learning Outcomes: The students will be able to

CLO1: Discuss three basic principles of design of experiments.

CLO2: Apply the concept of balancing.

CLO3: Understand the concept of missing plot techniques.

CLO4: Develop understanding of Balanced Incomplete Block Design, Split- Plot Design and Strip-Plot Design.

Units/Hours	Contents	Mapping with CLO
I 12 Hours	Three basic principles of design of experiments: Randomization, replication and local control. Fixed effect and random effect model. Design useful for elimination of heterogeneity, Completely randomized, randomized complete block design. **Activity:** Students will learn about three basic principles of design of experiments. They will also solve problems related to CRD and RCBD.	CLO1
II 11 Hours	Balanced incomplete block designs and their applications. Asymptotic relative efficiency of various designs, missing plot technique. Latin squares, Graeco Latin squares design. **Activity:** Students will understand the concept of BIBD and solve problems related to Latin square and Graeco Latin Square Design.	CLO2
III 11 Hours	Factorial designs, 2^2 and 2^3 factorial designs, confounding, fractional replication. **Activity:** Students will understand the concept of Factorial designs and solve problems related to them.	CLO3
IV 11 Hours	Nested Designs: Split- plot Design, Strip-plot Design. **Activity**: Students will learn about Split- plot design and strip plot design and understand their application in real life.	CLO4

Transaction mode: Lecture/Demonstration/ Co Operative learning/ programming / Practical/ Group discussion/Team teaching/Experimentation/Tutorial/Problem solving/Self-learning.

Suggested Readings:

1. D. C. Montgomery, *Design and Analysis of Experiment*, 10th Edition, John & sons, Wiley, 2019.
2. D. Raghavarao, *Construction and Combinatorial Problems in Design of Experiments*, Wiley, 1971.
3. M. C. Chakarbarti, *Mathematics of Design and Analysis of Experiments*, Asia Publishing House, 1970.
4. M. N. Dass and N. C. Giri, *Design and Analysis of Experiments*, 3rd Edition, Wiley, 2017.
5. O. Kempthorne, *Design and Analysis of Experiments, 2nd Edition, Vol I-II*, Wiley, 2007.
6. W. G. Cochran and G. M. Cox, *Design of Experiments*, 2nd Edition, John Wiley & Sons, 2003.

Course Title: Basics of LaTeX (Practical)

Course Code: MMAT.405

Course Type: Skill Based

Total Hours: 30

L	T	P	Credits
0	0	2	1

Learning outcomes: The students will be able to

1. Installation of the LaTeX software in Windows and Linux and understanding LaTeX compilation and LaTeX editors.
2. Basic syntax used in LaTeX.
3. Writing mathematical equations, Matrices, Tables, Inclusion of graphics into LaTeX file.
4. Page configurations**:** Title, Abstract, Keywords, Chapter, Sections and Subsections.
5. References and their citations.
6. Labeling of equations, Table of contents, List of figures.
7. Use of Packages**:** amsmath, amssymb, amsthm, amsfonts, graphic.
8. Use of document classes**:** Article, Report, Book, Beamer.
9. Applications of LaTeX in writing reports, books, research papers and thesis.

Transaction mode: Lecture/Demonstration/ Co Operative learning/ programming / Practical/ Group discussion/Team teaching/Experimentation/Tutorial/Problem solving/Self-learning.

Suggested Readings:

1 D. F. Griffiths and D. J. Higham, *Learning LaTeX,* 2nd Edition, Philadelphia, Pennsylvania, SIAM, 2016.

2 L. Lamport. *LATEX: A Document Preparation System, User's Guide and Reference Manual*. 2nd Edition, Addison Wesley, New York, 1994.

3 M. Goossens, F. M. Michel, and S. Alexander, *The LaTeX companion*, 2nd Edition, Addison-Wesley, 1994.

Course Title: Basics of Python Programming (Practical)
Course Code: MSTA.402
Course Type: Skill Based
Total Hours: 30

L	T	P	Credits
0	0	2	1

Learning Outcome.
The students will be able to

- Explain various mathematical operators
- Illustrate mathematical function in **Python**
- Discuss methods to handle dataset in **Python**

Laboratory Work. Program related to Python programming.

1. A brief introduction about Python and installation of anaconda.
2. Numerical computations including square root, trigonometric functions using math and cmath module.
3. Dealing with different data types such as list, tuple and dictionary.
4. If statements, for loop and While loops and simple programmes using these.
5. User-defined functions and modules.
6. Various uses of lists, tuples and dictionaries.
7. Use of Matplotlib to plot graphs in various formats.
8. Classes in Python.
9. Use of Numpy and Scipy for solving problems in linear algebra and calculus, differential equations.
10. Data handling using Pandas

Transaction mode: Lecture/Co Operative learning/ Practical/ Group discussion/Team teaching /Tutorial/Problem solving/Self-learning.

Suggested Reading

1. Kenneth A, Fundamentals of Python First programs 2nd edition - Lambert, Cengage, Learning India.
2. Amit Saha, Doing Math with Python -, No starch Press,
3. E. Balgurusamy, Problem solving and Python programming- Tata McGraw Hill.
4. Paul Zimmermann, Computational Mathematics with SageMath-.
5. Razvan A. Mezei, Introduction to Programming using SageMath-, Publisher Wiley, 2021.

Course Title: Numerical Analysis
Course Code: MMAT.404
Course Type: Skill Based
Total Hours: 45

L	T	P	Credits
3	0	0	3

Learning outcomes:
The students will be able to

- Review the basic concepts of various numerical techniques for a variety of mathematical problems occurring in science and engineering.
- Explain the basic concept of errors.
- Review the numerical techniques for interpolation and approximations with examples.
- Explain the concept of numerical integration and solutions of differential equations.

Units/Hours	Contents	Mapping with CLO
I 11 Hours	**Error Analysis:** Definition and sources of errors, Propagation of errors, Sensitivity and conditioning, Stability and accuracy, Floating-point arithmetic and rounding errors. **Numerical Solutions of Algebraic Equations**: Bisection method. Fixed-point iteration, Newton Raphson's method, Secant method, Convergence and order of convergence **Activity:** Students will explore the use of these methods in solving some real life problems.	CLO1
II 12 Hours	**Linear Systems of Equations:** Gauss elimination and Gauss-Jordan methods, Jacobi and Gauss- Seidel iteration methods. **Polynomial Interpolation:** Interpolating polynomial, Lagrange and Newton divided difference interpolation, Error in interpolation, Finite difference formulas, Hermite Interpolation. **Activity:** Students will make some programmes for implementing these methods using some computer software.	CLO2
III 11 Hours	**Numerical Differentiation and Integration:** Numerical differentiation with finite differences, Trapezoidal rule, Simpson's 1/3 - rule, Simpson's 3/8 rule, Error estimates for Trapezoidal rule and Simpson's rule, Gauss quadrature formulas. **Activity:** Students will make some programmes for implementing these methods using some computer software.	CLO3
IV 11 Hours	**Numerical Solution of Ordinary Differential Equations:** Solution by Taylor series, Picard method of successive approximations, Euler's method, Modified Euler method, Runge- Kutta methods. Finite difference method for boundary value problems. **Activity:** Students will explore the use of these methods in solving some scientific problems.	CLO4

TRANSACTION MODE: Lecture/Demonstration/Project Method/ Co Operative learning/ Seminar/Group discussion/Team teaching /Tutorial/Problem solving/E-team teaching/Self-learning.

Suggested Readings:

1. K. Atkinson, *An Introduction to Numerical Analysis*, 2nd Edition, John Wiley & Sons, 1989.
2. R. L. Burden and J. D. Faires, *Numerical Analysis*, 9th Edition, Cengage Learning, 2011.
3. C. F. Gerald and P. O. Wheatly,*Applied Numerical Analysis*, 7th Edition, Pearson LPE, 2009.
4. R. S. Gupta, *Elements of Numerical Analysis*, 2nd Edition, Cambridge University Press, 2015.
5. M. K. Jain, S.R.K. Iyengar and R.K. Jain, *Numerical Methods for Scientific and Engineering Computation*, 6th Edition, New Age International, New Delhi, 2015.
6. S. S. Sastry, *Introductory Methods of Numerical Analysis*, 4th Edition, PHI.

Course Title: Complex Analysis
Course Code: MMAT.407
Course Type: Skill Based
Total Hours: 45

L	T	P	Credits
3	0	0	3

Learning outcomes:

The students will be able to

CLO1: Recall complex number systems and algebra of complex variables.

CLO2: Illustrate the concept of analytic function and discuss the necessary and sufficient conditions for a function to be analytic.

CLO3: Understand the notion of complex line integral and related results.

CLO4: Discuss Mobius transformations and their properties.

CLO5: Apply ideas of Complex analysis in allied areas.

Units/Hours	Contents	Mapping with CLO
I 10 Hours	Functions of a complex variable, limit, continuity, uniform continuity, differentiability, analytic function, Cauchy- Riemann equations, harmonic functions and harmonic conjugate. **Activity:** Students will make use of Cauchy- Riemann equations to investigate the functions of complex variables which are analytic or not.	CLO1 CL02
II 12 Hours	Complex line integral, Cauchy's theorem, Cauchy-Goursat theorem, Cauchy's integral formula and its generalized form, Cauchy's inequality. Poisson's integral formula (Statement only), Morera's theorem. Liouville's theorem. Contour integral, power series, Taylor's and Laurent's series. **Activity:** Students will find the applications of important theorems like Cauchy's theorem and Cauchy's integral formula. They will also work on various examples of contour integrals.	CLO3
III 12 Hours	Singularities of analytic functions, Fundamental theorem of algebra, zeros of analytic function, poles, residues, residue theorem and its applications to contour integrals. Maximum modulus principle, Schwarz lemma. **Activity:** Students will do the examples related to singularities and poles of analytic functions. They will explore the concept of residues and its applications to solve contour integrals.	CLO4

IV 11 Hours	Meromorphic functions, the argument principle, Rouche's theorem, Mobius transformations and their properties, definition and examples of conformal mappings. **Activity:** Students will explore the concept of Mobius transformations and its applications in different fields.	CLO5

TRANSACTION MODE: Lecture/Demonstration/Project Method/ Co Operative learning/ Seminar/Group discussion/Team teaching /Tutorial/Problem solving/E-team teaching/Self-learning.

Suggested Readings:

1. H.S. Kasana, *Complex Variables:Theory and Applications,* 2nd Edition, PHI Learning Pvt. Ltd, 2005.
2. R. V. Churchill & J. W. Brown, *Complex Variables and Applications*, 9th Edition, Tata McGraw-Hill, 2014.
3. S. Ponnusamy, *Foundations of Complex Analysis*, 2nd Edition, Narosa Publishing House, 2007.
4. Theodore W. Gamelin, *Complex Analysis*. UTM, Springer-Verlag 2001.
5. W. Tutschke and H.L. Vasudeva, *An Introduction to Complex Analysis, Classical and Modern Approaches*, 1st Edition,CRC Publications, 2004.
6. Rajendra Kumar Sharma, Sudesh Kumari Shah and Asha Gauri Shankar, *Complex Numbers and Theory of Equations*, Anthem Press, 2011.
7. Lars V. Ahlfors, An Introduction to the Theory of Analytic Function of one complex variable, 3rd Edition, Tata McGraw-Hill, 2006.
8. Dennis G. Zill & Patrick D. Shanahan, A First Course in Complex Analysis with Application, 3rd Edition, Jones and Bartlett, 2003.
9. S. Kumaresan*, A Pathway to Complex Analysis, 1st Edition, Techno World Publication, 2021.*
10. Rajendra Kumar Sharma, Sudesh Kumari Shah and Asha Gauri Shankar, *Complex Numbers and Theory of Equations*, Anthem Press, 2011.

Course Title: Econometrics
Course Code: MSTA.520
Course Type: DEC
Total Hours: 45

L	T	P	Credits
3	0	0	3

Learning outcomes:
The students will be able to

CLO1: Understand the concept of OLS and GLS in general linear models (GLM).

CLO2: Explain problem of autocorrelation, multicollinearity in GLM.

CLO3: Discuss Simultaneous linear equations and identification problem.

CLO4: Get in-depth understanding of 2SLS estimators.

Units/Hours	Contents	Mapping with CLO
I 12 Hours	Nature of econometrics. The general linear model (GLM) and its assumptions. Ordinary least squares (OLS) estimation and prediction. Significance tests and confidence intervals, linear restrictions. Use of dummy variables. Generalized least squares (GLS) estimation and prediction. **Activity:** Students will explore various forms of least square estimation techniques and their assumptions.	CLO1
II 12 Hours	Auto correlation, its consequences, and tests. Estimation and prediction. Multicollinearity problem, its implications and tools for handling the problem. Autoregressive linear regression. **Activity:** Students will check whether the model satisfies the assumptions of linear regression model. Students will explore various other forms of regression and solve problems related to them	CLO2
III 10 Hours	Simultaneous linear equations model, examples. Identification problem. Restrictions on structural parameters –rank and order conditions. **Activities:** Students will solve problems related to Simultaneous Linear equations.	CLO3
IV 11 Hours	Estimation in simultaneous equations model. Recursive systems, 2 SLS estimators, Full information maximum likelihood method. Prediction and simultaneous confidence intervals. **Activities**: Students will explore two stage and three stage linear estimators and solve problems related to them.	CLO4

Transaction mode: Lecture/Demonstration/ Co Operative learning/programming/Practical/ Group discussion/Team teaching/Experimentation/Tutorial/Problem solving/Self-learning.

Suggested Readings:

1. A. Koutsyannis, *Theory of Econometrics, Mc Millian, 2004.*
2. D. N. Gujarati, D. Porter and S. Gunasekar, *Basic Econometrics*, 5th Edition, McGraw−Hill, 2017.
3. G. C. Judge, R. C. Hill, W. E. Griffiths, H. Lutkepohl and T. C. Lee, *Introduction to the Theory and Practice of Econometrics,* 2nd Edition, John Wiley & Sons, 1988.
4. J. Kmenta, *Elements of Econometrics*, 2nd Edition, Mac Millan, 1986.
5. J. Johnston, *Econometric Methods*, Mc Graw Hill, 1991.
6. W. H. Greene, *Econometric Analysis,* Prentice Hall, 8th Edition, 2018.

Course Title: Statistical Methods for Insurance

Course Code: MSTA.521

Course Type: DEC

Total Hours: 45

L	T	P	Credits
3	0	0	3

Learning outcomes:

The students will be able to

CLO1: Understand the concept of loss distributions.

CLO2: Explain Insurance contracts.

CLO3: Classify collective and individual risk models.

CLO4: Discuss ruin theory.

CLO5: Get in-depth understanding of Bayesian inference and credibility theory.

Units/Hours	Contents	Mapping with CLO
I 11Hours	Review of Loss distributions: Classical loss distributions, heavy-tailed distributions, reinsurance and loss distributions. Reinsurance and effect of inflation. **Activity:** Students will learn about loss distribution used in insurance sector.	CLO1
II 12 Hours	Risk models for aggregate claims: Collective risk model and individual risk model, premiums and reserves for aggregate claims, reinsurance for aggregate claims. **Activity:** Students will learn various types of risk models and solve problems related to them.	CLO2 CLO3
III 11 Hours	Ruin theory: Surplus process in discrete time and continuous time, probability of ruin in finite and infinite time, adjustment coefficient, Lundberg inequality, applications in reinsurance. **Activity:** Students will learn the concept of ruin theory and solve application part of ruin theory in insurance sector.	CLO4
IV 11 Hours	Introduction to Bayesian inference, Credibility Theory, Full credibility for claim frequency, claim severity and aggregate loss. Bayesian credibility, Empirical Bayes credibility. **Activity**: Students will learn about the concept of Bayesian inference and credibility theory and solve problems related to them.	CLO5

Transaction mode: Lecture/Demonstration/ Co Operative learning/programming/Practical/ Group discussion/Team teaching/Experimentation/Tutorial/Problem solving/Self-learning.

Suggested Readings:

1. D. C. M. Dickson, *Insurance Risk and Ruin*, Cambridge University Press, 2nd Edition., Cambridge, 2016.
2. E. S. Harrington and R. Gregory, *Risk Management and Insurance*: 2nd ed., Tata McGraw Hill Publicating Company Ltd. New Delhi,1998.
3. J. Grandell, *Aspects of Risk Theory*, Springer-Verlag, New York, 1990.
4. N. L. Bowers, H. U. Gerber, J. C. Hickman, D. A. Jones, and C. J. Nesbitt, *Actuarial Mathematics*, 2nd Edition, The Society of Actuaries. Sahaumburg, Illinois, 1984.
5. P. J. Boland, *Statistical and Probabilistic Methods in Actuarial Science*. Chapman & Hall, London, 2007.
6. S. Ramasubramanian, *Lectures on Insurance Models*, Hindustan Book Agency Texts and Readings in Mathematics, 2009.
7. T. Mikosch, *Non-Life Insurance Mathematics- An Introduction with a Poisson Process*, Springer, Berlin, 2004.

Course Title: Extreme Value Theory
Course Code: MSTA.522
Course Type: DEC
Total Hours: 45

L	T	P	Credits
3	0	0	3

Learning Outcomes:

The students will be able to

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

CLO1: Understand the basic concepts of order statistics, joint, marginal and conditional probability distributions of order statistics.

CLO2: Learn about distribution-free confidence intervals for population quantile and distribution free tolerance intervals for population distributions.

CLO3: Construct the recurrence relations and identities for moments of order statistics.

CLO4: Enhanced with the concepts of distributions of order statistics for independently and not identically distributed variates and also for dependent variates.

Units/Hours	Contents	Mapping with CLO
I **12 Hours**	Order Statistics: Distribution of first and last order statistics, Distribution of a single order statistic, Joint distribution of two consecutive order statistics, Distribution of Range, spacing between two order statistics, ratio of two order statistics. Illustrative examples considering different family of distributions. **Activity:** Students will explore various concepts of order statistics.	CLO1
II **11 Hours**	Fluctuations of Maxima - Limit distribution of linearly normalized maxima, Weak convergence of maxima. Maximum Domains of attraction and Norming constants – The maximum domains of attractions of extreme value distributions. Von Mises' theorem. Fluctuations of univariate upper order statistics. The Generalized Extreme Value Distribution, The Generalized Pareto Distribution **Activitiy:** Students will check various results and theorems related to mode of convergence for order statistics	CLO2
III **11 Hours**	Diagnostic procedure to identify maximum domains of attractions: Hill Plot, Probability Paper Plot, Zipf's plot, QQ Plot, Mean Excess Plot, Sum Plot. Illustration contains different classes of distributions. Test for identification of max domain of attractions: Hasofer and Wang's test, Segers and Teugels test, Ratio between Maximum to sum of excess. **Activitiy** Students will solve problems related to various diagnostic techniques.	CLO3
IV **11 Hours**	Analysis the Hydrology, Insurance, Finance, Geology, Environment, Meteorology, Seismic dataset by graphical diagnostic procedure and fitting of suitable extreme value distribution. **Activitiy**: Students will explore various applications of extreme value distributions in real applications.	CLO4

Transaction mode: Lecture/Demonstration/ Co Operative learning/programming/Practical/ Group discussion/Team teaching/Experimentation/Tutorial/Problem solving/Self-learning.

Suggested Readings:

1. Embrechts, P., Kluppelberg, C., & Mikosch, T. Modelling extremal events: For insurance and finance. Sringer, 2013.
2. Beirlant, J., Goegebeur, Y., Segers, J., &Teugels, J. L. Statistics of extremes: theory and applications. John Wiley & Sons, 2006.
3. Kotz, S., & Nadarajah, S. Extreme value distributions: theory and applications. World Scientific, 2000.
4. Castillo, E., Hadi, A. S., Balakrishnan, N., & Sarabia, J. M. Extreme value and related models with applications in engineering and science, Wiley, 2005.

Course Title: Actuarial Statistics
Course Code: MSTA.523
Course Type: DEC
Total Hours: 45

L	T	P	Credits
3	0	0	3

Learning outcomes: The students will be able to
CLO1: Discuss various forms of rate of interest and their applications.
CLO2: Understand the concept of interest rates.
CLO3: Explain the concept of future lifetime, survival and mortality.
CLO4: Get in-depth understanding of assurance and annuity contracts

Units/Hours	Contents	Mapping with CLO
I 10 Hours	Principles of compound interest: Nominal and effective rates of interest and discount, force of interest and discount, compound interest, accumulation factor. **Activitiy:** Students will solve problems related to different types of interest and discounting factor.	CLO1
II 09 Hours	Life tables function like $\boldsymbol{l_x}$, $\boldsymbol{d_x}$ and probability of survival and Probability of death and their select equivalents. **Activitiy:** Students will solve problems how to evaluate survival and death probability from life table	CLO2
III 10 Hours	Define the distribution and density function of continuous future lifetime and curtate future lifetime random variable. Define force of mortality, survival function and derive relationship between them. **Activitiy:** Students will explore the concept of future lifetime distribution, force of mortality and solve problems related to them.	CLO3
IV 16 Hours	Assurance and annuity contracts: definitions of benefits and premiums, various types of assurances and annuities, present value, formulae for mean and variance of various continuous and discrete payments. **Activitiy**: Students will learn about various types of assurance and annuity. Students will solve problems related how to derive mean and variance of these contracts.	CLO4

Transaction mode: Lecture/Co Operative learning/ Practical/ Group discussion/Team teaching /Tutorial/Problem solving/Self-learning.

Suggested Readings:

1 D. S. Borowaik and A. F. Shapiro, *Financial and Actuarial Statistics: An Introduction*, 2nd Edition, Marcel Dekker Inc., New York-Basel, 2014.

2 N. L. Bowers, H. U. Gerber, J. C. Hickman, D. A. Jones and C. J. Nesbitt, *Actuarial Mathematics*, 2nd Edition, Society of Actuaries, USA,1997.

3 P. J. Boland, *Statistical and Probabilistic Methods in Actuarial Science*, Chapman and Hall/CRC, 2007.

4 S. A. Klugman, H. H. Panjer, G. E. Willmot and G. G. Venter, *Loss Models:From Data to Decisions*. 5th Edition, Wiley-Interscience, 2019.

5 S. D. Promislow, *Fundamentals of Actuarial Mathematics*, 2nd Edition, Wiley, 2011.

Course Title: Basic Statistics (IDC)

Course Code: MSTA.506

Course Type: IDC
Total Hours: 30

L	T	P	Credits
2	0	0	2

Learning outcomes:
The student will be able to

CLO1: Explain descriptive statistics, probability distributions.
CLO2: Classify measures of central tendency and dispersion.
CLO3: Make use of basic approaches to probability.
CLO4: Justify axiomatic approach to probability.
CLO5: Discuss application of discrete and continuous random variables.

Units/Hours	Contents	Mapping with CLO
I 07 Hours	Descriptive Statistics: Meaning, need and importance of statistics. 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. **Activity:** Students will construct important statistical plots with the help of real data.	CLO1
II 08 Hours	Measures of central tendency, dispersion (including box and whisker plot), skewness and kurtosis. Data on two attributes, independence and association of attributes in 2x2 tables. Simple linear regression and correlation (Karl Pearson's and Spearman's) and residual plots. **Activity:** Students will understand measures of dispersion and skewness They will also be able to solve problems related to simple regression and correlation.	CLO2 CLO3
III 07 Hours	Random experiments, sample spaces (finite and infinite), events, algebra of events, three basic approaches to probability, combinatorial problems, conditional probability, Bayes' formula. **Activity:** Students will explore the concept of random experiments and learn the use of probability in daily life.	CLO4
IV 08 Hours	Random variables (discrete and continuous). Distribution Function and its properties, mean and variance. Discrete Distributions: Bernoulli, Binomial, Poisson, geometric, Continuous distribution: Uniform, exponential, normal. **Activity:** Students will solve problems on discrete and continuous distributions and learn how to apply these models in practical applications.	CLO5

Transaction mode: Lecture/Co Operative learning/Practical/ Group discussion/Team teaching /Tutorial/Problem solving/Self-learning.

Suggested Readings:

1. F. E. Croxton and D. J. Cowden, *Applied General Statistics*, 2nd Edition, Pitman, 1962.
2. P. G. Hoel, *Introduction to Mathematical Statistics*, 4th Edition, New York, John Wiley and Sons, 1971.
3. W. W. Daniel and C. L. Cross, *Biostatistics: A Foundation for Analysis in the Health Sciences*, 11th Edition, Wiley & Sons, 2018.
4. S.C. Gupta and V.K. Kapoor, *Fundamentals of Mathematical Statistic,* 12th Edition, Sultan Chand & Sons, 2014.
5. V. K. Rohatgi and A.K. Md. E. Saleh, *An Introduction to Probability and Statistics,* 3rd Edition, Wiley, 2015.

Course Title: Linear Programming
Course Code: MMAT.511
Course Type: VAC
Total Hours: 30

L	T	P	Credits
2	0	0	2

Learning outcomes:
The students will be able to
CLO1: Discuss the linear programming problem with formulation.
CLO2: Apply different methods to solve linear programming problems.
CLO3: explore the concept of Duality theory and Sensitivity analysis.
CLO4: Explain transportation problems and assignment problems with their mathematical formulation.

Units/Hours	Content	Mapping with CLO
I 8 Hours	Formulation of linear programming problems (LPP). Graphical solution to LPPs. Cases of unique and multiple optimal solutions. **Activity:** Students will do formulation of Linear programming problems and find the solutions using graphical methods.	CLO1
II 8 Hours	Feasible solution, basic feasible solutions, Optimal solution, Convex sets, Solution of LPP with Simplex methods. **Activity:** Students will solve linear programming problems with the simplex method.	CLO2
III 6 Hours	The dual problem. Formulation of the dual.Dual Simplex method. **Activity:** Students will do exercises related to dual linear programming problems.	CLO3
IV 8 Hours	Transportation and Assignment Problem: Transportation problems, Formulation of transportation problems, Feasible and optimal solution of transportation problems. Assignment problems. **Activity:** Students will do exercises on transportation problems and assignment problems.	CLO4

TRANSACTION MODE: Lecture/Demonstration/Project Method/ Co Operative learning/ Seminar/Group discussion/Team teaching /Tutorial/Problem solving/E-team teaching/Self-learning.

Suggested Readings:

1. H. A. Taha, *Operations Research - An Introduction,* Macmillan Publishing Company Inc., New York, 2006.
2. K. Swarup, P. K. Gupta and Man Mohan, *Operations Research*, Sultan Chand & Sons, New Delhi, 2001.
3. F. S. Hillier and G. J. Lieberman, *Introduction to Operations Research*, McGraw-Hill, New York, 2001.

Course Title: Vedic Mathematics and Data Science
Course Code: MMAT. 513
Course type: Value Added Course
Total Hours: 30

L	P	T	Credits
2	0	0	2

Learning outcomes:
The students will be able to

CLO1: Apply the knowledge of Vedic mathematics to understand some properties of statistics.
CLO2: Illustrate various properties of statistics with the help of Vedic mathematics and Computer programming.
CLO3: Explain the basic concepts of data science and linear algebra.
CLO4: Apply the Vedic mathematics sutra to solve the problems of linear algebra.
CLO5: Apply Vedic techniques in conjunction with data science tools and algorithms to tackle real world data analysis challenges.

Units/Hours	Contents	Mapping with CLO
I 8 Hours	Introduction to Vedic mathematics, Vedic mathematics sutras, and their applications in different fields. Basics of statistics, Mean, Median, Mode,Variance, Probability using Vedic techniques.	CLO 1 CLO2
II 7 Hours	**Application of Vedic mathematics in statistics**: Curve Fitting, Statistical Modelling, Random Variables and Probability Mass/Density Functions, Hypotheses Testing, Linear Regression. Data visualization and manipulation.	CLO2
III 8 hours	**Basics of data Science:**Solving linear equations using Vedic technique, the solution of Simultaneous linear equations using Vedic technique, Solution of quadratic equations using Vedic technique, Evaluation of determinants, Inversion of Matrices.	CLO 3 CLO 4
IV 7 hours	Optimization for data Science using Vedic mathematics, Linear Algebra for Data Science, Halfspaces, Eigenvalues, Eigenvectors, Solving Data Analysis Problems using Vedic techniques.	CLO 5

TRANSACTION MODE: Lecture/Demonstration/Project Method/Co Operative learning/ Seminar/Group discussion/Team teaching /Tutorial/Problem solving/E-team teaching/Self-learning.

Recommended Books:

1. Bharti Krishna Tirtha, Vedic Mathematics, Motilal Banarsi Das, New Delhi, 2015.
2. Bhaskaracharya, Beejganitam, Chokhambba Vidya Bhavan, Varanasi, 2022.
3. S.P. Gupta, Statistical Methods, Sultan Chand & Sons, 2014.
4. Ragunathan Rengasamy, Shankar Narasimhan, Data Science for Engineers, Computer Science and Engineering, NPTEL IIT Madras, 2019.
5. John Zelle, Python Programming: An introduction to computer science, Franklin, Beedle & Associates, 2016.

Semester – III

L	T	P	Credits
0	0	40	20

Course Title: Dissertation Part-I
Course Code: MSTA.599-1
Course Type: Skill Based
Total Hours: 600

Learning outcome:
The students will be able to
CLO1: develop interest in theoretical and practical research.
CLO2: decide their area of research as per their competency.
CLO3: get theoretical and practical knowledge of a specific area of research.
CLO4: prepare themselves for quality research in any mathematical discipline and allied areas.

Students will have an option to carry out dissertation work in industry, national institutes or Universities in the top 100 NIRF ranking.

Group dissertation may be opted, with a group consisting of a maximum of four students. These students may work using a single approach or multidisciplinary approach. Research projects can be taken up in collaboration with industry or in a group from within the discipline or across the discipline.

Transaction mode: Lecture/Demonstration/Project Method/ Co Operative learning/ Seminar/Group discussion/Team teaching/Problem solving/Self-learning.

Semester – IV

Course Title: Dissertation Part-II
Course Code: MSTA.599-2
Course Type: Skill Based
Total Hours: 600

L	T	P	Credits
0	0	40	20

Learning outcome:
The students will be able to
CLO1: develop interest in theoretical and practical research.
CLO2: decide their area of research as per their competency.
CLO3: get theoretical and practical knowledge of a specific area of research.
CLO4: prepare themselves for quality research in any mathematical discipline and allied areas.

Students will have an option to carry out dissertation work in industry, national institutes or Universities in the top 100 NIRF ranking.

Group dissertation may be opted, with a group consisting of a maximum of four students. These students may work using a single approach or multidisciplinary approach. Research projects can be taken up in collaboration with industry or in a group from within the discipline or across the discipline.

Transaction mode: Lecture/Demonstration/Project Method/ Co Operative learning/ Seminar/Group discussion/Team teaching/Problem solving/Self-learning.