Department of Mathematics and Statistics
Banasthali Vidyapith, Banasthali

Minutes of the Board of Studies held on 23.04.2016 at 10.30 A.M in CMS Conference Hall, Banasthali Vidyapith.

PRESENT

1. Prof. G.N. Purohit	:	Internal Member
2. Ms. GargiTyagi	:	Internal Member
3. Dr. Gulab Singh	:	Internal Member
4. Dr. IshaSangal	:	Internal Member
5. Prof. J.L. Arora	:	Internal Member
6. Dr. Kiran Gaur	:	Internal Member
7. Dr. Madhuri Jain	:	Internal Member
8. Dr. Naresh Chandra	:	Internal Member
9. Dr. Piyush Kant Rai	:	Internal Member
10. Dr. Prashant Kushwah	:	Internal Member
11. Dr. Shalini Chandra	:	Internal Member
12. Dr. Ujjwal Pandey	:	Internal Member
13. Dr. C.K. Jha	:	Special Invitee
14. MsAkankshaSekhsariya	:	Special Invitee
15. MsGopika Sharma	:	Special Invitee
16. Prof. M.M.Tripathi ,Varanasi	:	External Member
17. Prof. SarlaPareek	:	Convener

Note:Internal Members: Mr. Ashish Kumar Sharma, Dr. Geetanjali Sharma,Dr. Manoj Kumar, Dr. Narendra Singh Thakur, Mrs. Preeti Jain,Ms. Preeti Sharma,Dr. S.C.Pandey , Ms. ShanuGoyal,Dr. Usha Sharma and **External Members**: Prof. R.K. Sharma,New Delhi and Dr. R. K.Singh, Lucknow could not attend the meeting.

1. The board took up the minutes of its last meeting held on March11, 2012 and resolved that the minutes be confirmed in the light of the Academic Council's decisions taken in its last meeting.

2. The board reviewed the existing panel of examiners and suggested to update the address and phone numbers of the existing examiners for each examination up to and inclusive of all Master's degree examination keeping in view the by-law 15.03.02 of the Vidyapith. Updated panel is sent to the examination and secrecy section.

3. The board reviewed the Study/Curricula and scheme of examination for the following examinations:

I. B.A./B.Sc.(Mathematics) Examinations:

1.	First Semester Examination, December, 2016	**No Change**
2.	Second Semester Examination, April/May, 2017	**No Change**
3.	Third Semester Examination, December, 2017	**No Change**
4.	Fourth Semester Examination, April/May, 2018	**Change***
5.	Fifth Semester Examination, December, 2018	**No Change**
6.	Sixth Semester Examination, April/May, 2019	**No Change**

* Board suggested to rearrange the topics of "Linear Algebra" for its proper sequencing.The revised syllabus of Linear Algebra and list of books in above mentioned syllabus are given in **Annexure-I.**

Board also recommended implementing the proposed revision in syllabus of "Linear Algebra" by fourth semester examination, April-May, 2017.

BBA/BCA/BA Examinations:

BCA/BA papers in respect of Mathematics and Statistics **- No Change.**

Some changes are suggested in Syllabus,"Mathematics for Management" of BBA V Semester and"Mathematics for Business Applications" of B.Com.II Semester by theBoard.The revised syllabus is enclosed in **Annexure-II.**

II. M.Sc. (Mathematical Science) Examinations:

- Scheme of M. Sc. (Mathematical Sciences) has been revised and is enclosed as an **Annexure-III**) and board has agreed upon the following changes:

Pure Mathematics:

1.	First Semester Examination, December, 2016	**Change[1]**
2.	Second Semester Examination, April/May, 2017	**Change[2]**
3.	Third Semester Examination, December, 2017	**Change[3]**
4.	Fourth Semester Examination, April/May, 2018	**Change[4]**

1. The syllabus of "Abstract Algebra" and "Probability and Statistics" has been revised and enclosed as **Annexure-IV.**
2. A paper of "Topology"to be shifted from third semester to second semester in the place of "Data Structure & Object Oriented Programming". The syllabus of "Differential Equations" and "Linear Algebra" has been revised. In addition a Laboratory Practices is added to the course in Numerical Analysis with the help of MATLAB.The revised syllabi and List of practical is enclosed in **Annexure-V**.
3. In place of Topology a new paper "Advanced Calculus" is proposed. The paper. "Partial Differential Equations and Special Functions" is replaced by "Integral Transforms and Special Functions".The syllabus of "Mathematical Programming" is revised. Syllabi of the related papers are enclosed in **Annexure-VI**.
4. A paper, "Integral Transform" is replaced by "Partial Differential Equations". The syllabus of the same is enclosed in **Annexure- VII**.

Theoretical Computer Science:

1.	First Semester Examination, December, 2016	**Change[5]**
2.	Second Semester Examination, April/May, 2017	**Change[6]**
3.	Third Semester Examination, December, 2017	**Change[7]**
4.	Fourth Semester Examination, April/May, 2018	**No Change**

5. The syllabus of "Abstract Algebra" and "Probability and Statistics" has been revised and already enclosed in **Annexure-IV**.
6. The syllabus of "Linear Algebra" is revised and Laboratory Practices is added to the course in Numerical Analysis with the help of MATLAB. The revised syllabus and List of practical is already enclosed in **Annexure-V**. The Course,Data Structure & Object Oriented Programminghas been renamed as "Data Structures" with some changes in the syllabus which is enclosed in **Annexure-VIII**.

7. The paper “Algorithms” is renamed as “Design and Analysis of Algorithms”. Also, the syllabus of “Mathematical Programming” is revised and already enclosed in **Annexure-VI**.

Operations Research:

1.	First Semester Examination, December, 2016	**Change**[8]
2.	Second Semester Examination, April/May, 2017	**Change**[9]
3.	Third Semester Examination, December, 2017	**Change**[10]
4.	Fourth Semester Examination, April/May, 2018	**No Change**

8. The syllabus of “Abstract Algebra” and “Probability and Statistics” has been revised and already enclosed in **Annexure-IV**.
9. The syllabus of “Linear Algebra” is revised and Laboratory Practices is added to the course in Numerical Analysis with the help of MATLAB. The revised syllabus of “Linear Algebra” and List of practical is already enclosed in **Annexure-V**. The course in “Data Structure & Object Oriented Programming” has been renamed as “Data Structures” with some changes in the syllabus which is already enclosed in **Annexure-VIII**.
10. The syllabus of “Mathematical Programming” is revised and already enclosed in **Annexure-VI**.

Statistics:

1.	First Semester Examination, December, 2016	**Change**[11]
2.	Second Semester Examination, April/May, 2017	**Change**[12]
3.	Third Semester Examination, December, 2017	**Change**[13]
4.	Fourth Semester Examination, April/May, 2018	**Change**[14]

11. The syllabus of “Abstract Algebra” and “Probability and Statistics” has been revised and already enclosed in **Annexure-IV**.
12. The syllabus of “Linear Algebra” is revised and Laboratory Practices is added to the course in Numerical Analysis with the help of MATLAB. The revised syllabus and List of practical is already enclosed in **Annexure-V**. In the place of Data Structure & Object Oriented Programming a new paper “Statistical Inference” is proposed. Its syllabus is enclosed in **Annexure-IX**.

13. The syllabus of "Mathematical Programming" is revised and already enclosed in **Annexure-VI**.
14. The syllabus of "Advanced Inference" has been revised and enclosed in **Annexure-X**.

- The Syllabus of following electives have been also revised and enclosed in **Annexure-XI**.
    1. Econometrics
    2. Integral Equations and Calculus of Variations

  Board agreed and recommended implementation of revised electives from Session 2016-2017.
- Following new electives are proposed:
    1. "Analytical and Algebraic Number Theory" for the students of Pure Mathematics **(In place of Number Theory)**
    2. "Number Theory and Cryptography" for the students of Pure Mathematics (**In place of Mathematical Cryptography)**
    3. Regression Analysis for the students of Statistics **(New)**
    4. Statistical Computing for the students of Statistics **(New)**

  Board agreed and also recommended implementation of proposed electives from Session 2016-2017. The syllabi are enclosed in **Annexure-XII.**

III. M.Phil. (Mathematical Sciences) Examination

The Board reviewed the scheme and syllabi of M. Phil. (Mathematical Sciences) in the light of its one and half (36 months) years of duration and a new examination scheme is proposed.Detailed Course structure and Scheme of Examination are enclosed in **Annexure-XIII.**

IV. Certificate Examination

1. Certificate Course in statistical techniques and Applications, 2017:

   (No change in Syllabus and Scheme of the Examination)

   To make course more effective and insightful it is proposed to increase the duration of the course to one year in the place of six months. So, fee of the course should be Rs. 5500/ per year accordingly.
2. Certificate Course in Actuarial Science, 2017: **(No Change)**
3. Diploma Course in Actuarial Science, 2017: **(No Change)**

4. Board reviewed the reports received from the examiners of the different examinations of 2013, 2014 and 2015. All the reports were found to be with good remarks only three out of 24 found with “not satisfactory” comments. Board emphasized on the need of more practices by students and teachers are advised to encourage students for the same. Analysis of Examiner Reports is enclosed in **Annexure–XIV.**

5. The board evaluated the semester examination papers and found that most of them were analytic and application based depending on the nature of course. In some of the papers, few typographical errors and incomplete questions were found. To overcome this problem Board suggested to adopt moderation policy.Board advised to convey this message to Examination and Secrecy section. The Analysis summary of question papers is enclosed in **Annexure–XV.**

6. Under bye-law 9.2.03 to co-opt external members of the Board of Studies for a fresh term of three years commencing from 1st January, 2017 ,Board recommends following three eminent professors as external members of Board of Studies of Mathematics and Statistics:

1. Prof. C.S. Arvinda TIFR Centre for Applicable Mathematics, Bangalore
2. Prof. Arvind Mishra B.H.U. Varanasi
3. Prof. Sharad Gore Pune University

Meeting ended with vote of thanks.

Annexure-XIII

M.Phil. (Mathematical Science)

Eligibility: M.A./M.Sc. in Mathematical Sciences/ Mathematics/ Statistics/ Operations Research/Applied Mathematics from the Vidyapith or a recognized examination equivalent thereto with aggregate equal to or more than 55% marks.

Admission: Based on Entrance exam.

Course structure:

1. A three-semester course, with one core course, one elective and one reading elective in first and second semesters, and

2. **Dissertation:** Student must carry out a Dissertation (submitted in the end of third semester) under the supervision of faculty of Banasthali Vidyapith.

Dissertation Phase – I:

In this phase students have to decide the area on which they want to do their Dissertation work. The aim of the work must be clear. In the last week of October the selected topic need to be defended before the faculty members. The students will present a report specifying the area of dissertation with list of reviewed generals, articles and referred books.

Dissertation Phase – II:

In the first week of March, the student has to submit a synopsis of her Dissertation and the internal examiners committee is to be appointed. The synopsis must also bear the certificate by the supervisor/guide. Student will defend the synopsis in front of internal examiners committee

Dissertation Phase – III:

At the mid of the third semester a report of research work done, is to be submitted and defended in front of internal committee.

Dissertation Phase – IV:

At the end of the third semester final report is to be submitted and a presentation and viva-voce will be held.

Dissertation Phase – V:

Dissertation to be sent for external evaluation. The list of three external examiners will be made available by the supervisor in consent with the Head of the department.

Financial Assistance:

M.Phil. students are eligible for financial assistance as follows:

TA/RA ship:

Candidates admitted to the M.Phil. Program will be offered the teaching Assistantship (TA) or Research Assistantship provided they have secured at least 55 percent mark (50 percent for SC/ST candidates) in their qualifying degree examination and provided they are willing to assist in the teaching of undergraduate courses. A teaching assistant can be asked to conduct labs and can also be asked to teach tutorial sessions to the undergraduate students.

A research assistant can also be asked to support the department in various academic activities. It could be providing help in maintaining and upgrading department laboratories, downloading, installing software, etc. A candidate can also be assigned to faculty members to help them in their research effort.

The assistantship amount will be as per the amount provided to the Assistant Professor in self-financed certificate/diploma courses.

Scheme of Examination

1. The course of study for M.Phil. Examination shall extend over a period of one and half year divided into three semesters. First two semesters contains coursework with an examination at the end of each semester. Third semester contains submission of dissertation with a viva voice.

2. The Examination shall be conducted by means of Continuous assessment/Written Papers/ Practical/Dissertation/Project Report.

The following shall be the Scheme of Examination:

I SEMESTER

	Course	Contact Hours/ week		Cont. Ass. Marks		Ann. Ass. Marks		Total Marks		Min.	
		T	P	T	P	T	P	T	P	T	P
1.	Mathematical Modelling	4	0	20	0	40	0	60	0	22	0
2.	Elective I	4	-	20	-	40	-	60	-	22	-
3.	Reading Elective I	0	-	-	-	60	-	60	-	22	-
4.	Dissertation Phase I	2	-	30	-	-	-	30	-	15	-
5.	Total			70	-	140	-	210	-	81	-

II SEMESTER

	Course	Contact Hours/ week		Cont. Ass. Marks		Ann. Ass. Marks		Total Marks		Min.	
		T	P	T	P	T	P	T	P	T	P
1.	Advanced Analysis (for Mathematics) Advance Probability Theory (New Course) (for Stats/OR)	4	0	20	0	40	0	60	0	22	0
2.	Elective II	4	-	20	-	40	-	60	-	22	-
3.	Reading Elective II	0	-	-	-	60	-	60	-	22	-
4.	Dissertation Phase II	2	-	30	-	-	-	30	-	15	-
5.	Total			70	-	140	-	210	-	81	-

III SEMESTER

	Course	Contact Hours/ week		Cont. Ass. Marks		Ann. Ass. Marks		Total Marks		Min.	
		T	P	T	P	T	P	T	P	T	P
1.	Dissertation Phase III	-	-	30	-	-	-	30	-	15	-
2.	Dissertation Phase IV	-	-	30	-	-	-	30	-	15	-
3.	Dissertation Phase V	-	-	-	-	-	-	120	-	60	-
4.	Total			90	-	-	-	180	-	90	-

Grand Total =210 + 210 + 180 = 600

Elective must be relevant to the Area of Dissertation/ Project.

Students could not be allowed to take the course as an elective, which she had already done in M.A./M. Sc.

Electives:

	List of Electives	**Contact hours/week**	
		T	**P**
E-1	Abstract Algebra	4	0
E-2	Finsler Geometry	4	0
E-3	Advanced Graph Theory	4	0
E-4	Discrete Mathematics	4	0
E-5	Functional Analysis	4	0
E-6	Fuzzy Logic and Belief Theory	4	0
E-7	Analytic and Algebraic Number Theory	4	0
E-8	Rings and Modules	4	0
E-9	Tensor Analysis and Geometry of Manifolds	4	0
E-10	Topology	4	0
E-11	Mathematical Cryptography	4	0
E-12	Advanced Inference	4	0
E-13	Bayesian & Multivariate Analysis	4	0
E-14	Bayesian Inference	4	0
E-15	Reliability & Renewal Theory	4	0
E-16	Time Series and Stochastic Process	4	0
E-17	Time Series Modeling	4	0
E-18	Financial Mathematics	4	0
E-19	Information Theory	4	0
E-20	Network Analysis	4	0
E-21	Clinical Trials	4	0
E-22	Decision Theory	4	0
E-23	Demography and Advanced Sampling	4	0
E-24	Design of Experiments and Linear Model	4	0
E-25	Distribution Theory	4	0
E-26	Econometrics	4	0
E-27	Inventory Theory	4	0

E-28	Non- parametric Inference and Sequential Analysis	4	0
E-29	Population Sciences	4	0
E-30	Queueing Theory	4	0
E-31	Soft Computing	4	0
E-32	Regression Analysis	4	0

List of Reading Electives:

RE-1: Numerical Solutions of Partial Differential Equations (New Course)
RE-2: Operator theory (New Course)
RE-3: Supply Chain Management (New Course)
RE-4: Marketing Management (New Course)
RE-5: Inventory and Production Management (New Course)
RE-6: Decision and Game Theory (New Course)
RE-7: Algebraic Geometry (New Course)
RE-8: Algebraic Aspects of Cryptography (New Course)
RE-9: Advanced Cryptography (New Course)
RE-10: Finite Element Methods (New Course)
RE-11: Finite Field Theory (New Course)
RE-12: Special Functions (New Course)
RE-13: Algebraic Topology (New Course)
RE-14: Advanced Queueing Models (New Course)
RE-15: Advanced Reliability Theory
RE-16: Statistical Computing (New Course)
RE-17: Demographic Models (New Course)
RE-18: Intelligent Transport System (New Course)
RE-19: Generalised Linear Models (New Course)
RE-20: SurvivalAnalysis (New Course)
RE- 21: Biostatistics

Mathematical Modelling

Contact Hours: 60

SectionA

Mathematical modelling: Need, techniques, classification, characteristics of mathematical models, limitations of mathematical modelling.

Mathematical modelling through ordinary differential equations of first order and system of ordinary differential equations of first order: Linear growth and decay models, Non-linear growth and decay models, Compartmental models

SectionB

Mathematical modelling through ordinary differential equations of second order: Planetary motion, circular motions.

Mathematical modelling through difference equations: Basic theory of linear difference equations with constants coefficients, Models used in Economics, Finance, Population Dynamics, Genetics.

Mathematical modelling through partial differential equations: Methods to obtain PDE models.

SectionC

Mathematical modelling through graphs: Modelling by directed graphs, signed graphs and weighted digraphs. Mathematical modelling through differential difference equations, Linear programming, Nonlinear programming, Dynamic programming, Maximum principle, Principle of maximum entropy.

Suggested Text Books:

1. J.N. Kapur, **Matematical Modelling**, Wiley Eastern Ltd., 1990.

Suggested Reference books :

1. J. Caldwell and Y.M. Ram, **Mathematical Modelling: Concepts and Case Studies**, Springer, 1999.
2. A.A. Samarskii and A.P. Mikhailov, **Principles of Mathematical Modelling**, **Ideas, Methods, Examples**, Taylor and Francis, 2002

Advanced Analysis

Contact Hours: 60

SectionA

Normed linear spaces &Banach spaces, bounded linear transformations, multi linear mappings, inner product spaces, Hilbert spaces, orthonormal systems, the space of bounded functions, the space of continues functions, Stone-Weierstrass approximates theorem, equi continuous sets.

Section B

The derivative, directional derivative, partial derivative, mean value theorem, continuously differentiable maps, Higher derivatives, Taylor’s Theorem, existence theorem on differentiable maps, Fixed point theorem, step functions, regulated functions.

Section C

Spectral theory in finite dimensional normed spaces, Spectral properties of bounded linear operators, further properties of Resolvent& Spectral, Banach Algebras,Compact linear operators and their properties, Spectral properties of compact linear operation.

Suggested Text/ Reference Books:

1. J. Dieudonne, **Treatise on Analysis Volume – I: Foundations of Modern Analysis**, Academic Press New York.
2. H. Cartan, **Differential Calculus,** Kershaw Publishing Company Pvt. Ltd. London.
3. E. Hewitt and K. Stromberg, **Real and Abstract Analysis**, Springer – Verlag, New York.
4. K. Yosida, **Functional Analysis**, Springer Verlag, Berlin.
5. Erwin Kreyszig, **Introductory Functional Analysis with Applications**, John Wiley & Sons, New York, 1989.
6. G. Bachman & L. Naric, **Functional Analysis**, Dover Publication, 2000.

Advance Probability Theory

Contact Hours: 60

Section – A

Classes of sets, Fields and Sigma-fields, Limit of sequences of subsets, Sigma-field generated by a class of subsets, Borel fields, Probability measure on a sigma-field, Probability space, Continuity of a probability measure, Real and vector- valued random variables. Distributions of functions of random variables.

Section B

Inequalities: Basic inequality, Chebyschev's inequality, Cr- inequality, Cauchy-Schwartz inequalities, Holder inequalities, Minkowski inequality, Jensen inequality.. Convergence of sequence of random variables: Convergence in distribution, Convergence in probability, Almost sure convergence, Convergence in mean square. Helly bray theorem, Borel-Cantelli lemma and zero one law. Inversion and Continuity theorem.

Section C

Weak and strong law of large numbers: Khintchine, Kolmogorov theorem. One dimensional central limit theorem - Lindeberg levy, Lyapunov, Lindeberg Feller theorem. Representation of distribution function as a mixture of discrete and continuous distribution function, Convolutions, marginal and conditional distributions of bivariate distributions.

Text Books:

1. Chung, K. L. (2001). A Course in Probability Theory, Third Edition, Academic Press, London.
2. Bhat, B. R. (2007). Modern Probability Theory: An Introductory Text Book, New Age International.

Reference Books:

1. Feller, W.: An Introduction to Probability Theory and Applications. Vol I &Vol II.
2. Ash, R. B. (2000). Probability & Measure Theory, Academic Press
3. Rohtagi, V.K.: An Introduction to Probability and Mathematical Statistics, wiley Eastern Limited.
4. Halmos, P.R (1978).: Measure Theory., Springer.

E-1 Abstract Algebra

Contact Hours: 60

Section A

Groups: Dihedral groups, symmetric groups, matrix groups; subgroups generated by subsets of a group, Homomorphism and Normal Subgroups, Isomorphism theorems, group actions, stabilizers and kernels of group actions, cycle decompositions, Conjugates, Conjugacy in S_n, Class equation for a Group, Sylow's Theorems, Applications of Sylow's theorem, Simplicity of Alternating Group A_n for $n>5$, Commutator, Series of Subgroups, Jordan Holder Theorem, Solvable Groups.

Section B

Rings, ring homomorphism and quotient rings, Ideals: Prime and Maximal, rings of fractions, Divisibility, Euclidean and Principal Ideal Domains, Unique Factorization Domains, Polynomial Rings over fields, irreducibility criteria, polynomial in several variables, Noetherian ring, Hilbert basis theorem, Grobner basis, solving algebraic equation

Section C

Field Theory: characteristic of a field, prime subfield, extension fields, Algebraic Extensions, Splitting fields and algebraic closures, Normal and Separable Extensions, Fundamental Theorem of Galois Theory.

Text Book:

1. Dummit, D. S. and Foote, R. M.: Abstract Algebra, 3rd Ed., Wiley, 2004.

Reference Books:

1. Herstein, I.N.: Topics in Algebra, 2nd Ed., Wiley Eastern, New Delhi, 1991.
2. Gallian, J. A.: Contemporary Abstract Algebra, 8th Ed. Cengage Learning, 2006.

3. Jacobson, N.: Lectures in Abstract Algebra, D. Van Nostrand, New York, 1964.
4. Jacobson, N.: Basic Algebra-I, Hindustan Publishing, Delhi, 1984.
5. P. B. Bhattacharya, S.K. Jain and S.R. Nagpal, **Basic Abstract Algebra**. 2nd ed. Cambridge University Prees, 1990.

E-2 Finsler Geometry

Contact Hours: 60

Section A

Minkowski norms, Finsler Metrics, Riemannian metrics, Product Finsler metric, Funk metric, Length Structure and Volume form, Zermelo Navigation Problem, Cartan Torsion, Matsumoto torsion.

Section B

Chern connections, Structural equations, Finsler metrics of Constant flag curvature, Bianchi Identities, Sprays, Shortest paths, projectively equivalent Finsler metrics, Projectively flat metrics.

Section C

Parallel vector fields, Parallel translations, Berwald metrics, Landsberg metrics, S-curvature, Distorsion and S-curvature, Randers metrics of Isotropic S-curvature, Riemannian Curvature, Flag curvature.

Text Books:

S. S. Chern and Z. Shen, Riemann Finsler Geometry, Nankai Tracts in Mathematics, Vol. 6. World Scientific Publishing Co. Pte. Ltd., 2005.

Reference Books:

1. D. Bao, S.S. Chern, Z. Shen, *An Introduction to Riemann Finsler Geometry, Graduate texts in Mathematics 200,* Springer- Verlag New York, 2000.
2. P. L. Antonelli, R. S. Ingarden and M. Matsumoto, *The theory of sprays and Finsler spaces with Applications in Physics and Biology*, FTPH 58, Kluwer Academic Publishers, 1993.
3. M. Matsumoto, *Foundations of Finsler geometry and Special Finsler Spaces*, Kaiseisha Press, Saikawa, Japan, 1986.
4. H. Rund. *The Differential Geometry of Finsler spaces*, Springer- VerlagBerlin, 1959.

E-3 Advanced Graph Theory

Contact Hours: 60

Section A

Basic concepts of graph theory, Directed graph, Euler graph, Hamiltonian graph, Matrix representation of graphs, Shortest path in a weighted graph, K-connected and K-edge-connected graphs, Planar graphs, Coloring of graphs, Vertex coloring of graphs, Edge coloring of graphs, Vizing's theorem.

Trees: Rooted trees, Spanning tree and Cut set, Minimum-spanning tree, Flow network in a graph, max-flow- min cut theorem.

Section B

Blocks: Bridges and blocks, Block graph and cut-point graph, Partitions, Factorization: 1-Factorization, 2-Factorization, Arboricity.

Covering: Covering and independence, Critical points and lines.

Groups: The automorphism group of a graph, Operations on Permutation graphs, the group of a composite graph, Graphs with a given group, Symmetric graphs, Highly symmetric graphs (self reading).

Section C

Enumeration: Labeled Graphs, Polya's enumeration theorem, Enumeration of graphs, Enumeration of trees, Matchings in bipartite graphs, Hall's matching theorem, Ramsey's theorem, Ramsey numbers, Eigenvalues of graphs**.**

Suggested Text/ Reference Books:

1. NarsinghDeo, **Graph Theory**, Prentice Hall of India, 2002.
2. D.B. West, **Introduction to Graph Theory**, Prentice-Hall of India, 2001.
3. F. Harary, **Graph Theory**, Narosa Pub. House.
4. G. Chartrand and P. Zhang, **Introduction to Graph Theory**, Tata McGraw-Hill, 2011.

E-4 Discrete Mathematics

Contact Hours: 60

Section A

Sets and multisets, partial order relations, Chains and antichains. Permutation and combination of multisets. Pigeon hole Principle, Inclusion-Exclusion Principle, Derangements. Discrete numeric functions, Generating functions, Recurrence relations, linear recurrence relation with constant coefficients and their solutions. Solution by the method of generating functions. Boolean algebra, Lattices, Uniqueness of finite Boolean Lattices, Boolean functions and Boolean expression. Propositional Calculus.

Section B

Basic concepts of graph theory.Directed graph. Euler graph. Hamiltonian graph. Matrix representation of graphs. Shortest path in a weighted graph. E-connected and K-edge-connected graphs. Planar graphs. Coloring of graphs: Coloring of Graphs, Vertex colouring of graphs, Edge colouring of graphs, Vizing's theorem. Trees: Rooted trees, Spanning tree and cut set, Minimum-spanning tree. Flow network in a graph, max-flowmin cut theorem.

Section C

Types of Enumeration, Counting Labeled Trees, Burnside's lemma, Polya's counting theorem, Graph enumeration with Polya's theorem.

Matchings in bipartite graphs, Hall's matching theorem, Min-Max theorem, Independent sets.

Factorization: 1-Factorization, 2-Factorization, Arboricity.

Suggested Test/ References Books:

1. C.L. Liu, **Elements of Discrete Mathematics**, McGraw Hill, International editions, 1985.
2. NarsinghDeo, **Graph Theory**, Prentice Hall of India, 2002.
3. Kenneth H. Rosen, **Discrete mathematics Applications**, McGraw Hill, 1999.
4. K.D. Joshi, **Foundation of Discrete Mathematics**, Wiley Eastern Ltd., 1989.
5. D.B. West, **Introduction to Graph Theory**, Prentice-Hall of India, 2001.

6. F. Harary, **Graph Theory**, Narosa Pub. House.

E-5 Functional Analysis

Contact Hours: 60

Section A

Normed spaces, Banach spaces, further properties of Normed spaces, subspaces, linear operators, linear functionals, bounded and continuous linear operators, Normed spaces of operators, Dual spaces.

Section B

Hahn-Banach theorem (Extension of linear functionals) for normed spaces, application to bounded linear functionals on C[a, b], adjoint operators, reflexive spaces, uniform boundedness theorem, convergence of sequence of operators and functionals, Open mapping theorem, closed linear operators, Closed Graph Theorem.

Section C

Inner product spaces, Hilbert spaces, further properties of inner product spaces, orthogonal complements and direct sums, orthonormal sets and sequences, total orthonormal sets and sequences, representation of functionals on Hilbert spaces, Hilbert adjoint operators, Self adjoint, unitary and normal operators.

Suggested Text/ Reference Books:

1. E. Kreyszig, **Introductory Functional Analysis with Application,** John Willey and Sons, 1989.
2. P.K. Jain, O.P. Ahuja and Ahmed Khalil, **Functional Analysis**, New Age International, New Delhi 1991.
3. Bachman and Naricel, **Functional Analysis**.
4. G.F. Simmons, **Introduction to Topology and Modern Analysis**, McGraw -Hill Book Company.
5. W. Rudin, **Functional Analysis**, Tata McGraw- Hill, 1973.

E-6 Fuzzy Logic and Belief Theory

Contact Hours: 60

Section A

Basic Concepts of Fuzzy Logic: Introduction, Crisp sets and Fuzzy sets, the notation of Fuzzy sets, Fuzzy Logic, Linguistic Variables, Possibility Distribution.

Operations on Fuzzy Sets:Union, intersection, combinations of operations, general aggregation operations, geometrical interpretation of Fuzzy sets.

Properties of Fuzzy Sets:Cardinality, Height: Normal versus Subnormal, Support and Alpha-level Cuts Convex Fuzzy Sets.

Fuzzy Relations: Crisp and fuzzy relations, binary relations, binary relation on a single set, equivalence and similarity relations, compatibility and tolerance relation, Ordering , Fuzzy Relation equations, Fuzzy Graphs.

Fuzzy Numbers: Definitions, computing of fuzzy numbers, triangular fuzzy numbers, functions with fuzzy arguments, arithmetic operations on fuzzy numbers.

Section B

Fuzzy If –Then Rules: Basics of fuzzy rules, fuzzy mapping rules, fuzzy implication rules Fuzzy Rule-based Models for Function Approximation: Fuzzy Partition, Mapping a Fuzzy subspace to a local model, Fusion of local models through interpolative reasoning, Defuzzification.
Types of Fuzzy Rule-based Models: The Mamdani Model, The TSK model
Fuzzy Implications and Approximate Reasoning: Fuzzy implication, Approximate reasoning, Criteria for Fuzzy implication, Families of Fuzzy implications, Major Fuzzy implication Functions.

Section C

Fuzzy Logic and Probability Theory: Possibility versus Probability, Probability of a Fuzzy Event, Fuzzy Probability, Probabilistic interpretation of Fuzzy sets, Bayes' theorem for Fuzzy Events.
Fuzzy Measures:Belief and Plausibility Measures, Probability measures, Possibility and Necessity Measures, Relationship among classes of Fuzzy measures.
Belief Theory: Evidence Theory- Mathematical Theory of Evidence, Introduction to Shafer's Belief Theory, Belief Representation: mass of belief, belief measure, plausibility measure, properties of belief function-relation between belief measure and plausibilityeasure, Dempster's Rule of Combination

Suggested Text/ Reference Books:

1. George J. Klir, Tina A. Floger, **Fuzzy Sets, Uncertainty and Information**, PHI , New Delhi, 1993.
2. John Yen & Reza Langari, **Fuzzy Logic - Intelligence, Control and Information**, Pearson Education, New Delhi, 2005.
3. George J. Klir, Bo. Yuan, **Fuzzy Sets and Fuzzy Logic: Theory and Applications**, PHI, New Delhi, 2000.
4. Glenn Shafer, **A mathematical theory of evidence**, Princeton Univ. Press, Princeton, N. J, USA.

E-7Analytic and Algebraic Number Theory

Contact Hours: 60

Section A

Arithmetic functions, Dirichlet product of arithmetical functions, Multiplicative functions, Bell series of an arithmetical function, The Selberg identity, Euler's summation formula, Chebyshev's functions, equivalent forms of the prime number theorem, Dirichlet Series, Euler Products, Analytic Proof of the Prime Number Theorem

Section B

Algebraic numbers, conjugates and discriminants,algebraic integers, integral basis, norms and traces, ring of integers, quadratic fields, cyclotomic fields, trivial factorization, factorization into irreducibles, Non-unique factorization, consequences of unique factorization, Ramanujan-Nagell Theorem

Section C

Prime factorization of ideal, norm of an ideal, non-unique factorization in cyclotomic fields, lattices, quotient torus, Minkowski's theorem, two square theorem, four square theorem, class-group, finiteness of the class-group,Unique factorization of elements in an extension ring.

Text Books:

1. I. N. Stewart and D. O. Tall, Algebraic Number Theory, Chapman and Hall, London, 1987.
2. Tom M. Apostol, Introduction to Analytic Number Theory, Springer

Reference Books:

1. K. Ireland and M. Rosen, A Classical Introduction to Modern Number Theory, Springer-Verlag, 1990.
2. S. Lang, Algebraic Number Theory, Springer-Verlag, New York Inc., 1994.
3. D. A. Marcus, Number Fields, Springer-Verlag, New York Inc., 1987.

E-8 Rings and Modules

Contact Hours: 60

Section A

Rings, Matrix rings, Polynomial rings, Skew Polynomial rings, Laurant rings, Boolean rings, opposite ring, Characteristic of a ring, Direct Products.

Ideals, homomorphism of rings, Endomerphism rings, Field of fractions, Prime fields, PIDS and UFDS.

Section B

Modules Direct product, Direct sum of modules, free modules, homomorphisms, Maxima submodule, Minimal submodule, Simple modules, Schurs lemma, Annihilator of a Subset of a module.

Modules over PID's, Torsion modules, Torsion free modules.

Section C

Chain conditions, Artinian modules, Northerian modules, Composition series, Modules of finite length, Jordan Holder Theorem.

Artimian rings, Noetherian rings, Hilbert Basis Theorem, I.S.Cohen's Theorem, Introduction of Nil radical and Jacobson radical.

Suggested Text/ Reference Books:

1. C. Musili, **Introduction to Rings and Modules**, Narosa.
2. K.R. Gooderal and R.B. Warfield, **Introduction to Non-commutative Rings**.
3. N. McCoy, **Ring Theory**.

E-9 Tensor Analysis and Geometry of Manifolds

Contact Hours: 60

Section A

Tensor algebra: Contravariant and covariant vectors, Tensor product of vector spaces, Tensors, Contravariant, covariant and mixed tensors of second order, Tensors of type (r, s), Tensor product of Tensors, Contraction, symmetric and skew-symmetric tensors. Differential forms: Exterior algebra of order two, order p and of order p+q, Contraction of a form (inner product), Exterior derivative and Cartan's structural equations.

Section B

Differentiable Manifolds: Definition and examples, Differentiable functions on a manifold, Differentiable mapping between two manifolds, Differentiable curves, Tangent vectors, Tangent space, Tangent bundle, vector field, Lie bracket, sub manifolds, Lie groups (Definition and examples only).

Section C

Covariant differentiation of tensors, Linear connections: Invariant viewpoint of connections, covariant ∇P, Torsion and curvature tensors, Difference tensor of two connections, Lie derivatives, Riemannian metric, Riemannian connection, curvature tensor with respect to Chritoffel symbols, sectional curvature.

Suggested Text/ Reference Books:

1. W. M. Boothby, An Introduction to Differentiable Manifolds and Riemannian Geometry, Academic Press, 2003, 2nd edition.
2. L. Conlon, Differentiable Manifolds, 2nd edition, Modern Birkhauskar classics, 2009.
3. H. S. Shukla, B. N. Prasad & D. Naraiyan, Differential Geometry of Manifolds, VandanaPrakashan Gorakhpur, 2007.
4. N. J. Hicks, Notes of Differential Geometry, Van Nostrand Reinhold Company, New York, 1965.
5. K. S. Amur, D. J. Shetty and C. S. Bagewadi, An introduction to Differential geometry, Narosa Publishing House, New Delhi, 2010.
6. T. J. Willmore, An Introduction to Differential Geometry, Oxford University Press London, 1930.
7. U. C. De, A. A. Shaikh, Differential Geometry of Manifolds,Narosa Publishing House, New Delhi, 2007.
8. L. P. Eisenhart, An Introduction to Differential Geometry, Princeton Univ. Press, 1947.

E-10 Topology

Contact Hours: 60

Section A

Infinite sets and axiom of choice, well ordered sets, the maximum principle, Topological spaces, Bases for a Topology, The order Topology, The Product Topology, The Subspace Topology, Closed sets and Limit points, continuous Function.Continuity of a function, Homeomorphism, Construction of continuous functions, Metric Topology, The quotient Topology (Introduction only).

Section B

Connectedness and Compactness: Connected Spaces, Connected sets in the Real line, Components and path components, Local Connectedness, Compact spaces, Compact sets in the Real line limit point compactness.

Section C

The Tietze extension Theorem, The UrysohnMetrization Theorem, The Tychnoff Theorem, The completely regular spaces, The Stone-cechcompactification (Statement only), Complete Metric Spaces and Function spaces: Complete Metric Spaces, Compactness in Metric spaces, Point wise and compact convergence, the Compact Open Topology, Baire Spaces.

Suggested Text/ References Books:

1. J.R. Munkers, **Topology- A First Course**, Prentice Hall of India, (The scope is indicated by the chapters 1, 2, 3, 4, 5, 6 & 7)
2. J.N. Sharma, **Topology**, Krishna Prakashan, Meerut.
3. K.D. Joshi, **General Topology**.
4. M.G. Murdeshwar, **General Topology**.

5. G.F. Simmons, **Introduction to Topology & Modern Analysis**.

E-11Mathematical Cryptography

Contact Hours: 60

Section A

Basics of Number theory & Complexity theory, Introduction to cryptography, Classical cryptosystems and their cryptanalysis, Perfect Secrecy, One way and trapdoor functions, Discrete logarithm problem, Integer factorization problem, Pseudo random bit generators, Block ciphers; DES, Triple DES.

Section B

Deffie-Hellman key exchange protocol, Public key encryption, RSA cryptosystem, Rabin's public key cryptosystem, El-Gamal cryptosystem, Knapsacks cryptosystem, Attack Models, Hash functions, Message authentication Code.

Section C

Digital Signatures; RSA, El-Gamal, DSA, Rabin's signature schemes, Entity Authentication, Zero knowledge protocols, Secret Sharing Schemes, Digital Cash, Elliptic curves, Identity based encryption and signature.

Suggested Text/ Reference Books:

1. Forozan and Mukhopadhyay:Cryptography and Network Security, 2nd ed., McGraw Hill, 2010.
2. N. Koblit:A Course in Number Theory and Cryptography, Springer 1987.
3. Menezes, Oorschot and Vanstone:Handbook of Applied Cryptography, CRC Press, 1997.
4. W. Stallings:Cryptography and Network Security – Principles and Practices, Pearson Education, 3rd Edition, 2003.
5. Katz and Lindell:Introduction to Modern Cryptography, Chapman & Hall/CRC, Taylor & Francis Group, 2008.

E-12 Advanced Inference

Contact Hours: 60

Section A

Sufficient statistics and completeness, UMVUE, Cramer Rao inequality along with underlying conditions, Modification and extension of CR inequality, Rao Blackwell theorem, Lehman SehmanScheffe theorem. Introduction to Bhattacharya bounds.

Section B

Consistency of an estimator, Maximum Likelihood estimation and its large sample properties, BAN, CAN, Pitmann estimator and its efficiency.

Section C

Best critical region, GeneraliszedNeymann Pearson lemma, UMP tests for distribution with MLR, LR tests and their properties, unbiased tests, Locally most powerful tests. Similar regions and test of Neymann structure.

Suggested Text Book:

1. Mood, Graybill and Boes, **An Introduction to the theory of Statistics**, 3rd edition.

Suggested Reference Books:

1. Stuart Kendal, **The advanced theory of Statistics vol. II**, Charles Griffin.

2. E.L. Lehman, **Testing of Statistical hypothesis**, John Wiley & Wiley eastern.
3. E.L. Lehman, **Theory of point estimation,** John Wiley & Wiley eastern.
4. S. Zach, **The theory of Statistical inference,** John Wiley & Wiley eastern.
5. V.K. Rohtagi, **An Introduction to probability Theory and mathematical statistics,** John Wiley & Wiley eastern.

E-13 Bayesian and Multivariate Analysis

Contact Hours: 60

Section A

Bayes theorem for radom variables. Prior and posterior distributions. Types of prior: non informative and improper priors for location, scale and location scale parameters.
Loss functions, decision rule and risk functions. Bayes estimation, Bayes principle, Bayes risk, Bayes test.

Section B

Multivariate Normal distribution, marginal and conditional distributions, characteristics functions Wishart distributions and its properties. Hotelling T2, Mahalanobis D2 and their applications.

Section C

Classification and discriminant analysis. Principal Component analysis. Canonical Correlations and variables. Factor analysis.

Suggested Text Books:

1. J.O. Berger, **Statistical Decision Theory and Bayesian Analysis**.
2. T.W. Anderson, **Multivariate analysis**, John Wiley & Wiley eastern.

Suggested Reference Books:

1. J.M. Bemado, A.F.M. Smith, **Bayesian Theory**.
2. Johnson &Wichem, **Applied Multivariate Analysis**, Wiley & Wiley Eastern.

E-14 Bayesian Inference

Contact Hours: 60

Section A

Bayes Theorem for random variables; non-informative and improper prior distributions for location, scale and location scale parameters; Jeffery's priors. Hartingan's priors, maximum entropy priors; Bayes sufficiency, Factorization theorem; natural conjugate priors; posteriors distribution and normal approximations to posterior distribution, Bayes principle and Bayes risk; generalized maximum likelihood estimation; Bayes point estimate; Credible regions; H.P.D. credible regions.

SectionB

Finite action problem and hypothesis testing; prior and posterior odds ratio; Bayes factor; Lindley's paradox, two sample testing problems for the parameters of normal population; predictive density function; point and interval predictors.

SectionC

Empirical Bayes estimation, determination of prior distribution from past data; linear Bayes estimate, hierarchical Bayes analysis (Normal context); Preposterior analysis and determination of optimal fixed sample size; general discussion on Bayes computation (without proof).

Suggested Text/ Reference Books:

1. J. Aitchison and I.R. Dunsmore, **Statistical Prediction Analysis**.
2. J.O. Berger, **Statistical Decision Theory and Bayesian Analysis**.
3. G.E.P. Box and G.C. Tiao, **Bayesian Inference in Statistical Analysis**.
4. M.H. Degroot, **Optimal Statistical Decisions**.
5. P.M. Lee, **Bayesian Statistics**.
6. J.M. Bernards and A.F.M. Smith, **Bayesian Theory**.

E-15 Reliability& Renewal Theory

Contact Hours: 60

Section A

Concept of reliability, classes of life time distributions, evaluation of reliability function, shape of reliability function, system reliability evaluation: series & parallel system, partially redundant system, standby system with perfect switching/ imperfect switching**,** (k, n) system, bridge structure, availability theory and its molding for various configurations, introduction to software reliability.

Section B

Reliability models of maintained systems. Reliability Allocation Problems, Discrete Replacement Policies: Age, Block Policies, Preventive Maintenance Policies, Corrective Maintenance Policies, Concept of minimal repair, Notions of aging.

Section C

Renewal Theory, Distribution of number of renewals & moments, Recurrence time & its limiting distribution. Application of Renewal Theory, Solutions of Renewal type equations, Optimization problem with respect to system reliability.

Text Books:

1. Reliability and Life Testing:S. K. Sinha. Wiley Eastern Limited.
2. Reliability Theory. I. Gertsbakh. Springer International Edition 2009.
3. Renewal Theory.D. R. Cox.Matheun London, 1962.
4. Introduction to Reliability Engineering:E. E. Lewis: 2^{nd} edition. John Wiley & Sons, 1994.

Reference Books:

1. R.E. Barlow and F. Proschan, **Mathematical theory of Reliability**, John Wiley and Sons, New York, 1965.
2. John G. Rau, **Optimization and Probability in Systems Engineering**, Van Nostrand Reinhold Company, 1970.
3. E.E. Lewis, **Introduction to Reliability Engineering**, 2^{nd} edition, John Wiley & Sons, 1994.
4. R.E. Barlow and F. Proschan, **Statistical Theory of Reliability and Life Testing**, Holt, Rinehart & Winston Inc., 1975.
5. D.R. Cox., **Renewal Theory**, Matheun London (Chapters 1-5), 1962
6. A.K.S. Jardine, **Maintenance, Replacement and Reliability**, Pitman Publication (U.K.) (Chapter 6), 1973
7. P.M. Morse, **Queues, Inventories and Maintenance**, John Wiley and Sons, 1958.

8. Billinton Roy and W. Allan Ronald, **Reliability Evaluation of Engineering Systems,** Pitman Publication, 1983.
9. J.D. Musa, Antony Lannino, K. Okunoto, **Software Reliability Measurement, Prediction and Applications**, McGraw Hill, 1987.
10. P.K. Kapur, Santosh Kumar and R.B. Garg, **Contributions to Hardware and Software Reliability**, World Scientific, 1999.

E-16 Time Series and Stochastic Process

Contact Hours: 60

Section A

Time series as a stationary or non-stationary stochastic process, time domain analysis based on correlogram, sample autocovariance function and autocorrelation function at lag K, lag correlation.

Measurement of cyclic fluctuations: Periodogram and its relation with acvf, Harmonic analysis. Measurement of irregular component: Variate difference method.

AR(p) process, MA(q) process, mixed ARMA(p,q) process, Stationarity and inevitability conditions, ARIMA (p, d, q) model, estimation of parameters, tests for stationarity Stochastic – Process.

Section B

Markov Chain having two states, n-step transition probabilities, Classification of states, recurrent and transient states, Chapman-Kolmogorov equations, Stationary probability theorems and limit theorem for ergodic chains, martingales.

Section C

Poisson process, birth and death process, Random walk and Gambler's Ruin problem, Wiener process, Renewal theory and its application, Branching chains: Discrete Process (Galton-Watson), Continuous process (Markov Branching), Fundamental theorem of Extinction.

Suggested Text/ Reference Books :

1. P.G. Hoel, S.C. Port, C.J. Stone, **Introduction to stochastic processes**, Universal Book Store, New Delhi.
2. S.K. Srinivasan, K.M. Mehata, **Stochastic Processes**, Tata McGraw-Hill Publishing Company limited, New Delhi.
3. J. Medhi, **Stochastic Processes**.
4. G.E.P. Box and G.M. Jenkins, **Time Series Analysis: Forecasting and Control**.
5. C. Chatfield**, The Analysis of Time Series: Theory and Practice**.

E-17 Time series Modeling

ContactHours: 60

Section A

Review of Time series analysis: Estimation and elimination of of trend and Seasonal component. Simple time series models and their applications, Wald decomposition theorem, Estimation of AR/MA/ARMA models, Autocorrelation and partial autocorrelation functions. Diagnostic tests (AIC, BIC criterion), Forecasting ARMA processes.

Section B

Non stationary time series models (ARIMA): Estimation and forecasting. Testing of parameter stability, Multivariate time series models (ARMA), Cointegration: a general cointegrated system,

two variable model: Engle-Granger method, Johansen procedure; error correction model and tests for cointegration.

Section C

Vector autoregression and Granger causality. Non-linear models: Volatility, Autoregressive conditional heteroscedastic (ARCH/GARCH) models, different interpretations, various generalizations, estimation and testing.

Suggested Text/ Reference Books:

1. Peter J. Brockwell, Davis, A. Richard, **Introduction to Time series and Forecasting**, 2nd Edition, Springer, 2008.
2. A. Fuller Wayne, **Introduction to Statistical Time Series**, Wiley Series in Probability and Statistics, 2nd edition, 1996.
3. C. Chatifield (Reader in Statistics, The University of Bath, UK), The **Analysis of Time Series – An introduction**, 5th edition.
4. C. Mills Terence, **Time series techniques for economists**, Midland Montagu Centre for Financial Markets, City University Business School

E-18 Financial Mathematics

Contact Hours: 60

Section A

Role of Financial Management. Financial Analysis and planning. Working Capital Management. Cost of Capital, Capital Structure and Dividend Policies, Short term and Long term Financial Planning.

Section B

Analytical Approach to Finance. Technique of Goal Programming and its Application to Profit Planning and Financial Budgeting. Capital Expenditure Decision under Risk.

Section C

Financing Decision: Problem of determining optimal capital structure, Leasing, Debt Management, Analysis of commitment of funds and risk of cash insolvency; Receivables and Inventory Management Approaches, Simulation Approach to Working Capital Management.

Suggested Text/ References Books:

1. J.C. Van Horne, **Fundamentals of Financial Management**, Prentice Hall of India, 1998.
2. E.F. Brigham, L.C. Gapenski and C.E. Michael, **Financial Management: Theory and Practice**, The Dryden Press, 9th Ed., 1998.
3. M.Y. Khan and P.K. Jain, **Financial Management**, Tata McGraw Hill Pub. Co., New Delhi, 2000.
4. J.J. Clark, T.J. Hendland and R.E. Pritchard, **Capital Budgeting Planning and Control of Capital Expenditures**, Prentice Hall, Englewood Cliffs, NJ, 1986.
5. G. Donaldson and F. Bertrand, **Corporate Debt Capacity: A Study of Corporate Debt Policy and the Determination of Corporate Debt Capacity**, Beard Books, 2000.
6. R.H. Fogler and S. Ganpathy, **Financial Econometrics**, Prentice Hall, Englewood Cliffs, NJ, 1982.
7. H. Levy and M. Sarnat, **Capital Investment and Financial Decisions**, Prentice Hall, Englewood Cliffs, NJ, 1982.
8. J.C.T. Mao, **Quantitative Decision of Financial Decisions**, Macmillan, NY, 1969.

9. J.C. Van Horne, **Financial Management and Policy**, Prentice Hall, Englewood Cliffs, NJ, 11th Ed., 1997.
10. R.A. Yadav, **Financial Ratios and the Prediction of Corporate Failure,** Concept, New Delhi, 1987.

E-19 Information Theory

Contact Hours: 60

Section A

Information theory: Origin, concept and review of probability, Definition and implications of entropy, Shannon's entropy, Discrete information source: Discrete memoryless information source, Source coding, coding strategies, Most probable messages, Discrete information source with memory, Markov processes, coding aspect, Discrete communication channel: capacity of noiseless and noisy channels, error probability and equivocation, coding theorem.

SectionB

Continuous information sources: stochastic signals, continuous information measures, Information power, Continuous communication channel: capacity, capacity in the case of additive Gaussian white noise, capacity bound in the case of additive Gaussian white noise, Channel coding theorem.

SectionC

Rate distortion theory: Discrete rate distortion function and their properties, Source coding and information transmission theorems, The continuous rate distortion function, Network information theory: multi-access communication channel, Broadcast channels, Two-way channels.

Suggested Text/ Reference Books:

1. Van der Lubbe, J.C.A., **Information Theory**, Cambridge University Press, 1988.
2. T.M. Cover and J.A. Thomas, **Elements of Information Theory**, Wiley Interscience, 1991.
3. R.B. Ash, **Information Theory**, Dover Publications, 1990.
4. C.E. Shannon and W. Weaver, **The Mathematical Theory of Communication**, University of Illinois Press, 1963.
5. I. Csiszar and J. Koerner, **Information Theory: Coding Theorems for Discrete Memoryless Systems**,2nd ed., AkademiaiKlado, Budapest, 1997.

E-20Network Analysis

Contact Hours: 60

Section A

Flows in Network, Maximal Flow - Minimal Cut theorem using the concept of Duality, Maximal Flow problem, feasibility theorems, General Minimal Cost Flow problem, Hitchcock problem, Bottleneck Assignment problem, Out-of-Kilter algorithm, Shortest path problem, Minimal spanning tree.

Section B

PERT & CPM: Critical path, Activity floats, Project crashing, Resource leveling and Resource scheduling.

Section C

Sequencing problem; Finite sequencing for a single machine Flow shop and Job-shop problem, Sequencing with Stochastic processing times and parallel processing.

Suggested Text/ Reference Books :

1. R.K. Ahuja, T.L. Magnati and B. Orlin, **Network Flows-Theory, Algorithm and Applications,** Prentice Hall, New Jersey, 1993.
2. M.S. Bazaraa and J.J. Jarvis, **Linear programming and Network Flows**, 2nd Ed, John Wiley, New York, 1977.
3. S.D. Sharma, **Operations Research**, S. Chand and Co., New Delhi, 1988
4. L.R. Ford and D.R. Gulkerson, **Flows in Networks**, Princeton University press, 1962.
5. R.W. Conway, W.L. Maxwell and L.W. Miller, **Theory of Scheduling**, Addison Wesley, 1967.
6. S. Fiench, **Sequencing and Scheduling**, Ellis Horwood Ltd., 1982.
7. J.J. Modder, and C.R. Philips, **Project Management with PERT and CPM**, VanNostrand Reinhold Co., 1970.
8. P.A. Jenson and J.W. Barmes, **Network Flow Programming**, John Wiley and Sons, 1980.
9. S.E. Elmaghraby, **Activity Network, Project Planning and Control**, John Wiley and Sons, NY, 1977.
10. R. Panneerselvam, **Operations Research**, PHI, New Delhi, 2003

E-21Clinical Trials

Contact Hours: 60

Section A

Introduction to clinical trials,new drug application and clinical development, Bias and variability of primary clinical endpoint. Design consideration of clinical trials: Patient selection, selection of controls, statistical consideration,Randomisation and blinding.

Section B

Overview of phase I-IV trials. Designs for clinical trials: Parallel, crossover, Cross-sectional, longitudinal, titration, enrichment designs, Classification of clinical trials: Multicentre, active control combination, equivalence trials, Concept of surrogate endpoints. An introduction to meta analysis of clinical trials.

Section C

Group sequential methods in clinical trials, Pollock's and O'Brien & Fleming's tests (with properties),Group sequential tests for binary data, survival data, Analysis for categorical data.

Suggested Text/ Reference Books:

1. S. Piantadosi, **Clinical Trials; A Methodological Perspective**, Wiley and Sons, 1997.
2. C. Jennison and B.W. Turnbull, **Group Sequential Methods with Applications to Clinical Trials**, CRC Press, 1999.
3. L.M.C. Furburg& D.L. Demets, **Fundamentals of Clinical Trials**, Springer Verlag,1998.
4. J.L. Fleiss, **The Design and Analysis of Clinical Experiments**, Wiley & Sons, 1989.
5. E. Marubeni and M.G. Chi, **Analysing Survival Data from Clinical Trials and Observational Studies**, Wiley & Sons, 1994.

E-22Decision Theory

Contact Hours: 60

Section A

Concepts of process, Bayesian Procedure, Decision Functions, Different Decision Criterion for Decision Problems under risk and Uncertainty. Regret versus Loss Function, Expected Value of perfect Information, Utility and its Application in Decision Problems.

Section B

Multilevel (Multi-Stage) Decision problem, Principles of Diagramming and Locating of Optimal Strategy. Decision Analysis with Continuous Distribution for the Events.

Decision Process with Sampling Information: Simple Sampling and Binomial Sampling and with Updating the Prior Distribution of the Events (Use of Posterior Distribution). Decision Process and Normal Distribution of Event.

Section C

Basic Concepts of the Sampling time Markov Decision process Examples, Stationary Policies, Average Cost Criterion, Policy- Iteration Algorithm, Linear Programming Formulation Procedure and Comparison of Linear Programming Formulation Procedure and Policy Iteration Algorithm for Solving an Infinite Stage Markov Decision Problem. Simple Concept of Semi Markov Decision Process. Application of Markov Decision Process to Inventory Management, Maintenance, Manufacturing Process, Telecommunication and Queueing theory.

Suggested Text/ References Books:

1. Bruce F. Baird, **Managerial Decision under Uncertainty- An Introduction to the Analysis of Decision Making** (chapters- 7,8,10,12), John Wiley, 1989.
2. J.T. Buchanan, **Discrete and Dynamic Decision Analysis** (chapters-7, 9), 1982.
3. D.W. Bunn, **Applied Decision Analysis**, McGraw Hill Book Co., 1986.
4. French, Simon, **Decision Theory: An Introduction to the Mathematics of Nationality**, Ellis Horwood ltd., 1986.
5. Johns Mogran, **Introduction to Decision Theory** (chapters-5,6,8,9,10,11).
6. H.C. Tijms, **Stochastic model –An Algorithmic Approach** (chapters-2 & 3), John Wiley (1994).

E-23Demography and Advanced Sampling

Contact Hours: 60

Section A

Logistic models, measures of morbidity, mortality graduation, methods of construction of abridged life tables and its applications, population estimates and projection.

Section B

- Cluster sampling with equal clusters.
- Ratio and Regression estimators.
- Sampling with varying probability of selection (WR and WOR)
- Cumulative Total and Lahiri's method of selection.
- Estimation of population mean.
- Desraj Ordered estimates.
- Horwitz Thompson estimates.
- Midzunosen and Narain Methods of sampling.

Section C

- Post stratification and deep stratification.
- Double sampling in ratio and regression estimation.
- Two stage and multistage sampling.
- Basic idea of randomised response technique.
- Non sampling errors: Interpenetrating samples.

Suggested Text/ Reference Books:

1. P.V. Sukhatme, B.V. Sukhatme, C. Ashok, **Sampling Theory of Surveys with Applications**, 2nd Ed., Piyush Publication Delhi.
2. K.B. Pathak and F. Ram, **Techniques of Demographic Analysis**, II Revised ed., Himalaya Publishing House, Mumbai.
3. M.N. Murthy, **Sampling Theory and Methods**, Sage Pub., New Delhi.
4. Des Raj. and P. Chandok; **Sampling Survey Theory**, ND Narosa.
5. D. Singh and F.S. Chaudhary, **Theory and Analysis of Sample survey Design**, NewAge International Publication.
6. K. Srinivasan, **Demographic and Socio Economic Aspects of the Child in India**, Himalaya Publication.

E-24Design of Experiments & Linear Models

Contact Hours: 60

Section A

Estimable functions, estimation and error space, linear models and regression, Standard Gauss Markov Models, Best linear unbiased estimate (BLUE), Method of least squares and Gauss - Markov theorem, Variance covariance matrix of BLUES, use of g-inverse.

Section B

General two – way classification, Analysis of covariance (2n, 32 and 33) factorial experiments, complete and partial confounding. Split and strip plot designs.

Section C

Balanced Incomplete Block design (BIBD) Construction of BIBD, Intra block and inter block Analysis, BIBD with recovery of inter block information, partially balanced Incomplete block design (PBIBD), quasi-Latin square design.

Suggested Text/ Reference Books:

1. D.D. Joshi, **Linear Estimation and Design of Experiments**, Wiley Eastern.
2. N.C. Giri, **Analysis of Variance**, South Asian Publishers, 1986.
3. M.N. Das and N.C. Giri, **Design and analysis of experiments**, Wiley Eastern.
4. C.R. Rao, **Linear statistical inference**, John Wiley, Singapore 2nd Ed.
5. AlokDey, **Theory of block designs**, Wiley Eastern.

E-25Distribution Theory

Contact Hours: 60

Section A

Random Experiments and its sample space, random vatriables, cdf, pdf and pmf, absolutely continuous and discrete distributions, mixtures of probability distributions. Some common distributions like Bernoulli, uniform, binomial, Poisson, geometric, rectangular, exponential,

normal, Cauchy, hypergeometric, multinomial, Laplace, negative binomial, beta, gamma, lognormal and compound. Poisson distribution, Weibull distribution.

Section B

Distributions of functions of random variables. Transformations, moments, m.g.f., p.g.f. Independence of random variables, convolutions, conditional expectations and variances.
Random vectors, joint distributions, joint m.g.f., mixed moments and variance- covariance matrix. Correlation and regression.

Section C

Sampling distributions of statistics from univariate normal random samples such as linear and quadratic forms. Fisher's Cochran theorem. Non central chi-square, t and F distributions.

Suggested Text/ Reference Books:

1. Mood, Graybill and Boes, **An Introduction to Statistics**, Tata McGraw-Hill publisher
2. Kotz, Balakrishnan and Johnson, **Continuous Univariate Distributions Vol II**, A Wiley Interscience Publication, 2nd ed., 2000.
3. Kotz, Balakrishnan and Johnson, **Discrete Univariate Distributions**, A Wiley Interscience Publication, 2nd ed., 2000.

E-26Econometrics

Contact Hours: 60

Section A

Review of multiple linear regression models,Polynomial Regression, Stepwise Regression, Lasso Regression, Model Selection Methods: AIC, BIC, Mallow's Cp, Cross-validation, Regression regularization methods.

Section B

Distributed lag models: Finite polynomial lags, determination of the degree of polynomial.
Infinite distributed lags, adaptive expectations and partial adjustment models, determination of lag length. Methods of estimation.
Introduction to logistic and Poisson regression

Section C

Simultaneous equation model: concept of structural and reduced forms, problem of identification, rank and order conditions of identifiability, indirect least squares; two stage least squares, Maximum likelihood estimation.

Suggested Text/ References Books:

1. J. Johnston, **Econometric Methods**,Tata McGraw-Hill.
2. C.G. Judge, W.E. Griffiths, R.C. Hill, Hitkepohl and T.C. Lee, **The Theory and Practice of Econometrics**.
3. D.N. Gujrati,**Basic Econometrics**, McGraw-Hill.

E-27Inventory Theory

Contact Hours: 60

Section A

Analytical structure of Production and Inventory problems, Inventory related costs, Properties of Inventory system, Factors influencing inventories.
Deterministic inventory models and extensions without and with lead time, Inventory models with partial backlogging and sales, Models with continuous production and non-constant demand

with known production capacity, Inventory models with constraints, Quantity discounts; All units and incremental. Sensitivity of the lot size system, N-products and M-Machines model.

Section B

Stochastic Inventory Models and Extension without and with lead time, Use of transformation from time-dependent for continuous and discrete demand, Power demand pattern Inventory Model, Safety stock and Buffer stock.

Section C

Simulation in Inventory system, Production scheduling, Classification of items viz; BAC, VED, FNS, Two-way analysis of ABC & FNS, Case studies.

Suggested Text/ Reference Books:

1. E. Koenigsber, J.E. Buchan, **Scientific Inventory Management**, Prentice Hall, 1963.
2. G. Hadley, T.M. Whitin, **Analysis of Inventory Systems**, Prentice Hall, 1963.
3. Hansman, Fred, **Operations Research in Production and Inventory Control**, John Wiley, 1968.
4. E. Naddor, **Inventory System**, John Wiley, 1966.
5. L.A. Johnson, D.C. Montgomery, **Operations Research in Production Planning, Scheduling and Inventory Control**, John Wiley, 1974.
6. L. Stephen, **Inventory Control**, McGraw Hill, 1979.
7. E. Silver and R. Perterson, **Decision System for Inventory Management and Production Control**, Wiley, NY, 1985.

E-28Non-parametric Statistical Inference and Sequential Analysis

Contact Hours: 60

Section A

Distribution free and non-parametric methods, order statistics, joint distribution of order statistics, marginal distribution of order statistics, distribution of median and range, exact moments, confidence interval, estimates for population quantities, Exact null distribution of R moments of the null distribution of R, test based on total number of runs, chi-square goodness of fit test, empirical distribution function.

Section B

Ordinary sign test, Wilcoxon signed rank test, Kolmogorov Smirnov one sample & two sample test and their merits and demerits, Median test, Kruskal- Wallis one way analysis of variance by ranks, McNemar change test.

Section C

Sequential analysis Wald's SPRT, properties of SPRT, OC and ASN functions of SPRT, Applications of SPRT, Testing of mean of a binomial distribution, Testing of mean of a normal distribution with known & unknown standard deviations.

Suggested Text/ Reference Books:

1. Siegel, Sidney and Castellan Jr. N. John, **Non-parametric Statistics for the Behavioral Sciences**, McGraw Hill,International edition 1988.
2. G. Casella and R.L. Berger, **Statistical Inference**, Duxbury Press, California, 1990.
3. A. Wald, **Sequential Analysis**, John Wiley and Sons, 1947.
4. J.D. Gibbons and SubhabrataChakraborti, **Non-parametric Statistical Inference**, Marcel Dekker Inc., 3rd Edition.

E-29Population Sciences

Contact Hours: 60

Section A

Definition of demography, Population Sciences, Source of population data, Census, Civil Registration System (CRS), Sample Registration Scheme (SRS), National Sample Survey (NSS), Demographic surveys and other sources (Nature and limitation of the data from each of the sources), Population Composition and change, Concept of aging, Population Theories- Theories of population growth-Malthus to Modern, theory of Demographic Transition, Theories related to fertility, migration and urbanization, Population, Development and Environment, Population and Gender, HDI.

Section B

Nuptiality& Fertility (Concepts, Measures Determinants of fertility). Mortality, Morbidity& Health (Concepts &Measures). Life Tables (Basic concepts, type and forms of life table),lexis diagram, Model life table. Reproductive Health, Migration and Urbanization (basic concepts, types, measures). Determinants and Consequences of migration, trends and pattern of urbanization in India, Issues in urbanization and urban problems in developing countries with focus on India.

Section C

Population estimation: Inter-Censual & Post Censual, Methods of population projection population policies and programmes. Population policies in the context of growth, structure, distribution and quality of life:policies related to medical termination of pregnancy (MTP), age at marriage, Sex Determination tests. National & state population policies in India. Evolution of family welfare programme in India. Programme Component and organization at different levels (National, State, District). Goals and achievements of the family welfare programme. Impact Assessment.

Suggested Text/ Reference Books:

1. P.R. Cox, **Demography Methods and Materials of Demography Vol. I**, UNO Publication.
2. K.B. Pathak and F. Ram, **Techniques of Demography Analysis**, II Revised Ed.
3. K. Srinivasan, **Demographic & Socio Economic Aspects of the Child in India**.
4. Ramkumar, **Demography India**.

E-30Queueing Theory

Contact Hours: 60

Section A

Concept of stochastic processes, Markov Chains discrete and continuous time parameter, Objectives and different characteristics of a Queueing system, Performance measures. Steady state solution of Markovian Models (M/M/1, M/M/c, M/Ek/1, Ek/M/1).

Section B

Analytical method and use of randomization technique to find the transient solution of M/M/1, M/M/c and M/M/µ Queueing models including busy period distribution.

Section C

Imbedded markov chain technique and its use to the Queueing models: M/G/1, GI/M/1 and M/D/c, Bulk queueing models, Different design and control policies ((O, N) and vacation policies) for MarkovianQueueing models. Introduction to discrete time Queueing system.
Simulation procedures: Data generation and Book- keeping aspects.

Suggested Text/ Reference Books:

1. D. Gross and C.M. Harris, **Fundamentals of Queueing Theory**, 2nd ed., John Wiley, 1985.
2. Michel E. Woodward, **Communication and Computer Networks Modeling with Discrete Time Queues**, IEEE Computer Society Press, 1994. (Chapter 4)
3. R.B. Cooper, **Introduction to Queueing Theory**, 2nd Ed, North Holland, 1981
4. D.R. Cox and W.L. Smith, **Queues**, Mathuen, 1961.
5. L. Kleinrock, **Queueing Systems**, Vol. I, John Wiley, 1975.
6. J. Medhi, **Stochastic Model in Queueing theory**, Academic Press, 1991.
7. T.L. Satty, **Elements of Queueing Theory with Applications**, Mc-Graw Hill, 1961.

E-31Soft Computing

Contact Hours: 60

Section A

Neural Network (NN) Paradigms: Introduction, Neuron model, Neural network architectures, Learning Rules (Hebbian, Competitive, Baltzmann, Supervised, unsupervised) Types of neural networks: Perceptron, MLP, radial basis function network, recurrent network, self-organizing Feature maps, Boltzamann m/c, Applications of NN.

Section B

Fuzzy Logic: Introduction, Fuzzy sets, Basic operations on fuzzy sets, relations, rule based models and linguistic variables, fuzzy control, interpolation in fuzzy rule base, Applications of Fuzzy logic.

Section C

Evolutionary Computations: Introduction, Genetic Algorithm (GA), Evolutionary programming, Classifier systems, genetic programming parse trees, Mathematical foundation of GA variants of GA (hybrid GA, Fuzzy GA Enhancements of genetic programming, application).

Suggested Text/ Reference Books:

1. Zimmermann, **Fuzzy set theory and its application**.
2. S. Haykins, **Neural Networks**.
3. H. Li. and M.M. Gupta, **Fuzzy logic and intelligent systems.**
4. L.C. Jain, **Soft Computing Techniques in knowledge-based intelligent engineering systems, approaches and application**.
5. Geyer-Schulz Andrers, **Fuzzy Rule-Based Export Systems and Genetic Machine Learning,** Second revised and enlarged edition.
6. B. Yegnanrayana, **Artificial Neural Networks**.
7. B. Rao Valluru and V. RaoHayagriva, **C++ Neural Networks and Fuzzy Logic**.
8. D. Ruan, **Fuzzy Systems and Soft Computing in Nuclear Engineering**.
9. J.A. Anderbon, **An introduction to Neural Network**.
10. B. Kosko, **Neural Networks and Fuzzy Systems, A Dynamically Systems approaches to machine intelligence**.

E-32 Regression Analysis

Total Contact Hours : 60

Section – A

Review of the two-variable linear model, p-variable linear model: underlying assumption, ordinary least squares estimators, set of linear hypothesis: Testing a single coefficient, testing the significance of a subset of coefficients, testing the significance of the complete regression. Confidence estimation, R2 and adjusted R2. Residual Analysis.

Section B

Problems of multicollinearity: its detection and remedies, ridge estimator, PCR estimator, Use of extraneous information in terms of exact and stochastic linear restrictions. Estimation of parameters by generalized least squares in models with non-spherical disturbances: heteroscedasticity of disturbances and the problem of autocorrelation.

Section C

Dummy Variables in Linear Regression Models, tests for structural break, Specification Errors, Nonlinear Associations and Interaction Terms, Influential Observations: Leverage Points and Outliers,A Brief Introduction to Logistic Regression.

Reference Books:

1. John P. Hoffmann, **Linear Regression Analysis: Applications and Assumptions,** Second Edition**.**
2. Draper, N. R. and Smith, H. (1998). Applied Regression Analysis (John Wiley) Third Edition.

RE-1: Numerical Solutions of Partial Differential Equations

Numerical solutions of parabolic PDE in one space: two and three levels explicit and implicit difference scheme. Numerical solution of parabolic PDE of second order in two dimensional space implicit methods, alternating direction implicit (ADI) methods,Non-linear initial BVP.
Difference schemes for parabolic PDE in spherical and cylindrical coordinate systems in one dimension. Numerical solution of hyperbolic PDE in one and two space dimension: explicit and implicit schemes. Lax's equivalence theorem, Finite difference schemes for initial and boundary value problems - FTCS, backward Euler and Crank-Nicolson schemes, Difference schemes for first order equations.
Numerical solutions of elliptic equations, approximations of Laplace and biharmonic operators. Solutions of Dirichlet, Neuman and mixed type problems.

Recommended Books:

1. M.K. Jain, S.R.K. Iyenger and R. K. Jain, Computational methods for Partial Differential Equation, Willey Eastern,1994.
2. M..K. Jain, Numerical solution of Differential Equations, 2^n edition, Wiley Eastern.
3. S. S. Sastry, Introductory Methods of Numerical Analysis, Prentice-Hall of India, 2002.
4. D.V. Griffiths and I.M. Smith, Numerical Methods of Engineers, Oxford University Press, 1993.
5. C.F. General and P.O. Wheatley, Applied Numerical Analysis, Addison-Wesley, 1998.
6. G.D. Smith, Numerical Solutions to Partial Differential Equations, Oxford University Press, 3rdEdn., 1986.

RE-2: Operator theory

Dual space considerations: Representation of duals of the spaces with p-norms, and c with supremum-norm, C[a,b] and . Reflexivity, Weak and weak* convergences. Best Approximation in Reflexive spaces.
Operators on Banach and Hilbert spaces: Compact operators and its properties; Integral operators as compact operators; Adjoint of operators between Hilbert spaces; Self-adjoint, Normal and unitary operators; Numerical range and numerical radius; Hilbert--Schmidt operators.
Spectral results for Banach and Hilbert space operators: Eigen spectrum, Approximate eigen spectrum, Spectrum and resolvent; Spectral radius formula, Spectral mapping theorem; Riesz-Schauder theory, Spectral results for normal, Self-adjoint and unitary operators; Functions of self-adjoint operators.

Text books:

1. M.T. Nair, Functional Analysis: A first course, Prentice Hall of India, 2002.

References books:

1. B.V. Limaye, Functional Analysis, Second Edition, New Age Internationals,1996.
2. J.B. Conway, A Course in Functional Analysis, 2nd ed., Springer, Berlin, 1990.
3. C. Goffman and G. Pedrick, First Course in Functional Analysis, Prentice Hall, 1974.
4. I. Gohberg and S. Goldberg, Basic Operator Theory, Birkhauser, 1981.

5. E. Kreyzig, Introduction to Functional Analysis with Applications, Wiley, 1989.
6. G. Bachman, L. Narici, Functional analysis, Academic Press, N.Y., 1964.

RE-3: Supply Chain Management

Building Blocks of a Supply Chain Network, Business Process in Supply Chains, Types of Supply Chains and Examples, Strategic, Tactical, and Operational Decisions in Supply Chains, Supply Chain Performance Measures.
Supply Chain Inventory Management: Newsboy, Base-stock, and (Q,r) Models, Multi-Echelon Supply Chains, Performance of Supply Chains using Markov Chains and Queueing Networks.
Mathematical Programming Models for Supply Chain Planning, Design and Optimization, Internet- Enabled Supply Chains ERP and Supply Chains, Customer Relationship Management.

Suggested Books:

1. S.Chopra and Peter Meindel, Supply Chain Management: Strategy, Planning, and Operation, Prentice Hall of India, 2002.
2. Jeremy F. Shapiro. Modelling the Supply Chain, Duxbury Thomson Learning, 2001.
3. N. Viswanadham. Analysis of Manufacturing Enterprises, Kluwer Academic Publishers, 2000.
4. Sridhar Tayur, Ram Ganeshan, Michael Magazine (editors). Quantitative Models for Supply Chain Management, Kluwer Academic Publishers, 1999.
5. R.B. Handfield and E.L. Nochols, Jr. Introduction to Supply Chain Management, PrenticeHall, 1999.
6. N. Viswanadham and Y. Narahari, Performance Modeling of Automated manufacturing Systems, Prentice Hall of India, 1998.
7. Relevant Research Papers

RE-4: Marketing Management

Consumer Behavior, Contribution of Consumer Behavior in Marketing Management; Market Segmentation; Purchasing Decision with Market price Increase Anticipated; Purchasing under Varying marketing Parameters viz: Price, Quality, Promotional Effort and Distribution Expenses; Promotional and Pricing Decisions under Competition; Planning Suitable Channels of Distribution appropriate to various Classes of Goods and Customers; Media Planning and Media Allocation Models Determining the Optimal Return on Investment for an Advertising Campaign. Diffusion of Products with Limited Supply and Known Expiration Date. Diffusion of Innovation under Supply Constraints.

Suggested Books:

1. Perry Bliss, Marketing and Behavioral Sciences.
2. Frank M. Bass, Charles King and EgarPessemier, Application of Sciences to Marketing Management, John Wiley & Sons-New York.
3. Gary L. Lilien and ArvindRangaswamy, Marketing Engineering, Person Education, Singapore, (2003).
4. Robert G. Murdick, Mathematical Models in Marketing,Intext Educational Publisher, (1971).

5. Graham J. Hooley and Michael K Hussey, Quantitative Methods in Marketing International Thomson Business Press (1999).
6. Relevant Research Papers

RE-5: Inventory and Production Management

Deterministic Inventory Lot-Size Model with Time proportional demand. Deterministic joint replenishment policy. Inventory Control of deteriorating items (discrete and Continuous). Inventory control under inflationary conditions. Inventory models with stock dependent demand. Interaction of inventory and trade credit policies. Impact with marketing policies on inventory decisions. Joint buyer-seller inventory model. The distribution free newsboy problem and its extensions.
Introduction to VMI and Supply chain.
Interaction of Inventory, Queues and Reliability.
Aggregate Production Planning Fixed and Variable Work Force Model. Inventory Location Model. Production Planning with Time Varying Demand.

Suggested Books:

1. Walters, C.D. J., 2003, Inventory Control & Management, John Wiley & Sons
2. Heizer, J. and Render, B., 2001, Principles of Operation Management, Prentice Hall.
3. Zipkin, P.H., 2000, Foundations of Inventory Management, McGraw-Hill/Irwin.
4. NJ Bernard, P. 1999, Integrated Inventory Management, John Wiley and Sons, New York.
5. Silver, E., Pyke, D., and Peterson, R. 1998. Inventory Management and Production and Scheduling, John Wiley and Sons, New York.
6. Tony Wild, 1998, Best Practice in Inventory Management, John Wiley & Sons.
7. Bedworth and Bailey, 1987, Integrated Production Control Systems, John Wiley & Sons, New York.
8. Plossl, G., 1985, Production and Inventory Control, Principles and Techniques, Prentice hall, Englewood Cliffs, NJ.
9. Relevant Research Papers.

RE-6: Decision and Game Theory

Finite Games, Equilibrium Points, Games with Infinitely many Strategies, Infinite Games, Concave-Convex Games, Multistages Games, Stochastic Games, Two Person General-Sum Games, Bimatrix Games, Non-Atomic Games.
Differential Games, Nash Equilibrium, Identifying Nash Equilibria, Solution of n-persons games with and without zero-sun restriction. Lanchester's equations and their application to games of strategy, Statistical Games, General Techniques for Solving Statistical Games.
Bayesian Decision Theory, Preposterior and Sequential Analysis, Group Decisions and Social Choice, Influence Diagrams, Mulyi Attribute Utiltiy.

Suggested Books:

1. G. Owen, Game Theory, Second Edition, Academic press, 1982.

2. Mekinsey J.C.C., Introduction to the Theory Of Games, McGraw-Hill Book Company, INC, 1952.
3. Neyerson, R, Game Theory: Analysis of Conflict, Harvard University Press, Cambridge Mass, 1991.
4. Steffen J. and Georges, Z., Differential Games in Marketing, Kluwer Academic Publishers, 2004.
5. J.Q. Smith, Decision Analysis- A Bayesian Approach Chapman & Hall, 1988.
6. D.V. Lindley, making Decisions, Second Edition, Wiley, 1985.
7. S. French, Decision Theory-An Introduction to the Mathematics of Rationality, Ellis Horeood, Chichester, 1986.
8. M.H. Degroot, Optimal Statistical Decisions, Second Edition, McGraw Hill, 1970.
9. R.T. Clemen, Making Hard Decision, Second Edition, Duxbury Press, 1995.

RE-7Algebraic Geometry

Algebraic curves in plane, closed subset of affine space, rational functions, projective and quasi projective varieties, projective spaces, hypersurfaces, product and maps of quasiprojective varieties, Normal varieties.
Dimension and degree, singular and non-singular points, singularities of a map, divisors, divisors on curves, plane cubic, algebraic group, differential forms, Riemann-Roch theorem on curves.

Reference Books:

1. Shafarevich: Basic Algebraic geometry I, Springer 1994. Cox-Little-O'Shea (CLO) "Ideals, Varieties, Algorithms", Springer 1992.
2. Hartshorne, Robin. Algebraic Geometry. New York, NY: Springer, 1997.
3. Schenck (S) "Computational Algebraic Geometry", Cambridge 2003.
4. Harris (H) "Algebraic Geometry: a first course", Springer 1992.

RE-8 Algebraic Aspects of Cryptography

Finite field arithmetic: Introduction to finite fields, Prime field arithmetic, Binary field arithmetic, optimal extension field arithmetic.
Elliptic Curves: Group law, projective coordinate and Jacobian coordinates, Endomorphisms, Torsion points, Divisors and Tate pairings, Supersingular and singular elliptic curves Elliptic curves over finite field, Elliptic Curve Cryptography.
Lattices: Basic definitions and properties, Short vectors in lattices, Babai's Algorithm, NTRU public key cryptosystem, Lattice based digital signature algorithm, Lattice reduction algorithm.

Reference Books:

1. Hankerson, D., Menezes, A. and Vanstone, S.: Guide to Elliptic Curve Cryptography, Springer-Verlag, New York, 2004. (Chapter 2)
2. Washington, L. C.: Elliptic Curves, Number Theory and Cryptography, 2nd Ed., Taylor & Francis, 2008. (Chapter 2, 3, 4, 6)
3. Martin, L.: Introduction to Identity based Encryption, Artech House, London, 2008. (Chapter 3, 4, 6)

4. Hoffstein, J., Pipher, J. and Silverman: An introduction to Mathematical Cryptography, 2nd Ed., Springer, 2014. (Chapter 7)

RE-9 Advanced Cryptography

Digital signatures: Definitions, formal definition of security, relations between security notions, strong unforgeability, one time signature, signature from one-way function, hash-and-sign paradigm, security of RSA signature, Schnorr signature scheme, Certificates and public key infrastructure.
Signcryption: Definitions, security models for signcryption, signcryption scheme based on Diffie-Hellman Problem.
Identity Based Cryptography: Cocks, Boneh-Franklin, Boneh-Boyen, Sakai-Kasahara identity based encryption schemes.

Suggested Books:

1. Katz, J.: Digital Signature, Springer, 2010. (Chapter 1, 3)
2. Katz, J. and Lindell, Y.: Introduction to Modern Cryptography, 2nd Ed., Chapman & Hall/CRC, Taylor & Francis Group, 2015. (Chapter 12)
3. Dent, A. W. and Zheng, Y.: Practical signcryption, Springer, 2010. (Chapter 2, 3, 4)
4. Martin, L.: Introduction to Identity based Encryption, Artech House, London, 2008. (chapter 7, 8, 9, 10)

RE-10 Finite Element Methods

The fundamentals of finite element methods, Discritization of the bounded area, stiffness matrix, assembly of stiffness matrices, Global stiffness matrix.
Shape function: Linear and higher order shape functions for linear, triangular and rectangular elements, Variational Formulation, Rayleigh-Ritz method and Weighted residue method, Galerkin's method
Finite Element formulation for PDE, Laplace equation, wave equation and diffusion equation.

Suggested Text/ Reference Books:

1. J.N. Raddy, **Finite Element Methods**, 2nded, McGraw Hill, 1993.
2. D.H. Norrie and G. Devries, **Introduction to Finite Element Methods**, Academic Press.
3. K.E. Brenner and R. Scott, **The Mathematical Theory of Finite Element Methods**, Springer-Verang, Berlin, 1994.
4. P.G. Ciarlet, **The Finite Element Methods for Elliptic Problems**, North Holand, Amsterdam, 1978.
5. C. Johnson, **Numerical Solution of Partial Differential Equations by Finite Element Methods**, Cambridge University Press, Cambridge, 1987.
6. C. Mercier, **Lectures on Topics in Finite Element Solution of Elliptic Problems, TIFR Lectures on Mathematics and Physics, Vol. 63**, Narosa Publ. House, New Delhi, 1979.

RE-11 Finite Field Theory

Introduction to finite fields, extension fields, trace and norm function, bases linearized polynomial, irreducible polynomial, primitive polynomial, factorization of polynomials, normal bases, Completely normal bases, Gauss, Jacobi, and Kloosterman sums, exponential and character sums, Some applications of character sums

Suggested Books:

1. Mullen, G. L. and Panario, D.: Handbook of finite fields, CRC Press, 2013.
2. Lidl, R and Niederreiter, H.: Introduction to finite fields and their applications, Cambridge University Press, 1986.
3. Menezes, A. J.: Applications of finite fields, Springer, 1993.

RE-12Special Functions

The Gamma and Beta Functions: Eulers' integral forΓ(z), the beta function, factorial function, Legendre's duplication formula, Gauss's multiplication theorem, summation formula due to Euler, behavior of log Γ(z) for large |z |. The Hypergeometric function: An integral representation, differential equation and solutions. F(a,b,c;1) as a function of the parameters, evaluation of F(a,b,c;1), contiguous function relations

The hypergeometric differential equation, logarithmic solutions of the hypergeometric equation, F(a,b,c;z) as a function of its parameters, Elementary series manipulations, simple transformations, relation between functions of Γ(z) and, Γ(1-z) quadratric transformations, theorem due to Kummer, additional properties. The Confluent Hypergeometric function: Basic properties of 1F1, Kummer's first formula. Kummer's second formula, Generalized Hypergeometric Series: The function pFq, the exponential and binomial functions, differential equation, contiguous function relations, integral representation pFq, with unit argument, Saalshutz' theorem, Whipple's theorem, Dixon's theorem, Contour integrals of Barnes' type.

Bessel Functions: Definition, Differential equation, differential recurrence relations, pure recurrence relation, generating function, Bessel's Integral, index half an odd integer, modified Bessel functions,

Introduction to Legendre function, Meijer G-function and some basic properties, Fox's H-Function.

Text/Reference Books:

1. Earl. D. Ranvillie: Special Functions, Macmillan, 1960.
2. L.C. Andrews: Special Functions of Mathematics for Engineers, SPIE Press, 1992.
3. Gabor Szego: Orthogonal Polynomials, American mathematical society, 1939.
4. L. J. Slater: Generalized Hypergeometric Functions, Cambridge University Press, 2008.
5. A.M. Mathai, H.J. Haubold: Special Functions for Applied Scientists, Springer, 2008.

RE-13 Algebraic Topology

Homotopy of paths, fundamental group of a space, homomorphism between fundamental groups induced by a map between spaces, homotopy equivalence and homotopy type, the Seifert-van Kampen's theorem and its applications.

Covering spaces: Definition and examples, lifting of paths, fundamental group of a covering space, lifting of maps, deck transformations and group actions, regular covering spaces and quotient spaces.

Homology: Simplicial homology, singular homology, invariance of homology groups under homotopy.

Texts/References:

1. W. S. Massey, A Basic Course in Algebraic Topology, Springer, 1991.
2. A. Hatcher, Algebraic Topology, Cambridge, 2002.
3. J. R. Munkres, Elements of Algebraic Topology, Perseus Publishing, 1984.

RE-14 Advanced Queueing Models

Time dependent solution of M/M/1 queueing model: Difference equation techniques, Probability generating function techniques, Pegden and Rosenshine technique, Catastrophized M/M/1 queue: Cresenzo et.al technique, Kumar B. K. et.al technique. Steady state solution of M/G/1 and M/G/1/N using supplementary variable technique; GI/M/1, Geo/M/1 using embedded Markov chain technique.

Reference Books:

1. Bunday B. D., "An Introduction to Queueing Theory", Arnold Publisher(1996).
2. Crescenzo, A. Di et.al, **"**On the M/M/1 queue with catastrophes and its continuous approximation", Queueing System, Vol. 43, pp. 329- 347, (2003)
3. Conolly B.W., " A difference equation techniques applied to the simple queue", Journal of Royal Statistical Society, Series B. Vol. 20, pp. 165-167,(1957).
4. Gross D. Harris C.M. , "Fundamental of queueing theory", Wiley 2nd edition (2003).
5. Hideaki Takagi, "Queueing Analysis Vol. I, II and III", Elevier Sci. Publisher (1993).
6. Kumar B.K. et.al, "Transient solution of an M/M/1 queue with catastrophes", Computer and mathematics with application, Vol. 40, pp. 1233-1244,(2000).
7. Pegden C. D. and Rosenshine. M., " Some new results for the M/M/1 queue, Management Science, Vol 28 pp. 821-828, (1982).
8. Saaty T. L., " Elements of Queueing theory with Application", McGraw Hill, New York (1983).

RE-15 Advanced Reliability Theory

Concept of Reliability: Definition of reliability and its measures, Importance of reliability, Concept of failure, Fault tree analysis.

Lifetime Models: Notion of aging, concept of hazard rate for life time distributions (exponential, Weibull, Log-Normal, Gamma, Inverse Gaussian) , Increasing failure rate (IFR) and Decreasing failure rate (DFR) class of life distributions, Bath-tub failure curve.

Life Testing and inference: Life testing, Complete data and censored data, Type-I, Type-II, hybrid and random censoring schemes. Parametric inference based on complete and censored data, Nonparametric estimate (Life table and Kaplan-Meier) of reliability, Graphical methods (PP, QQ and TTT plots) and standard statistical tests for model validation.

Bayesian Reliability: Bayesian approximations and Reliability estimation, Bayesian intervals for parameters and Reliability functions.

Reference:

1. Statistical Theory of Reliability and Life Testing Probability Models; Barlow R.E. &Proschan, F., Holt, Rinehart and Winston, New York.
2. Mathematical Theory of Reliability; Barlow, R.E. and Proschan, F, John Wiley, New York. Page 18 of 35
3. System Reliability Theory: Models and Statistical Methods; Hoyland, A. AndRausand M., John Wiley, New York.
4. Reliability in Engineering Design; Kapur, K.C. and Lamberson, L.R., John Wiley, New York.
5. Statistical Models and Methods for Lifetime Data; Lawless, J.F., Wiley, New York,
6. Life Time Data: Statistical Models and Methods; Deshpande, J. V. And Purohit, S. G., World Scientific, Singapore.
7. Statistical Methods for Reliability Data; Meeker, W. Q. and Escobar, L. A., John Wiley, New York.
8. Applied Life Data Analysis; Nelson, W. Wiley, New York.
9. Reliability and Life Testing; Sinha, S. K. (1986),Wiley Eastern Limited, New Delhi.

RE-16 Statistical Computing

Random numbers, Pseudo random number generation: Inverse transform method, Acceptance-rejection, Transformations. Tests for randomness. Multivariate probability calculation, Simulation and Monte Carlo integration, , Variance reduction, Importance sampling.

Markov-Chain Monte Carlo: Metropolis-Hastings algorithm, Gibbs sampling, Jack-knife method, Bootstrap method, Bootstrap confidence intervals, Likelihood estimation, Bootstrap of dependent data.

Density estimation: Univariate and Multivariate estimation, Bayesian posterior density estimation, Monte Carlo EM.

Text Books

1. GIvens, H.G. and Hoeting, J.A. (2013), Computational Statistics, 2nd Edition, Wiley.

Reference Books

1. Law, A. M. and Kelton, W.D. (2000), Simulation, Modelling and Analysis 3rd Ed. Tata McGraw Hill.

2. Thisted, R.A. (1988), Elements of Statistical Computing, Chapman and Hall.

3. Robert, C. and Casella, G. (2009), Introducing Monte Carlo Methods with R, Springer Verlag.

RE-17 Demographic Models

Preliminaries: Introduction to matrix algebra, Review of unstructured population models and life table analysis. Demography: Measures of mortality, description of life table, construction of complete and abridged life tables, maximum likelihood, MVU and CAN estimators of life table parameters.

Age-structured (leslie matrix) models: model formulation and parameterization, population growth rate, stable age distribution, reproductive values, sensitivity analysis, Measures of fertility: models for population growth, intrinsic growth rate, stable population analysis, population projection by component method and using Leslie matrix.

Parameter estimation: estimation of survival and transition probabilities, estimation of reproductive parameters.Stochastic models.

Text Book:

1. Caswell, Hal. 2001. Matrix population models: Construction, analysis and interpretation. 2d ed. Sunderland, MA: Sinauer Associates.

Reference books:

1. DeAngelis, Donald L., and Loui J. Gross. 1992. Individual-based models and approaches in ecology: Populations, communities and ecosystems. New York: Chapman and Hall.
2. Murdoch, William W., Cheryl J. Briggs, and Roger M. Nisbet. 2003. Consumer-resource dynamics. Population Monographs Series 36. Princeton, NJ: Princeton Univ. Press.
3. Daley, D.J. and Gani, J. 1999. Epidemic Modelling. Cambridge Univ. Press.
4. Tuljapurkar, S. and Caswell, H. (Ed.). Structured-Population Models in Marine, Terrestrial, and Freshwater Systems. Chapman and Hall, New York.

RE-18 Intelligent Transport System

Definition of ITS, historical context of ITS from both public policy and market economic perspectives, Types of ITS; Benefits of ITS.

Importance of telecommunications in the ITS. Information Management, Traffic Management Centers (TMC). Application of sensors to Traffic management; ITS Data collection techniques – Detectors, Automatic Vehicle Location (AVL), Automatic Vehicle Identification (AVI), GIS, video data collection.

ITS User Needs and Services and Functional areas: Introduction, Advanced Traffic Management systems (ATMS), Advanced Traveler Information systems (ATIS), Advanced Vehicle Control systems (AVCS), Advanced Public Transportation systems (APTS), ITS and safety, ITS and security,ITS planning.

ITS applications:Traffic and incident management systems; ITS and sustainable mobility, travel demand management, electronic toll collection, ITS and road-pricing.; public transportation applications; ITS and regional strategic transportation planning, ITS Programs in the World – Overview of ITS implementations in developed countries, ITS in developing countries.

References:

1. Fundamentals of intelligent transportation systems planning By Mashrur A. Chowdhury, Adel WadidSadek
2. Lawrence A. Klein, Sensor technologies and Data requirements of ITS.
3. ITS Hand Book 2000: *Recommendations for World Road Association (PIARC)* by Kan Paul Chen, John Miles.
4. Sussman, J. M., *Perspective on ITS*,Artech House Publishers, 2005.
5. National ITS Architecture Documentation, US Department of Transportation, 2007.

RE-19 Generalised Linear Models

Logistic Regression: Logit transform. ML estimation. Tests of hypotheses, Wald test, LR test, score test, test for overall regression, multiple logistic regression, forward, backward method, interpretation of parameters, relation with categorical data analysis.

Poisson Regression: Introduction to Poisson regression, MLE for Poisson regression, Applications in Poisson regressions.

Family of Generalized Linear Models: Exponential family of distributions, Formal structurefor the class of GLMs, Likelihood equations, Quasi likelihood, Link functions, Importantdistributions for GLMs, Power class link function.

Reference Books:

1. Christensen, R. (1997). Log-linear Models and Logistic Regression, Second Edition,Springer.
2. Dobson, A.J. and Barnett, A.G. (2008). Introduction to Generalized Linear Models, Third Edition, Chapman and Hall/CRC. London.
3. Hastie, T.J. and Tibshirani, R.J. (1990). Generalized Additive Models. Second Edition, Chapman and Hall, New York.
4. Hosmer, D.W. and Lemeshow, S. (2000). Applied Logistic Regression, Second Edition. Wiley, New York.
5. Lindsey, J. K. (1997). Applying generalized linear models, Springer-Verlag, New York.
6.McCullagh, P. and Nelder, J.A. (1989). Generalized Linear Models, Second Edition, Chapman and Hall.
7. McCulloch, C.E. and Searle, S.R. (2001). Generalized, Linear and Mixed Models, John Wiley & Sons, Inc. New York.
8. Myers, R.H., Montgomery, D.C and Vining, G.G. (2002). Generalized Linear Models with Applications in Engineering and the Sciences, John Wiley & Sons.

RE-20 SurvivalAnalysis

Concepts of time, order and random censoring. Life distributions - exponential gamma, Lognormal, pareto, linear failure rate. Life tables, failure rate, mean residual life and their elementary properties. Ageing classes - IFR, IFRA, NBU, NBUE, HNBUE and their duals, Bathtub failure rate.

Estimation of survival function - Actuarial estimator, Kaplan - Meier estimator. Estimation under the assumption of IFR/DFR.

Semi-parametric regression for failure rate - Cox's proportional hazards model. Competing risk models. Repair models. Probabilistic models. Joint distribution of failure times. Unconditional tests for the time truncated case. Tests for exponentiality, two sample non-parametric problem.

Reference Books:

1. Cox, D.R. and Oakes, D. (1984). Analysis of Survival Data, Chapman and Hall.
2. Deshpande, J.V. and Purohit S.G. (2005). Life Time Data: Statistical Models and Methods, Word Scientific.
3. Duchateau, L. and Johnson, P. (2008). The Frailty Model. Springer: New York.
4. Gross A.J. and Clark, V. A. (1975) Survival Distributions: Reliability Applications in the Biomedical Sciences, John Wiley and Sons.
5 Hanagal, D. D. (2011). Modeling Survival Data Using Frailty Models. CRC Press: New York.
6. Hougaard, P. (2000). Analysis of Multivariate Survival Data. Springer: New York.

RE- 21 Biostatistics

Measuring the occurrence of disease: Measures of morbidity - prevalence and incidence rate, association between prevalence and incidence, uses of prevalence and incidence, problems with incidence and prevalence measurements; Clinical agreement: kappa statistics, intra-class correlation; Surveillance;
Assessing the validity and reliability of diagnostic and screening test: Validity of screening test – sensitivity, specificity, positive predictive value and negative predictive value; Reliability; Relationship between validity and reliability; ROC curve and its applications; Overall accuracy;
Issues in epidemiology: Association; causation; causal inference; Errors and bias; Confounding; Controlling confounding; Measurement of interactions; Generalizability;
Odds ratios for retrospective studies; Odds ratios approximating the prospective RR; Exact inference for odds ratio analysis of matched case-control data;

Reference Books:

1. Altman D G: Practical Statistics for Medical Research, London: Chapman and Hall, 2006.
2. Rosner B: Fundamentals of Biostatistics, ed. 6, 2006.

Verified

Offg. Secretary
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Department of Mathematics and Statistics

Banasthali Vidyapith, Banasthali

Minutes of the Board of Studies held on 26.12.2018 at 11.00 A.M in the CMS Conference Hall, Banasthali Vidyapith.

Present

1. Dr. Abhishek Singh	:	Internal Member
2. Dr. Amit Kumar	:	Internal Member
3. Mr. Ankush Goel	:	Internal Member
4. Ms. Anu Sirohi	:	Internal Member
5. Ms. Bhawna Jha	:	Internal Member
6. Prof. G.N. Purohit	:	Internal Member
7. Dr. GargiTyagi	:	Internal Member
8. Dr. Geetanjali Sharma	:	Internal Member
9. Dr. Gulab Singh	:	Internal Member
10. Dr. IshaSangal	:	Internal Member
11. Dr. Madhuri Jain	:	Internal Member
12. Mr. Manish Raghav	:	Internal Member
13. Ms. Manju Suresh Prasad	:	Internal Member
14. Dr. Manoj Kumar Singh	:	Internal Member
15. Dr. Naresh Chandra	:	Internal Member
16. Dr. Prashant Kushwah	:	Internal Member
17. Dr. Preeti Jain	:	Internal Member
18. Mr. Ramdayal Kushwaha	:	Internal Member
19. Ms. Renu Naresh	:	Internal Member
20. Dr. Sandeep Kumar Maurya	:	Internal Member
21. Prof. SarlaPareek	:	Internal Member
22. Prof. Shalini Chandra	:	Convener
23. Dr. Shanu Goyal	:	Internal Member
24. Dr. Shared Chand Pandey	:	Internal Member
25. Ms. Teena Goyal	:	Internal Member
26. Dr. Usha Sharma	:	Internal Member
27. Prof. Sharad Gore	:	External Member

Note: Prof. C.S. Aravinda, TIFR Mumbai, Prof. Arvind Mishra, B.H.U. Varanasi(External Members)and Dr. Narendra Singh Thakur (Internal Member)could not attend the meeting.

The meeting started with a welcome of the members, by the convener of Board of Studies for Mathematics and Statistics, Prof. Shalini Chandra, Head, Department of Mathematics and Statistics, Banasthali Vidyapith, Rajasthan

1. The board took up the minutes of its last meeting held on April, 23, 2016.

   The Board resolved that the minutes to be confirmed.

2. The board reviewed the existing panel of examiners and suggested to update the address and phone numbers of the existing examiners for each examination up to and inclusive of all Master's degree examination keeping in view the by-law 15.03.02 of the Vidyapith. Updated panel is sent to the examination and secrecy section.

3. The board reviewed the Study/Curricula, scheme of examination and proposed revisions in various courses of study as follows:

3 IB.A./B.Sc. (Mathematics) Examinations:

i.	First Semester Examination, December, 2019	No Change
ii.	Second Semester Examination, April/May, 2020	No Change
iii.	Third Semester Examination, December, 2020	Change[a,b]
iv.	Fourth Semester Examination, April/May, 2021	Revised [c]
v.	Fifth Semester Examination, December, 2021	Revised[d, e]
vi.	Sixth Semester Examination, April/May, 2022	Revised[d, f]

The Board reviewed the objectives, schemes, syllabi and learning outcomes of the B.A./B.Sc. (Mathematics) programmes.

(**a)**In B.A./B.Sc. (Mathematics)III Semester, revision in the syllabus of *Abstract Algebra*(Course Code: MATH 201) was proposed. Board discussed the revision proposed and agreed upon the suggested syllabus. Board also recommended implementing the proposed revision in syllabus of *Abstract Algebra* by III Semester Examination, **December, 2019**.

(**b)**In B.A./B.Sc. (Statistics as a discipline)III Semester, Board reviewed the syllabus of *Numerical Analysis and Sampling Distribution* (Course Code: STAT 203) and *Numerical Analysis and Sampling Distribution Lab* (Course Code: STAT 203L). It was found that students of Statistics also study Numerical Analysis in VI semester. Board suggested removing numerical analysis portion from this course and strengthens the sampling distribution. The title of the course should be Sampling Distributions. Therefore, in B.A./B.Sc. (Statistics)III Semester, the course *Numerical Analysis and Sampling Distribution* (Course

Code: STAT 203) should be replaced by *Sampling Distributions* (Course Code: *to be generated*) and *Numerical Analysis and Sampling Distribution Lab* (Course Code: STAT 203L) should be replaced by *Sampling Distributions Lab* (Course Code: *to be generated*).Board recommended implementing the proposed revision of the III Semester Examination, **December, 2020**.

(c) In B.A./B.Sc. (Mathematics) IV Semester, Board suggested to replace the course *Introduction to Mechanics* (Course Code: MATH 203) by the course *Complex Analysis* (Course Code: MATH 301). Board recommended implementing the proposed change in scheme by IV Semester Examination, April**, 2021**.

(d) In B.A./B.Sc. (Mathematics) and B.A. (Applied Statistics as a discipline) 3rd Year, Board suggested to include discipline electives in the scheme. Following is the list of electives

B.A./B.Sc. (Mathematics) discipline electives:

Introduction to Mechanics
Linear Programing & Its Applications
Vector Calculus
Number Theory

B.A./B.Sc.(Mathematics) discipline electives for (Statistics/ Applied Statistics):

Sampling Techniques and Design of Experiments
Applied Statistics
Financial Statistics
Health Statistics & Population Dynamics

Board recommend the implementation of electives form **Session 2021-2022.**
The course *Introduction to Discrete Mathematics* (Course Code: MATH 302) and *Introduction to Numerical Analysis* (Course Code: MATH 303) are the core course in B.A./B.Sc. (Mathematics) V and VI Semester respectively with the following suggestions.

(e) The Board had a discussion on the course *Introduction to Discrete Mathematics* (Course Code: MATH 302) which is running in B.A./B.Sc. (Mathematics) V Semester, B.Tech. (CS) V Semester and MCA II Semester. To bring uniformity in the syllabus of the course across the various programs, board suggested revisionsin the syllabus of *Introduction to Discrete Mathematics*. Board also recommended implementing the proposed revision by V Semester Examination, **December, 2019**.

(f) In B.A./B.Sc. (Mathematics) VI Semester, revision in the syllabus and recommended books of *Introduction to Numerical Analysis* (Course Code: MATH 303) was proposed. Board discussed the revision and found that proposed syllabus is more elaborated and well arranged with the inclusion of some topics. It will help student to find the flow of study and understand the topics in the syllabus. Board agreed upon the revised syllabus and also recommended implementing the proposed revision in the syllabus of *Introduction to Numerical Analysis* by VI Semester Examination, **April/May, 2020**.

Programme specific outcomes and the list of disciplinary courses of the B.A./B.Sc. (Mathematics) and B.A. (Applied Statistics as a discipline) programmes are attached and marked as **Annexure-I.**
The revised syllabus, learning outcomes and e-learning material of the B.A./B.Sc. (Mathematics) and B.A. (Applied Statistics as a discipline) programmes are attached and marked as **Annexure-II.**

3 II. B.Tech. (BT/CE/CS/IT/ECE/EEE/EIE/MCTR) Examination:

i.	First Semester Examination, December, 2019	No Change
ii.	Second Semester Examination, April/May, 2020	No Change
iii.	Third Semester Examination, December, 2020	Change[a]
iv.	Fourth Semester Examination, April/May, 2021	Change[a]
v.	Fifth Semester Examination, December, 2021	Change[b,c]
vi.	Sixth Semester Examination, April/May, 2022	Change[c]
vii.	Seventh Semester Examination, December, 2022	No Change
viii.	Eighth Semester Examination, April/May, 2023	No Change

(a) The Board discussed the various course running in B.Tech. Programme of Vidyapith by the department. Board recommended a tutorial in every course. Board suggested to revise the L-T-P-C of course *Differential Equation* (Course Code: MATH 208) from 4-0-0-4 to 3-1-0-4 and Complex Variables (Course Code: MATH 207) from 3-0-0-3 to 3-1-0-4. Board recommended implementing the proposed revision by **Session 2019-2020**.

(b) As discussed in 3.I (d), in B.Tech. (CS)V Semester, board recommended implementing the revised syllabus of "*Introduction to Discrete Mathematics*" by V Semester Examination, **December, 2019**.

(c) Syllabus of "Probability and Statistical Methods" and "Numerical Methods" in B.Tech. third year were proposed. Both the papers have L-T-P-C 3-1-0-4.Board discussed the syllabus and agreed upon implementing new syllabi from **session 2019-2020**.

(d) TheBoard reviewed all the syllabi of Mathematics and Statistics courses running in B. Tech. programme in respect of learning outcomes and suggested readings.

Learning outcomes, proposed revised/ new syllabi, suggested books and suggested e-learning material of the B.Tech. (BT/CE/CS/IT/ECE/EEE/EIE/MCTR)courses is attached and marked as**Annexure-III.**

3 III. M.Sc. (Mathematical Science) Examination:

The Board discussedthe recent trends in mathematical science education at postgraduate level and found that the knowledge of computational software is the necessity of today's research environment. In addition to this, more weightageshould be given to self-learning and independent research activities.In the light of the above-mentioned suggestions, the board proposed revisions in the scheme of M.Sc. (Mathematical Science) with specialization in pure mathematics/statistics/operations research/theoretical computer science.

3 IIIA M.Sc. (Mathematical Science – Pure Mathematics) Examination

i.	First Semester Examination, December, 2019	Revised
ii.	Second Semester Examination, April/May, 2020	Revised
iii.	Third Semester Examination, December, 2020	Revised
iv.	Fourth Semester Examination, April/May, 2021	Revised

(a) TheBoard reviewed the syllabi of *Numerical Analysis* (Course Code: MATH 409) and *Numerical Analysis Lab* (Course Code: MATH 409L), it was found that students had already studied an introductory course on numerical analysis in their graduation. It was suggested to introduce advanced techniques in numerical analysis at post graduate level while covering the essential basics. Board recommended implementing the proposed revision in syllabus of *Numerical Analysis*by II Semester Examination, **April/May, 2020**.

(b) TheBoard had detailed discussion on the *Term Paper* (MATH 528P). To improve the quality of Term Paper and to inculcate best practices in the students, formal guidelines were proposed including the evaluation scheme. The proposed guidelines are given in **Annexure-IV**. Board also recommended implementing the proposed guidelines by III Semester Examination, **December, 2019**.

(c) TheBoard also has proposed new electives in the curricula as follows:

- Coding Theory (New Course)
- Fixed Point Theory (New Course)
- Introduction to Dynamical System (New Course)

- Bio Mathematics (New Course)
- Algebraic Topology (New Course)
- Combinatorial Optimization (New Course)
- Transportation System Analysis (New Course)
- Integral Transform and Special Functions (New Course)
- Fields and Galois Theory (New Course)

Board recommended implementing the new electives by **Session 2020-2021**.

(d) TheBoard proposed to omit Rings and Modules (MATH 524) from the list of electives of pure mathematics. Board recommended implementing the change by**Session 2020-2021**.

(e) TheBoard has proposed following new reading electives in the curricula:

- Network Biology (New Course)
- Fractional Calculus (New Course)
- Quantum Graphs (New Course)
- Point set topology (New Course)
- Operational Research Applications (New Course)

Board recommended implementing the reading electives by **Session 2020-2021**.

(f) To ensure the quality of Dissertation, formal guidelines are given in **Annexure-IV**

3 IIIB M.Sc. (Mathematical Science – Statistics) Examination

i.	First Semester Examination, December, 2019	Revised
ii.	Second Semester Examination, April/May, 2020	Revised
iii.	Third Semester Examination, December, 2020	Revised
iv.	Fourth Semester Examination, April/May, 2021	Revised

(a) TheBoard reviewed the syllabi of *Numerical Analysis* (Course Code: MATH 409) and *Numerical Analysis Lab* (Course Code: MATH 409L), it was found that students had already studied an introductory course on numerical analysis in their graduation. It was suggested to introduce advanced techniques in numerical analysis at post graduate level while covering the essential basics. Board recommended implementing the proposed revision in syllabus of *Numerical Analysis* by II Semester Examination, **April/May, 2020**.

(b) TheBoard had detailed discussion on the *Seminar* (Course Code: STAT 514S). To improve the quality of *Seminar* and to inculcate best practices in the students, a formal guideline was proposed including the evaluation scheme. The proposed guidelines are attached and marked as **Annexure-IV**. Board

also recommended implementing the proposed guideline by III Semester Examination, **December, 2019**.

(c) TheBoard reviewed the process of *Project* (Course Code: STAT 512P) and recommended formal guidelines for it. The proposed guidelines with evaluation scheme are attached and marked as **Annexure-IV**. Board also recommended implementing the proposed guidelines by IV Semester Examination, **April/May, 2020**.

(d) TheBoard reviewed the list of electives and found that the title of *Econometrics Models* (Course Code: MATH 510) should be replaced by *Econometric Model*s. Board also suggested that some more models should be added. Board recommended implementing the proposed revision in syllabus of *Econometric Model*s by**Session 2019-2020**.

(e) TheBoard also has proposed some new electivesin the curricula as follows:

- Stochastic Models (New Course)
- Demography (New Course)
- Actuarial Statistics (New Course)
- Survival Analysis (New Course)
- Reliability and Renewal Theory (New Course)
- Operations Research (New Course)

Board recommended implementing the new electives by **Session 2020-2021**.

(f) TheBoard proposed following new reading electives in the curricula:

- Step-Stress Modelling (New Course)
- Categorical Data Analysis (New Course)
- Official Statistics (New Course)
- Robust Estimation in Non-Linear Models (New Course)
- Operational Research Applications (New Course)

Board recommended implementing the reading electives by **Session 2020-2021**.

3 III M.Sc. (Mathematical Science – Operations Research) Examination

i.	First Semester Examination, December, 2019	Revised
ii.	Second Semester Examination, April/May, 2020	Revised
iii.	Third Semester Examination, December, 2020	Revised
iv.	Fourth Semester Examination, April/May, 2021	Revised

(a) TheBoard reviewed the syllabi of *Numerical Analysis* (Course Code: MATH 409) and *Numerical Analysis Lab* (Course Code: MATH 409L), it was found that students had already studied an introductory course on numerical analysis in

their graduation. It was suggested to introduce advanced techniques in numerical analysis at post graduate level while covering the essential basics. Board recommended implementing the proposed revision in syllabus of *Numerical Analysis* by II Semester Examination, **April/May, 2020**.

(b) TheBoard suggested that similar guidelines as suggested for *Seminar* (Course Code: STAT 514S), should be followed for Seminar (Course Code: MATH 525S). Board also recommended implementing the proposed guidelines by III Semester Examination, **December, 2019**.

(c) TheBoard suggested that similar guidelines as suggestedfor *Project* (STAT 512P), should be followed for Project (Course Code: MATH 520P). Board also recommended implementing the proposed guidelines by IV Semester Examination, **April/May, 2020**.

(d) TheBoard also has proposed some electives in the curricula as follows:

- Combinatorial Optimization
- Transportation System Analysis (New Course)
- Stochastic Models (New Course)
- Fuzzy logic and Belief Theory
- Partial Differential Equations (New Course)

Board recommended implementing the new electives by the**Session 2020-2021**.

(e) TheBoard has proposed following reading electives in the curricula:

- Selected Applications of Stochastic Models
- Operational Research Applications
- Step-Stress Modelling
- Categorical Data Analysis

Board recommended implementing the reading electives by **Session 2020-2021**.

3 III D M.Sc. (Mathematical Science – Theoretical Computer Science) Examination

i.	First Semester Examination, December, 2019	Revised
ii.	Second Semester Examination, April/May, 2020	Revised
iii.	Third Semester Examination, December, 2020	Revised
iv.	Fourth Semester Examination, April/May, 2021	Revised

(a) Board reviewed the syllabi of *Numerical Analysis* (Course Code: MATH 409) and *Numerical Analysis Lab* (Course Code: MATH 409L), it was found that students had already studied an introductory course on numerical analysis in their graduation. It was suggested to introduce advanced techniques in

numerical analysis at post graduate level while covering the essential basics. Board recommended implementing the proposed revision in syllabus of *Numerical Analysis* by II Semester Examination, **April/May, 2020**.

(b) Board has proposed following reading electives in the curricula:

- Operational Research Applications (New Course)
- Categorical Data Analysis (New Course)
- Network Biology (New Course)
- Fractional Calculus
- Quantum Graphs

The Board also recommended implementing the reading electives by **Session 2020-2021**.

(c) To bring uniformity in the credits of elective courses, Board suggested to remove following electives form the list of electives of M.A./M.Sc. (Mathematical Sciences – Theoretical Computer Science)

Web Development and .Net Framework
Web Development and .Net Framework Lab
Advanced communication Networks
Advanced communication Networks Lab
Data Communication and Networking
Data Communication and Networking Lab

The Board also recommended implementing the suggestion by **Session 2019-2020**.

Programmeeducational objectives and outcomes and the scheme of M.A./M.Sc. (Mathematical Sciences) programmeare attached and marked as **Annexure-V**

The revised syllabus, learning outcomes and e-learning material of the M.A./M.Sc. (Mathematical Sciences) programme is attached and marked as **Annexure-VI.**

3 IV. M. Phil. (Mathematical Science)Examination

Board discussed the curriculum structure of M. Phil. (Mathematical Science) and advised to restructure the programme in the light of one-year duration.

3 V. Certificate Examinations:

(a) The board suggested minor changes in the syllabus of *Certificate Course in Statistical Techniques and Applications*. Board recommended implementing the revised syllabus by **Examination, 2020**.

(b) Board discussed the syllabus of *Certificate Course in Actuarial Sciences*and suggested few changes. The revised syllabus is attached and marked as**Annexure-VII.** Board recommended implementing the revised syllabus by **April,2020**.

3 VI. Diploma Examinations:

The board suggested minor changes in the syllabus of *Diploma Course in Actuarial Sciences*. The revised syllabus is attached and marked as **Annexure-VII.** Board recommended implementing the revised syllabus by **Examination, 2020**.

4. Board reviewed the curriculum for the courses running in the other programsof the Vidyapith. Following suggestions were given

Bachelor of Business Administration		
MATH 306	Mathematics for Management	No Change
STAT 108	Statistics for Management	No Change
STAT 108L	Statistics for Management Lab	No Change
Bachelor of Commerce		
MATH 109	Mathematics for Business Applications	No Change
STAT 201	Business Statistics	No Change
STAT 201L	Business Statistics Lab	No Change
Bachelor of Computer Applications		
MATH 108	Mathematics -I	No Change
MATH 204	Mathematics -II	No Change
MATH 302	Introduction to Discrete Mathematics	No Change
MATH 308	Quantitative Techniques (Math)	No Change
Bachelor of Pharmacy		
MATH 110	Remedial Mathematics	No Change
Bachelor of Science (Aviation Science)		
MATH 102	Basic Mathematics	No Change
Master of Computer Applications		
MATH 302	Introduction to Discrete Mathematics	Change [a]
Master of Science (Bioinformatics)		
MATH 406	Introductory Mathematics	No Change
STAT 405	Statistical Techniques	No Change
STAT 405L	Statistical Techniques Lab	No Change
Master of Science (Chemistry)		
MATH 407	Mathematics for Chemists	No Change
Master of Technology (Biotechnology)		

MATH 506	Engineering Mathematics	No Change

(a) As discussed in 3.I (c), forM.C.A.II Semester, board recommended implementing the revised syllabus of "*Introduction to Discrete Mathematics*" by II Semester Examination, **April/May, 2019**.

(b) Board reviewed all the syllabi of Mathematics and Statistics courses running in other programmesof the Vidyapithin respect of learning outcomes and suggested readings. Course outcomes, suggested books and suggested e-learning material of remaining coursesis attached and marked as**Annexure-VIII.**

5. Board reviewed the reports received from the examiners of different examinations of 2017 and 2018. All the reports were found to be satisfactory except three. The analysis of the reports received is enclosed in **Annexure–IX.**

6. The board evaluated the semester examination papers and found that most of them were analytic, descriptive and application based depending on the nature of course. The analysis of question papers is enclosed in **Annexure–X.**

7. The Board suggested starting two new P. G. programmes in Mathematics & Statistics along with M.Sc. (Mathematical Sciences) for the students who have interest in conventional degrees like M.Sc.(Mathematics) and M.Sc.(Statistics). The proposed schemes and courses are attached and marked as **Annexure-V** and **Annexure VI,** respectively.

8. Board suggested seeing the feasibility of beginning a certificate course on Data Science with linkage to industry which will have direct bearing on employability.

9. Board also suggested starting internship program of two months for statistics students at post graduate level to give them exposure of field surveys.

Meeting ended with vote of thanks.

AnnexureI

Name of Programmes:B.Sc (Mathematics)

Programme Educational Objectives:

Banasthali's education ideology is to nurture women leaders in all walks of life with strong value base. At the undergraduate level, Vidyapith promotes the development of a balanced and harmonious personality of the students through it's 'Panchmukhi Shiksha'. Panchmukhi Shiksha attempts a balance of the five aspects of education, namely Physical, Practical, Aesthetic, Moral and Intellectual. The educational objective of the B.Sc. (Mathematics)programme is to provide high quality education in mathematics, statistics, physics, electronics and computer science in order to prepare students for professional careers or higher education in science and related fields.

The main objectives of the B.Sc. programme are:

- To develop an understanding of mathematics and related areas opt by them.
- To develop an ability to identify, formulate, analyze and solve scientific problems.
- To develop a capacity to integrate knowledge from more than one subject and to apply appropriates mathematical principles to arrive at correct and effective solutions.
- To develop communication skills which enables them to effective multidisciplinary teamwork
- To develop their skillswhich will enable them to become a multi facet personality shining in any chosen field.

ProgrammeOutcomes: B.Sc. (Mathematics)

PO1: Knowledge Domain: Demonstrate an understanding of the basic concepts in mathematics, statistics, physics, electronics and computer scienceand their importance in the solution of some real-world problems.

PO2: Technical Skills: Understand tools of appropriate laboratory and perform experiments that support the development of scientific theory.

PO3: Ethics: Applyknowledge and moral principles by using a systematic approach of rational arguments.Understand the responsibility and the way our perception of right and wrong can play a part in politics and society.

PO4: Communication: Effectively communicate information by speaking, writing, or using some other mediumwith their peer and society at large, such as, being able to comprehend and write effective reports and make effective presentations.

PO5: Life- long learning: Demonstrate the ability to read and learn on their own that encourage the continuingdevelopment of knowledge and skills throughout their lives.

AnnexureI

Programme Specific Outcomes (Applied Statistics)

PSO1: Understand the basic concepts of sequence, series, sets, calculus, matrix theory, probability, inference, sample surveys and design of experiments and their applications.

PSO2: Interpret statistical summaries such as formulas, functions, graphs, tables, and schematics, drawing conclusions and making inferences based on the summaries.

PSO3: Develop an understanding of importance of statistical methods and techniques.

PSO4: Learn statistical software as exploratory, visualization, and computational tools.

Programme Specific Outcomes (Mathematics)

PSO1: Understand the basic concepts of calculus, geometry, analysis, algebra and their applications. Solve arithmetic, algebraic, geometric expressions, equations, functions and problems using appropriate methods.

PSO2: Analyse the relationships among structures in mathematics (e.g. sets, functions, groups, rings, vector spaces) and their importance within and outside the discipline.

PSO3: Develop an understanding of importance of axioms, proofs and theorems.

PSO4: Recognize and appreciate the connections between theory and applications.

Programme Specific Outcomes (Statistics)

PSO1: Understand the basic concepts of probability theory, inference, sample surveys and design of experiments and their applications.

PSO2: Interpret statistical summaries such as formulas, functions, graphs, tables, and schematics, drawing conclusions and making inferences based on the summaries.

PSO3: Develop an understanding of importance of statistical methods and techniques.

PSO4: Learn statistical software as exploratory, visualization, and computational tools.

AnnexureI

Programme Scheme: B.A./B.Sc. (Mathematics) /B.A-B.Ed./B.Sc.-B.Ed.

Semester – I

Applied Statistics

Existing

Course Code	Course Name	L	T	P	C
MATH 102	Basic Mathematics	4	0	0	4
STAT 101	Basic Statistics	4	0	0	4

Proposed

Course Code	Course Name	L	T	P	C
MATH 102	Basic Mathematics	4	0	0	4
STAT 101	Basic Statistics	4	0	0	4

Mathematics

Existing

Course Code	Course Name	L	T	P	C
MATH 106	Introduction to Calculus	4	0	0	4
STAT 104	Introduction to Probability and Statistics	4	0	0	4

Proposed

Course Code	Course Name	L	T	P	C
MATH 106	Introduction to Calculus	4	0	0	4
STAT 104	Introduction to Probability and Statistics	4	0	0	4

Statistics

Existing

Course Code	Course Name	L	T	P	C
STAT 106	Probability and Descriptive Statistics	6	0	0	6
STAT 106L	Probability and Descriptive Statistics Lab	0	0	4	2

Proposed

Course Code	Course Name	L	T	P	C
STAT 106	Probability and Descriptive Statistics	6	0	4	8

Semester – II

Applied Statistics

Existing

Course Code	Course Name	L	T	P	C
STAT 107	Statistical Methods	6	0	0	6
STAT 107L	Statistical Methods Lab	0	0	4	2

Proposed

Course Code	Course Name	L	T	P	C
STAT 107	Statistical Methods	6	0	4	8

Mathematics

Existing

Course Code	Course Name	L	T	P	C
MATH 101	Analytic Solid Geometry	4	0	0	4

Proposed

Course Code	Course Name	L	T	P	C
MATH 101	Analytic Solid Geometry	4	0	0	4

STAT 104	Differential Equations	4	0	0	4

STAT 104	Differential Equations	4	0	0	4

Statistics

Existing

Course Code	Course Name	L	T	P	C
STAT 105	Measures of Association and Probability Distributions	6	0	0	6
STAT 105L	Measures of Association and Probability Distributions Lab	0	0	4	2

Proposed

Course Code	Course Name	L	T	P	C
STAT 105	Measures of Association and Probability Distributions	6	0	4	8

Semester – III

Applied Statistics

Existing

Course Code	Course Name	L	T	P	C
STAT 205	Probability Distributions and Numerical Analysis	6	0	0	6
STAT 205L	Probability Distributions and Numerical Analysis Lab	0	0	4	2

Proposed

Course Code	Course Name	L	T	P	C
STAT 205	Probability Distributions and Numerical Analysis	6	0	4	8

Mathematics

Existing

Course Code	Course Name	L	T	P	C
MATH 201	Abstract Algebra	4	0	0	4
MATH 206	Real Analysis	4	0	0	4

Proposed

Course Code	Course Name	L	T	P	C
MATH 201	Abstract Algebra	4	0	0	4
MATH 206	Real Analysis	4	0	0	4

Statistics

Existing

Course Code	Course Name	L	T	P	C
STAT 203	Numerical Analysis & Sampling Distribution	6	0	0	6
STAT 203L	Numerical Analysis & Sampling Distribution Lab	0	0	4	2

Proposed

Course Code	Course Name	L	T	P	C
	Sampling Distributions	6	0	4	8

Semester – IV

Applied Statistics

Existing

Course Code	Course Name	L	T	P	C
STAT 202	Inferential Statistics and Quality Control	6	0	0	6
STAT	Inferential Statistics	0	0	4	2

Proposed

Course Code	Course Name	L	T	P	C
STAT 202	Inferential Statistics and Quality Control	6	0	4	8

202L	and Quality Control Lab				

Mathematics

Existing

Course Code	Course Name	L	T	P	C
MATH 202	Introduction to Linear Algebra	4	0	0	4
MATH 203	Introduction to Mechanics	4	0	0	4

Proposed

Course Code	Course Name	L	T	P	C
MATH 202	Introduction to Linear Algebra	4	0	0	4
MATH 301	Complex Analysis	4	0	0	4

Statistics

Existing

Course Code	Course Name	L	T	P	C
STAT 207	Statistical Inference and Quality Control	6	0	0	6
STAT 207L	Statistical Inference and Quality Control Lab	0	0	4	2

Proposed

Course Code	Course Name	L	T	P	C
STAT 207	Statistical Inference and Quality Control	6	0	4	8

Semester – V

Applied Statistics

Existing

Course Code	Course Name	L	T	P	C
STAT 302	Sampling Techniques and Design of Experiments	6	0	0	6
STAT 302L	Sampling Techniques and Design of Experiments Lab	0	0	4	2

Proposed

Course Code	Course Name	L	T	P	C
	Discipline Elective I	6	0	4	8

Mathematics

Existing

Course Code	Course Name	L	T	P	C
MATH 302	Introduction to Discrete Mathematics	4	0	0	4
MATH 304	Linear Programing & Its Applications	4	0	0	4

Proposed

Course Code	Course Name	L	T	P	C
MATH 302	Introduction to Discrete Mathematics	4	0	0	4
	Discipline Elective I	4	0	0	4

Statistics

Existing

Course Code	Course Name	L	T	P	C
STAT 302	Sampling Techniques and Design of Experiments	6	0	0	6
STAT 302L	Sampling Techniques and Design of Experiments Lab	0	0	4	2

Proposed

Course Code	Course Name	L	T	P	C
	Discipline Elective I	6	0	4	8

AnnexureI

Semester – VI

Applied Statistics

Existing

Course Code	Course Name	L	T	P	C
STAT 301	Applied Statistics	6	0	0	6
STAT 301L	Applied Statistics Lab	0	0	4	2

Proposed

Course Code	Course Name	L	T	P	C
	Discipline Elective II	6	0	4	8

Mathematics

Existing

Course Code	Course Name	L	T	P	C
MATH 301	Complex Analysis	4	0	0	4
MATH 303	Introduction to Numerical Analysis	4	0	0	4

Proposed

Course Code	Course Name	L	T	P	C
MATH 303	Introduction to Numerical Analysis	4	0	0	4
	Discipline Elective II	4	0	0	4

Statistics

Existing

Course Code	Course Name	L	T	P	C
STAT 301	Applied Statistics	6	0	0	6
STAT 301L	Applied Statistics Lab	0	0	4	2

Proposed

Course Code	Course Name	L	T	P	C
	Discipline Elective II	6	0	4	8

List of Discipline Electives

Applied Statistics

Course Code	Course Name	L	T	P	C
STAT 302	Sampling Techniques and Design of Experiments	6	0	4	8
STAT 301	Applied Statistics	6	0	4	8
	Financial Statistics (New Course)	6	0	4	8
	Health Statistics & Population Dynamics (New Course)	6	0	4	8

Mathematics

Course Code	Course Name	L	T	P	C
MATH 203	Introduction to Mechanics	4	0	0	4
MATH 304	Linear Programing & Its Applications	4	0	0	4
	Vector Calculus (New Course)	4	0	0	4
	Number Theory (New Course)	4	0	0	4

AnnexureI

Statistics

Course Code	Course Name	L	T	P	C
STAT 302	Sampling Techniques and Design of Experiments	6	0	4	8
STAT 301	Applied Statistics	6	0	4	8
	Financial Statistics (New Course)	6	0	4	8
	Health Statistics & Population Dynamics (New Course)	6	0	4	8

Student can opt for at most 2 additional Open (Generic) audit/credit Electives from any discipline opting at most 1 per semester from Semesters III onwards with prior permission of respective heads and time table permitting.

CourseDetails: (SeeannexureII)

Annexure II

Name of Programmes: B.A./B.A.-B.Ed./B.Sc.(Mathematics)/B.Sc.-B.Ed.

Course Details:

FIRST SEMESTER

Subject: Applied Statistics

S.N.	Course List	Learning Outcomes	Existing Syllabus	Suggested Syllabus	Remark
1.	MATH 102 Basic Mathematics	On successful completion of the course, students will be able to, • Understand the basic rules of logic, including the role of axioms or assumptions. • Appreciate the role of mathematical proof in formal deductive reasoning. • Distinguish a coherent argument from a fallacious one, both in mathematical reasoning and in everyday life. • Understand the differences between inductive and deductive reasoning. • Proficiently construct logical arguments and rigorous proofs. • Formulate and solve abstract mathematical problems.	-	**Suggested E-learning material** 1. Matrix https://www.askiitians.com/iit-jee-algebra/matrices-and-determinants. 2. Sequence and Series ncert.nic.in/ncerts/l/keep209.pdf 3. Set, Function, Relation ncert.nic.in/ncerts/l/keep201.pdf 4. *LPP* https://www.analyticsvidhya.com/.../lintroductory-guide-on-linear-programming-explain	No change in the syllabus
2.	STAT 101 Basic Statistics	On successful completion of the course, students will be able to, • Distinguish between qualitative variables and quantitative variables. • Differentiate between discrete and	-	**Suggested E-learning material** 1. Probability and its concept- https://ocw.mit.edu/courses/mathematics/18-05-introduction-to-probability-and-statistics-spring-2014/	No change in the syllabus

		continuous variables. • Construct/draft questionnaire. • Identify the need of Classification and Tabulation. • Construct frequency tables, interprets the data, and identifies the importance of diagrammatic presentation of data. • Explain and evaluate various measures of central tendency. • Evaluate and interpret partition values – Quartiles, Deciles and Percentiles		2. Elementary Statistics - https://newonlinecourses.science.psu.edu/statprogram/stat200 3. Probability and Statistics- https://nptel.ac.in/courses/111105041/ 4. Permutation and Combination- https://nptel.ac.in/courses/106106094/28 5. Matrices- https://nptel.ac.in/courses/122104018/	

Subject: Mathematics

S.N.	Course List	Learning Outcomes	Existing Syllabus	Suggested Syllabus	Remark
1.	MATH 106 Introduction to Calculus	On completion of the course, students will be able to, • Apply the concept and principles of differential and integral calculus to solve geometric and physical problems. • Evaluate various limit problems both algebraically and graphically. • Differentiate and integrate the functions which are applicable in real life situations. • Interpret the geometric meaning of differential and integral calculus. • Apply differentiation to find linear approximation,extrema, monotonicity,and concavity of functions.	-	**Suggested E-learning material:** 1. Single Variable Calculus https://ocw.mit.edu/courses/mathematics/18-01sc-single-variable-calculus-fall-2010/ 2. Differentiation of two variables https://nptel.ac.in/courses/111104085/21 3. Multiple Integral https://nptel.ac.in/courses/111104085/29	No change in the syllabus

2.	STAT 104 Introductiont oProbability & Statistics	On completion of the course, students will be able to, • Compute numerical quantities that measure the central tendency and dispersion of a set of data. • Understand basic probability axioms and rules and the moments of discrete and continuous random variables as well as be familiar with common named discrete and continuous random variables. • Apply general properties of the expectation and variance operators. • Understand the properties and fitting of the Normal, Binomial and Poisson distribution. • Fit the straight line, second degree parabola and curves of type: ab^x and ax^b • Understand the concept of Correlation (Karl Pearson) and Linear Regression.	-	**Suggested E-learning material:** 1. Probability and Mathematical Statistics; Platform: http://www.math.louisville.edu/~pksaho01/teaching/Math662TB-09S.pdf	No change in the syllabus

Subject: Statistics

S.N.	Course List	Learning Outcomes	Existing Syllabus	Suggested Syllabus	Remark
1.	STAT 106 Probability and Descriptive Statistics	On completion of the course, students will be able to, • Understand and differentiate between population and sample, variables and attributes in any survey. • Represent the data using suitable tabular and/or graphical method. • Identify and calculate appropriate summary statistics for the data.	-	**Suggested E-learning material:** 1. Video lectures on Probability and Statistics: https://nptel.ac.in/courses/111105090/ 2. Video lectures on Introduction to Data Analytics: https://nptel.ac.in/courses/110106072/	No change in the syllabus

		• Understand the concept of probability, probability mass and density functions. • Define a random variable and obtain its properties.			
2.	STAT 106L Probability and Descriptive Statistics Lab	On completion of the course, students will be able to, • Express raw data in terms of frequency table by using exclusive and inclusive method of classification for continuous/discrete variable. • Apply and justify the use of, various graphical representations such as Histogram, Frequency polygon etc. • Interpret and analyze the data using various averages such as arithmetic Mean, Median and Mode. • Compare different data sets using methods such as standard deviation, mean deviation, quartile deviation and coefficient of variation. • Employ and interpret the measures of Skewness and Kurtosis.	-	-	No change in the syllabus

Annexure II

SECOND SEMESTER

Subject: Applied Statistics

S.N.	Course List	Learning Outcomes	Existing Syllabus	Suggested Syllabus	Remark
1.	STAT 107 Statistical Methods	On successful completion of the course, students will be able to, • Explain the purpose of measures of dispersion, and the information they convey. • Select an appropriate measure of dispersion and correctly calculate and interpret the statistic. • Describe and explain the mathematical characteristics of the standard deviation. • Apply the definition of independence to attempt to determine whether an assumption of independence is justifiable in a given situation. • Find probabilities of single events, complementary events and the unions and intersections of collections of events. • Describe the main properties of probability distributions and random variables. • Identify the random variable(s) of interest in a given scenario.		**Suggested E-learning material** 1. Introduction to Probability and Statistics- https://ocw.mit.edu/courses/mathematics/18-05-introduction-to-probability-and-statistics-spring-2014/ 2. Elementary Statistics- https://newonlinecourses.science.psu.edu/statprogram/stat200 3. Probability and Statistics- https://nptel.ac.in/courses/111105041/	No change in the syllabus

2.	STAT 107L Statistical Methods Lab	On successful completion of the course, students will be able to, • Make the frequency distribution for inclusive and exclusive type of class intervals on excel. • Construct the table for given raw data. • Draw the graphs for the given data like histogram, frequency polygon, frequency curve and ogives. • Draw the diagrams like bar diagram and pie charts etc. • Calculate the measures of central tendency and dispersion on excel for given set of observations. • Fit the curves like straight line, parabola, exponential and power curve by using excel.	-	-	No change in the syllabus

Subject: Mathematics

S.N.	Course List	Learning Outcomes	Existing Syllabus	Suggested Syllabus	Remark
1.	MATH 101 Analytical Solid Geometry	On completion of this course, student will be able to, • Understand the basic applications of analytic and solid geometry. • Understand geometrical terminology for planes, tetrahedron, spheres, paraboloids, hyperboloids and ellipsoids. • Visualize and represent geometric figures and classify different geometric solids.	-	**Suggested E-learning material:** 1. Plane and solid Geometry: http://www.aproged.pt/biblioteca/planeandsolidgeometry.pdf 2. Solid Geometry introduction: http://altairuniversity.com/wp-content/uploads/2014/02/HM_SolidGeomintro.pdf 3. Math handbook of formulas, Process &Trics:	No change in the syllabus

				http://www.mathguy.us/Handbooks/GeometryHandbook.pdf	
2.	MATH 104 Differential Equations	On completion of this course the student will be able to: • Identify the type of a given differential equation and select and apply the appropriate analytical technique for finding the solution. • Student will be able to solve first order differential equations utilizing the standard techniques for separable, exact, linear, homogeneous, or Bernoulli cases. • Create and analyze mathematical models using first order differential equations to solve application problems. • Determine solutions to the linear and nonlinear ordinary differential equations of first and second order. • Determine the complete solution of a differential equation with constant coefficients by variation of parameters • Evaluate the Laplace and Inverse Laplace transform of functions of one variable	-	**Suggested E-learning material:** 1. Separable, homogeneous, exact, Linear differential equations, Laplace transformhttps://nptel.ac.in/courses/122104018/7 2. Open course in Differential Equations (All topics)https://nptel.ac.in/courses/111106100/ 3. Open course in Differential Equations (All topics)https://swayam.gov.in/course/3787-differential-equations 4. Second order linear differential equation with constant coefficient thttps://ocw.mit.edu/courses/mathematics/18-03sc-differential-equations-fall-2011/ 5. Laplace transformhttps://www.math.ust.hk/~machas/differential-equations.pdf	No change in the syllabus

Annexure II

Subject: Statistics

S.N.	Course List	Learning Outcomes	Existing Syllabus	Suggested Syllabus	Remark
1.	STAT 105 Measures of Association and Probability Distributions	On completion of the course, students will be able to, • Fit the linear regression equation for real data sets arising in various fields of the populations. • Understand the concept of multiple and partial correlation. • Apply selected probability distributions to solve problems • Understand how to check the independence of attributes. • Fit the Binomial, Poisson and Normal distribution for real life data.	-	**Suggested E-learning material:** 1. Probability and Random variables. MIT Open Course. https://ocw.mit.edu/courses/mathematics/18-440-probability-and-random-variables-spring-2014/lecture-notes/ 2. Probability and Statistics, NPTEL. https://nptel.ac.in/courses/111105041/27	No change in the syllabus
2.	STAT 105L Measures of Association and Probability Distributions Lab	On completion of the course, students will be able to, • Apply and use fitting of various curves such as Straight line, parabola, exponential curve etc. • Effectively distinguish between and compute, correlation and rank correlation, Partial and Multiple correlations. • Understand and perform the fitting of Binomial, Poisson and Normal distribution	-	-	No change in the syllabus

Annexure II

THIRD SEMESTER

Subject: Applied Statistics

S.N.	Course List	Learning Outcomes	Existing Syllabus	Suggested Syllabus	Remark
1.	STAT 205 Probability Distributions and Numerical Analysis	On successful completion of the course, students will be able to: • Understand the basic principles of Probability, sample space, conditional probability. • Differentiate between basic discrete & continuous distributions & how to work with them. • Understand cumulative distribution function, expectation and distributions for functions of random variables. • Work with bivariate distributions & basic two variable statistics. • Derive numerical methods for various mathematical operations and tasks, such as interpolation, differentiation, integration, the solution of linear and nonlinear equations, and the solution of differential equations and apply them to obtain approximate solutions to mathematical problems.	-	**Suggested E-learning material** 1. *Introduction to Numerical Analysis » Lecture notes.* https://ocw.mit.edu/courses/mathematics/18-330-introduction-to-numerical-analysis-spring-2004/lecture-notes/ 2. Probability and Random Variables https://ocw.mit.edu/courses/mathematics/18-440-probability-and-random-variables-spring-2014/ 3. Numerical Analysis- https://nptel.ac.in/courses/111107062/ 4. Probability - https://nptel.ac.in/courses/111104032/ 5. Probability distributions- https://nptel.ac.in/courses/111105041/8	No change in the syllabus
2.	STAT 205L Probability Distributions and Numerical Analysis Lab	On successful completion of the course, students will be able to: • Fit the probability distributions by using Excel. • Find out the missing values using interpolation • Get the approximate values of	-	-	No change in the syllabus

		differentiation and integration by using excel. • Obtain the solution of linear and nonlinear equations and the solution of differential equations and apply them to obtain approximate solutions to mathematical problems.			

Subject: Mathematics

S.N.	Course List	Learning Outcomes	Existing Syllabus	Suggested Syllabus	Remark
1.	MATH 201 Abstract Algebra	On completing the course, students are able to, • Demonstrate the mathematical maturity of understanding the proof. • Understand the definition of a group and be able to test a set with binary operation to determine if it is a group. • Find the order of elements of groups. • Identify subgroups of a given group, cycle groups, normal groups. • Understand permutation groups and be able to decompose permutations into 2-cycles. • Grasp the significance of the concepts of homomorphism, isomorphism, and automorphism and be able to check a given function is one of these.	**Unit 1** ~~***[Set, Relations, Functions and]***~~ Binary operations~~, [Binary operations in contrast to unary and ternary operations,]~~ Group: Definition, examples and simple properties of group and subgroup. **Unit 2** Permutation group, Cyclic group, Cosets, Lagrange's theorem. Homomorphism and Isomorphism of group, Cayley's theorem. **Unit 3** Normal subgroup and [~~***Quotient]***~~ group, Fundamental theorem of homomorphism of group (First, Second and third theorem of isomorphism). **Unit 4** Rings: Definition, and example, [~~***Residue classes ring, Special classes of ring,]***~~ Integral Domain, Division ring ~~***(ring,***~~ field~~***[), Simple properties of ring, Subring, Subfield],***~~Ring homomorphism and ring isomorphism. **Unit 5** Ideal, Principal ideal, Principal ideal [~~***ring, Quotient]***~~ ring, Prime ideal, Maximal ideal, ~~Euclidean ring and its properties, Polynomial~~	**Unit 1** Divisibility in Z, division algorithm, greatest common divisor, Euclidean Algorithm, modular arithmetic, Binary Operations, Group: Definition, examples and properties of group. **Unit 2** Subgroups, Cyclic groups, Permutation group, symmetric and alternating groups of degree n, external direct products of groups. **Unit 3** Cosets, Lagrange's theorem, Homomorphism and Isomorphism of group, Cayley's theorem, Normal subgroups and Factor groups. **Unit 4** Fundamental theorem of homomorphism of group (First, Second and third theorem of isomorphism). Rings: Definition and examples, Integral Domain, Division ring, fields **Unit 5** Ideal, Principal ideal, Principal ideal domain, Factor ring, Prime ideal, Maximal	1. Student learn the concepts of sets, relations and functions in the real analysis course. 2. To better understand the examples of

		• Classify groups up to isomorphism. • Identify a set with to binary operation forms a ring or not. • Understand the special types of rings and be able to construct new examples from the old ones. • Check a subset of a ring is an ideal or not and be able to identify proper and maximal ideal.	~~ring.~~ **Suggested Text Books:** **1.** V.K. Khanna and S.K. Bhambri, **A Course in Abstract Algebra:** Vikas Pub. House, New Delhi, 2nd rev. ed. 1998. **2.** A.R. Vashistha, **Modern Algebra:** Krishna Prakashan Mandir, Meerut, 2nd rev. ed., 1971. **Suggested Reference Book :** 1. I.N. Herstein, **Topics in Algebra:** Wiley Eastern, New Delhi, 2nd ed. 1975.	ideal, Ring homomorphism and ring isomorphism. **Text Books:** 1. Gallian, J. A. (2013). *Contemporary abstract algebra*. (8th Ed.). Boston, MA: Brooks/Cole Cengage Learning. **Reference Books:** 1. Dummit, D. S. & Foote, R. M. (2004) *Abstract algebra*(3rd Ed.). New Jersey: Wiley. 2. Hungerford, T. W. (2014) *Abstract algebra: An introduction* (3rd Ed.). Australia: Brooks/Cole Cengage Learning. 3. Hillman A. P. &Alexandersor, G. L. (2015) *Abstract algebra: A first undergraduate course*(5th Ed.). CBS Publishers & Distributors Pvt. Ltd. 4. Fraleigh, J. B. (2003) *A first course in abstract algebra* (7th Ed.). Harlow: Pearson. 5. Sen, M. K., Ghosh, S., Mukhopadhyay, P. &Maity, S. K. (2019) *Topics in abstract algebra* (3rd Ed.). University Press. 6. Herstein, I. N. (1991) *Topics in algebra* (2nd Ed.). New Delhi: Wiley Eastern. 7. Khanna, V.K. & Bhambri, S. K. (2008) *A course in abstract algebra*, (3rd Ed.). New Delhi: Vikas Pub. House.	groups such as Z_n, $U(n)$, $G\ (2,n)$, concepts of divisibility and modular arithmetic is important. 3. External direct product is needed to understand the classification of groups upto isomorphism. 4. Some

				Suggested E-learning material: 1. Lecture Notes: https://ocw.mit.edu/courses/mathematics/18-703-modern-algebra-spring-2013/related-resources/ 2. Video Lectures: https://www.extension.harvard.edu/open-learning-initiative/abstract-algebra	advanced topics such as Euclidean ring and polynomial rings are removed from Unit V.
2.	MATH 206 Real Analysis	On completion of the course, students will be able to, • Think about basic proof techniques and fundamental definitions related to the real number system. • Understand the concept of real-valued functions, limit, continuity, and differentiability. • Find expansions of real functions in series forms. • Demonstrate some of the fundamental theorems of analysis. • Develop the capacity to solve real integral while understanding of integrable	-	**Suggested E-learning material** 1. Real Analysis;NPTEL: https://nptel.ac.in/courses/111106053/	No change in the syllabus

		functions.			

Subject: Statistics

S.N.	Course List	Learning Outcomes	Existing Syllabus	Suggested Syllabus	Remark
1.	STAT (to be generated) Sampling Distributions	On completion of the course, students will be able to, • Understand the difference between probability distribution and sampling distribution. • Understand the sampling distribution of the mean of a sample from a Normal Population. • Understand the properties of the sampling distribution of the sample mean in general situations, using the Central Limit Theorem. • Understand the concepts of the t, F and x2 distributions. • Apply t, F and x2 tests on real life data.	-	**Unit 1** Limit laws: convergence in probability, almost sure convergence, convergence in mean square and convergence in distribution and their inter relations, Chebyshev's inequality, W.L.L.N., S.L.L.N. and their applications, De-Moivre Laplace theorem, Central Limit Theorem (C.L.T.) for i.i.d. variates, applications of C.L.T. and Liapunov Theorem (without proof). **Unit 2** Basic concept of Sampling and sampling distribution, sampling distribution of sample mean for Binomial, Poisson and Normal populations, standard errors of sample mean, sample variance and sample proportion. Null and alternative hypotheses, level of significance, Type I and Type II errors, their probabilities and critical region. Concept of p-values. **Unit 3** Large sample tests of significance: Sampling for attributes and variables, Tests of significance and confidence intervals for proportion, difference of	This paper is a replacement of the paper STAT 203 Numerical Analysis and Sampling Distribution.

				two proportions, single mean, difference of two means, standard deviation and difference of standard deviations. **Unit 4** Chi-square distribution with its moment generating function, moments and cumulant, Additive property of chi-square variates, Limiting case of chi-square distribution. Tests of significance and confidence intervals based on Chi- Square distribution. Yates Correction for 2x2 contingency table. **Unit 5** Students 't' and Fishers 't' statistics and their distributions Application of 't' test for one sample and two sample problems and for testing the significance of a sample, Correlation coefficient Paired 't' test, F-statistic and its distribution. Application of F-test for testing the equality of variance, Fisher's transformation and its uses. Relationship between 't' and 'F' statistics and F and Chi-square statistics **Note:** Use of scientific calculator is permissible. **Text Books:** 1. Hogg, R. V., & Tanis, E. (2009). *Probability and Statistical Inference.* Prentice Hall. 2. Goon, A. M., Gupta, B. D. & M. K.	

				Gupta.(1968). *Fundamental of Statistics.* (Vol. I).The World Press Pvt. Ltd. Kolkata. **Reference Books:** 1. Mood, A. M., Graybill, F. A., &Boes, D. C. (1974). *Introduction to Theory of Statistics*. McGraw- Hill International. 2. Gupta, S. C., & Kapoor, V. K. (2013). *Fundamental of Mathematical Statistics* (11thed.). New Delhi: Sultan Chand Publication. 3. Gupta, S.P. (2014). *Statistical Methods* (44th. ed.). Sultan Chand & Sons. 4. Freund, J. E. (2004). *Modern Elementary Statistics* (12th. ed.). New Jersey: Pearson Prentice Hall. **Suggested E-learning material** 1. Sampling distribution and central limit; Platform: Colorado State University https://www.stat.colostate.edu//~vollmer/stat307pdfs/LN5_2017.pdf	
2.	STAT (to be generated) Sampling Distributions Lab	On completion of the course, students will be able to, • Effectively compute and understand testing of significance and confidence intervals in various contexts such as, for single proportion, difference of two proportions for large sample, for single mean, difference of two means for large sample.		**List of Practicals** 1. Testing of significance and confidence intervals for single proportion and difference of two proportions for large sample. 2. Testing of significance and confidence intervals for single mean and difference of two means for large sample. 3. Testing of significance and confidence for mean and difference of means	This paper is a replacement of the paper STAT 203LNu

		• Proficiently test for goodness of fit, independence of attributes. • Understand how and when to use testing for equality of two population variances		(paired and unpaired cases) and for correlation coefficient 4. Testing of significance and confidence intervals for difference of two standard deviations. 5. Testing if the population variance has a specific value and its confidence intervals. 6. Testing of goodness of fit. 7. Testing of independence of attributes. 8. Testing based on 2 X 2 contingency table without and with Yates' corrections. 9. Testing of significance and confidence intervals of an observed sample correlation coefficient. 10. Testing and confidence intervals of equality of two population variances **Note:** (i) The above list is only for the guidance of the students. (ii) Whenever it is feasible, students should be asked to collect the required data themselves to use it in their practical. (iii) Where it is feasible practical practice should be done through spreadsheet, package or programming.	merical Analysis and Samplin g Distribu tion Lab.

Annexure II

FOURTH SEMESTER

Subject: Applied Statistics

S.N.	Course List	Learning Outcomes	Existing Syllabus	Suggested Syllabus	Remark
1.	STAT 202 Inferential Statistics and Quality Control	On successful completion of the course, students will be able to, • Define estimator, its unbiasedness and efficiency. • Obtain maximum likelihood estimates of parameters of some simple distributions. • Perform testing of significance of single mean, proportion, s. d. and difference of two means, proportions, s. d. and variances for small and large samples. • Understand the concept of non-parametric testing. • Apply the non-parametric methods to test for single population and two populations. • Understand the concept of statistical quality control. • Construct control charts for variables and attributes.	-	**Suggested E-learning material:** 1. Lecture notes and video on "Parameters, Statistics, and Sampling Error": http://www.statisticslectures.com/topics/parametersstatistics/ 2. Video lectures on Introduction to Data Analytics: https://nptel.ac.in/courses/110106064/ 3. Lecture notes and video on "Quality Control in Textile Industry": https://nptel.ac.in/courses/116102019/	No change in the syllabus
2.	STAT 202L Inferential Statistics and Quality Control Lab	On successful completion of the course, students will be able to, • Test the significance of single mean, proportion, s. d. and difference of two means, proportions, s. d. and variances for small and large samples. • Understand when and how to use various non-parametric tests such as Sign	-	-	No change

		test, Run test, Median test etc. for single population and two populations. • Plot various control charts for variables and attributes such as *X*, R, and s charts and determine whether the given procedure is in statistical control or out of statistical control.			

Subject: Mathematics

S.N.	Course List	Learning Outcomes	Existing Syllabus	Suggested Syllabus	Remark
1.	MATH 202 Introduction to Linear Algebra	After completing this course, students will be able to • Understand vector spaces over a field and subspaces and apply their properties. • Understand linear independence and dependence. • Find basis and dimension of a vector space, and understand change of basis. • Compute linear transformations, kernel and range, and inverse linear transformations, and find matrices of general linear transformations. • Find eigenvalues and eigenvectors of a matrix and of linear transformation. • Understand inner product on a vector space.	-	**Suggested E-learning Material:** 1. Video Lectures:https://www.edx.org/learn/linear-algebra 2. Video Lectures:https://ocw.mit.edu/courses/mathematics/18-06-linear-algebra-spring-2010/ 3. Video Lectures:https://onlinecourses.nptel.ac.in/noc17_ma04/preview	No change in the syllabus

		• Understand the concept of orthogonality in inner product spaces. • Create orthogonal and orthonormal bases: Gram-Schmidt process.			
2.	MATH 301 Complex Analysis	On completion of the course, students will be able to, • Demonstrate understanding of the basic concepts and fundamental definitions underlying complex analysis. • Investigate complex functions, concept of limit, continuity and differentiability of complex functions. • Demonstrate capacity for mathematical reasoning through analyzing analytic functions. • Prove and explain concepts of series and integration complex functions. • Understand problem-solving using complex analysis techniques. • Enjoy the roll of complex functions today's mathematics and applied contexts.	-	**Suggested E-learning material** 1. Complex Analysis; NPTEL https://nptel.ac.in/courses/111103070/	No change in the syllabus Shifted from VI Semester to IV Semester.

Subject: Statistics

S.N.	Course List	Learning Outcomes	Existing Syllabus	Suggested Syllabus	Remark
1.	STAT 207 Statistical Inference and	On completion of the course, students will be able to, • Apply various basic parametric, non-	-	**Suggested E-learning material** 1. Statistical Inference; Platform:	No change in the

Annexure II

	Quality Control	parametric and sequential estimation techniques and testing procedures to deal with real life problems. • Understand the concept of confidence interval in case of normal distribution, Neyman-Pearson fundamental lemma, UMP test. • Understand SPRT, OC and ASN function. • Understand the non-parametric techniques such as sign, median and run test.		MITOPENCOURSEWARE https://ocw.mit.edu/index.htm 2. Statistical Inference; Platform: Coursera https://www.coursera.org 3. Statistical Inference: Platform: e-PG Pathshalahttps://epgp.inflibnet.ac.in	syllabus
2.	STAT 207L Statistical Inference and Quality Control Lab	On completion of the course, students will be able to, • Understand when and how to use various control charts such as $\bar{X}$, R, and s charts. • Effectively understand and determine the AOQ and AOQL plots. • Understand when and how to use various non - parametric tests such as Sign test, Run test, Median test etc.	-	-	No change

Annexure II

FIFTH SEMESTER

Subject: Mathematics (Core Course)

S.N.	Course List	Learning Outcomes	Existing Syllabus	Suggested Syllabus	Remark
1.	MATH 302 Introduction to Discrete Mathematics	On completion of the course, students will be able to, • Write an argument using logical notation and determine if the argument is or is not valid. • Demonstrate the ability to write and evaluate a proof or outline the basic structure of and give examples of each proof technique described. • Understand the basic principles of sets and operations in sets. • Prove basic set equalities. • Apply counting principles to determine probabilities. • Demonstrate an understanding of relations and functions and be able to determine their properties. • Determine when a function is 1-1 and "onto". • Demonstrate different traversal methods for trees and graphs. • Model problems in Computer Science using graphs and trees.	**Unit 1** Sets and Multisets, Relations and Functions, Equivalence relations, Partial order relations, Chains and Antichains. Permutations, Combinations, selection with & without replacement, Permutation and Combinations of multisets. Discrete probability. The rules of sum and product. **Unit 2** Basic concepts of graph theory, Multi-graphs, weighted graphs, Paths & Circuits. Matrix representation of graphs, Eulerian path and circuits, Hamiltonian path and circuits. Shortest path in weighted graph, Planar graphs. **Unit 3** ~~*[K-connected and K-edge connected graphs. Chromatic number,]*~~ Edge coloring of graphs, Vizing's theorem. Trees and cut sets- Trees, Rooted tree, Path lengths in rooted trees, Spanning tree and cut set, Minimum spanning tree. **Unit 4** Pigeon hole principle, Inclusion-exclusion principle. Discrete numeric functions-manipulation of numeric functions. Asymptotic behavior of numeric functions. Generating functions and recurrence relations. Linear recurrence relation with constant coefficients and their solutions.	**Unit 1** Sets and Multisets, Relations and Functions, Equivalence relations, Partial order relations, Chains and Antichains. Permutations, Combinations, selection with & without replacement, Permutation and Combinations of multisets. Discrete probability. The rules of sum and product. **Unit 2** Basic concepts of graph theory, Multi-graphs, Paths & Circuits, Eulerian path and circuits, Hamiltonian path and circuits, weighted graphs, Shortest path in weighted graph, Planar graphs, Vertex connectivity and edge connectivity of graphs. **Unit 3** Vertex coloring and edge coloring of graphs, Vizing's theorem, Trees and cut sets- Trees, Rooted tree, Path lengths in rooted trees, Spanning tree and cut set, Minimum spanning tree, Matrix representation of graphs. **Unit 4** Pigeon hole principle, Inclusion-exclusion principle. Discrete numeric	Conventional terminologies necessary for the concerned unit are included.

			Unit 5 Lattices and Boolean algebra. Uniqueness of finite Boolean algebra. Boolean functions and Boolean expressions. Propositional Calculus. **Text Books :** **1.** C.L. Liu, **Elements of Discrete mathematics:** McGraw Hill, International editions, 2008. **2.** Narsingh Deo, **Graph Theory:** Prentice Hall of India, 2004. **Reference Books:** **1.** N.L. Biggs, **Discrete Mathematics:** Oxford Science Publication, 1985. **2.** Kenneth H. Rosen, **Discrete Mathematics and its Applications:** McGraw Hill, 1999. **3.** T. Koshy, **Discrete Mathematics with Applications:** Academic Press, 2005.	functions-manipulation of numeric functions. Asymptotic behavior of numeric functions. Generating functions and recurrence relations. Linear recurrence relation with constant coefficients and their solutions. **Unit 5** Mathematical logic: Basic Connectives, normal forms (CNF and DNF), proof of Validity, Predicate logic, Lattices and Boolean algebra. Uniqueness of finite Boolean algebra. Boolean functions and Boolean expressions. Propositional Calculus. **Text Books:** 1. Rosen, K.H. (1999). *Discrete mathematics and it's applications*. McGraw Hill. 2. Liu, C.L. & Mohapatra, D.P. (2008). *Elements of discrete mathematics*, Tata McGraw Hill. 3. Deo, N. (2004). *Graph theory*., New Delhi: Prentice Hall of India. **Reference Books:** 1. Biggs, N.L. (1985). *Discrete mathematics*. Oxford Science Publication. 2. Koshy, T. (2005). *Discrete mathematics with applications*. Academic Press. **Suggested E-learning material:** 1. Notes on Graph Theory: https://www.geeksforgeeks.org/engineering-mathematics-tutorials/	

Annexure II

SIXTH SEMESTER

Subject: Mathematics (Core Course)

S.N.	Course List	Learning Outcomes	Existing Syllabus	Suggested Syllabus	Remark
1.	MATH 303 Introduction to Numerical Analysis	On completion of the course, students will be able to, • Apply numerical methods to obtain approximate solutions to mathematical problems. • Solve the nonlinear equations, system of linear equations and interpolation problems using numerical methods. • Examine the appropriate numerical differentiation and integration methods to solve problems. • Apply the numerical methods to solve differential equations.	**Unit 1** Error- its sources, propagation and analysis, Numerical solution of system of linear equations, Direct methods-The matrix inversion method, Gauss elimination method, Gauss–Jordan method, Iterative methods: Gauss-Jacobi Method, Gauss Siedel method. **Unit 2** Differences, Relation between difference and derivatives, Differencesof polynomials, Newton's formula for forward and backward interpolation, Divided differences and simple differences, Newton's general interpolation formula, Lagrange's interpolation formula, Error in interpolation. **Unit 3** Numerical differentiation and numerical integration- Simpson's, Weddle's and Trapezoidal rules, Newton's Cotes Quadrature formula, Gauss Quadrature formula. **Unit 4** Root finding for nonlinear equations (Transcendental and Algebraic equations), Iterative method, Bisection method, Regula-Falsi method, Newton Raphson's method, order of convergence.	**Unit 1** **Error analysis:** Exact and approximate numbers, rounding of numbers, Significant digits, various types of errors encountered in computations, error in function approximation, the general error formula, Taylor's series, error in series approximation.**Numerical solution of system of linear equations:** Direct methods: The matrix inversion method, Gauss elimination method with pivoting strategies, Gauss–Jordan method, Factorization methods (LU- Doolittle, Crout, LDL^T, Cholesky), computing inverse of a matrix. Iterative methods: Gauss-Jacobi Method, Gauss-Siedel method. **Unit 2** **Finite differences:**forward, backward, central and divided difference operators, their properties and difference tables, propagation of error in difference table, missing data calculation, Relation between difference and derivatives, differences of polynomials. **Polynomial**	Subtopics of the existing topic, necessary for the efficient teaching, are elaborated in proposed syllabus. Factorization methods have been added as these are important to solve some matrix based problems.

			Unit 5 Numerical solution of first and second order differential equations, Euler's Method, Picard's Method, Taylor's series approximation, Runge-Kutta'sMethod . **Suggested Text Books:** 1. S.S. Sastri, **An Introductory Methods in Numerical Analysis:** P.H.I, New Delhi, 4th edition 2005. 2. ~~J.L. Bansal, J.P.N. Ojha, **Numerical Analysis:** JPH, Jaipur, 1991.~~ **Reference Books:** 1. ~~Kendall E. Atkinson, **An Introduction to Numerical Analysis:** John Wiley, New York, 2nd edition 2001.~~ 2. ~~P.K. De, **Computer Based Numerical Methods and Statistical Techniques:**CBS Publication, New Delhi, 1st edition 2006.~~	**interpolation:** Newton-Gregory forward and backward interpolation, Gauss's forward and backward, Stirling's, Bessel's interpolation, Lagrange's and Newton's divided differences interpolation, inverse interpolation, computation errors in these formulae and analysis of errors. **Unit 3** **Numerical differentiation, Numerical integration**: Newton's Cotes Quadrature formula, Simpson's, Weddle's and Trapezoidal rules, Gauss Quadrature formula. **Unit 4** **Root finding for nonlinear equations** (Transcendental and Algebraic equations), Iterative method, Bisection method, Regula-Falsi method, Newton Raphson's method, order of convergence. **Unit 5** **Numerical solution of first and second order differential equations**: Euler's Method, Picard's Method, Taylor's series approximation, Runge-Kutta's Method. **Text Books:** 1. Sastry, S.S. (2012). *Introductory methods of numerical analysis***.** New Delhi, ND**:** PHI Learning Private Limited.	

				2. Chauhan, D. S., Vyas, P., &Soni, V. (2005). Studies in numerical analysis. Jaipur, Jaipur Publishing House. **Reference Books:** 1. Jain, M. K., Iyengar, S. R. K., & Jain, R. K. (2007). Numerical methods for scientific and engineering computations. New Delhi, ND: New Age International. 2. Rajaraman, V. (1984). Computer oriented numerical methods. New Delhi, ND: Prentice Hall of India. 3. Phillips, G.M., & Taylor, P.J. (1996). Theory and applications of numerical analysis. Academic Press, Elsevier. 4. Burden, R.L., Faires, D.J., Burden, A.M. (2016). Numerical Analysis. Cengage learning. **Suggested E-learning material:** 1. Elementary Numerical Analysis; Platform: Nptelhttps://nptel.ac.in/courses/111101003/ 2. Numerical Differentiation and Numerical Integration; Platform: MIT open courseware https://ocw.mit.edu/courses/mechanical-engineering/2-993j-introduction-to-numerical-analysis-for-engineering-13-002j-spring-2005/lecture-notes/lect_9.pdf 3. Computational Error; Platform: Nptelhttps://nptel.ac.in/courses/111107062/	

Annexure II

Discipline Electives

Subject: Mathematics

S.N.	Course List	Learning Outcomes	Existing Syllabus	Suggested Syllabus	Remark
1.	MATH 203 Introduction to Mechanics	On completion of the course, students will be able to, • Explain the geometry of the motion of particle in plane curve, i.e. position, velocity, and acceleration, and how those quantities are related through calculus. • Learn Newton's laws of motion and examines their application to a wide variety of problems. • Learn the basic concept of composition and resolution of forces and friction. • Understand and visualize the real physical problem in terms of Mathematics. • Learn one-dimensional (SHM), multi-dimensional (Projectile motion), and constrained motion, motion of particle with or without connecting with string.	-	**Suggested E-learning material:** 1. Engineering Mechanics: Statics & Dynamics; Platform: cosmolearning, https://cosmolearning.org/courses/engineering-mechanics-statics-dynamics/ 2. Engineering Mechanics: Statics & Dynamics; Platform: nptel https://nptel.ac.in/courses/112106180/ 3. Engineering Dynamics; Platform: MIT Open courseware, https://ocw.mit.edu/courses/mechanical-engineering/2-003sc-engineering-dynamics-fall-2011/	No change in the syllabus
2.	MATH 304 Linear Programming & Its Applications	On completion of the course, students will be able to, • Formulate the LPP. • Conceptualize the feasible region.	-	**Suggested E-learning material** 1.Linear Programming, a CPLEX tutorialhttps://ibmdecisionoptimization.github.io/tutorials/html/Linear_Programming.	No change in the syllabus

		• Solve the LPP with two variables using graphical method. • Solve the LPP using simplex method. • Formulate the dual problem from primal. • Solve Transportation and Assignment problems • Solve the problems of competitive situations between two competitors.		html 2.Linear Programming Tutorial | Sophia Learning https://www.sophia.org/tutorials/linear-programming--5 3.Lectures – nptel: https://nptel.ac.in/courses/111102012/	
3.	MATH (code to be generated) Vector Calculus	On completion of the course, students will be able to, • Manipulate vectors to perform geometrical calculations in three dimensions. • Use Green's theorem and the Divergence theorem to compute integrals. Explain how Green's Theorem is a generalization of the Fundamental Theorem of Calculus. • Communicate Calculus and other mathematical ideas effectively in speech and in writing. • Recognize when it is appropriate to use a scalar and when to use a vector in problem solving.		**Unit I** Definition and examples of vector and scalar; Basic operations: addition, subtraction, multiplication and scalar product of vectors, geometric representation of vectors, magnitude and direction, dot product and cross product. **Unit II** Scalar and vector product of three vectors, product of four vectors, vector-valued function; Scalar-valued function, limit, Continuity, differentiability and Integration of vector-valued functions of one variable. **Unit III** Partial derivatives: chain rule, exact differentials, Del Applied to scalar valued Function (gradient), Del applied to vector point function (Divergence, Curl), Physical interpretation of divergence, Physical interpretation of curl, Irrotational and Solenoidal vector-valued function. **Unit IV** Directional derivative, tangent planes and	New Course

				normal lines, Tangential line integral, Circulation, Work, Independence of path, Conservative fields, Normal Surface integral, Flux across a surface. **Unit V** Vector fields, characterization of Irrotational and Solenoidal vector fields, Green's theorem in a plane, Gauss divergence theorem and Stoke's theorem, Simple applications. **TEXT / REFERENCE BOOKS** 1. Thomas, G.B., Weir, M.D., &Hass, J. (2011). *Thomas' Calculus*(11th edition). Pearson Education. 2. Grewal ,B.S., & Grewal, J.S. (2005).*Higher Engineering Mathematics*(37th edition).New Delhi: Khanna Publishers. 3. Davis, H. F., &Snider, A. D. (1998).*Introduction to Vector Analysis*(7th edition). William C Brown Publication. 4. Matthews, P. C. (1998).*Vector Calculus*.Springer-Verlag. **Suggested E-learning material** https://www.brightstorm.com/tag/scalar/	
4.	MATH (code to be generated) Number Theory	On completion of the course, students will be able to, • Understand the concept of divisibility and able to find greatest common divisor of large integers using Euclidean algorithm. • Appreciate the importance of prime		**Unit I** Integers, well-ordering principle, induction, Fibonacci numbers, divisibility, Greatest Common Divisor, least common multiple, Euclidean algorithm, prime numbers, distribution of primes, fundamental theorem of arithmetic.	New Course

		numbers and their distribution. • Solve linear congruences and system of linear congruences. • Know Euler's theorem, Fermat's theorem and Wilson's theorem. • Demonstrate the applications of number theory in cryptography.		**Unit II** Congruences, linear congruences, Chinese remainder theorem, congurences with prime power modulai. linear Diophantine equations. **Unit III** Arithmetic functions, Euler's Theorem, Fermat's little theorem, Wilson's theorem, primality testing and pseudoprimes and Carmichael numbers. **Unit IV** Group of units, Euler's function, primitive root, the group U_{p^e} and U_{2^e}. Mobius inversion formula, Quadratic residues, Legendre symbol, Gauss's lemma, quadratic reciprocity, **Unit V** Perfect numbers, Fermat and Mersenne prime. Applications of number theory in cryptography. **Text Books:** 1. Burton, D. M. (2012). *Elementary number theory*. McGraw-Hill Education (India). **Reference Books:** 1. Niven, I., Zuckerman, H. S., & Montgomery, H. L. (2013). *An introduction to the theory of numbers*. New York: Wiley. 2. Rosen, K. H. (2005). *Elementary number theory and its applications*. Boston: Pearson/Addison Wesley. **Suggested E-learning Material:** 1. Lecture Notes: NPTEL: https://nptel.ac.in/courses/111103020/	

				2. Lecture Notes: MIT OPEN COURSE WARE: https://ocw.mit.edu/courses/mathematics/18-781-theory-of-numbers-spring-2012/index.htm	

Subject: Statistics/Applied Statistics

S.N.	Course List	Learning Outcomes	Existing Syllabus	Suggested Syllabus	Remark
1.	STAT 302 Sampling Techniques and Design of Experiments	On completion of the course, students will be able to, • Understand the methods for designing and selecting a sample from a population. • Estimate finite population parameters e.g. totals and means, for some standard sampling schemes. • Analyze the results of a designed experiment in order to conduct the appropriate statistical analysis of the data. • Describe how the analysis of the data from the experiment should be carried out. • Develop understanding of the principles and methods used to design survey sampling schemes focusing on methodology for survey-based estimation for population totals and related quantities for some standard sample designs and statistical sampling techniques that are	-	**Suggested E-learning material** 1. Sampling Theory, NPTEL. https://nptel.ac.in/courses/111104073/ 2. Biostatistics and Design of Experiments, NPTEL, https://nptel.ac.in/courses/102106051/ 3. Design of Experiments and sample Survey. ePATHSHALA. https://epgp.inflibnet.ac.in/ahl.php?csrno=34	No change in the syllabus

		used to make inferences about a population. • Understand why the sampling design is essential for data collection and to determine how we choose to graph the data, estimate certain parameters, and quantify the uncertainty in these estimates with a margin of error.			
2.	STAT 302L Sampling Techniques and Design of Experiments Lab	On successful completion of the course, students will be able to, • Comprehend the basic principles underlying survey design and estimation. • Describe how to draw a random sample by using with and with replacement sampling technique in excel. • Calculate the sampling mean and sampling variance in case of SRSWR and SRSWOR. • Draw a random sample from stratified and systematic sampling and also to compare the efficiencies of these sampling techniques with respect to each other. • Analyze the results of a designed experiment in order to conduct the appropriate statistical analysis of the data. • Compare several means by using the technique of one way and twoway ANOVA.	-	-	No change

		• Compare the three designs named CRD, RBD and LSD in terms of their efficiencies.			
3.	STAT 301 Applied Statistics	On completion of the course, students will be able to, • Understand the concept of time series data and its application in various fields. • Identify principle sources of demographic data and assess their strengths and weaknesses.	-	-	No change
4.	STAT 301L Applied Statistics Lab	On completion of the course, students will be able to, • Measure trend and seasonal fluctuations, based on real life data. • Compute and interpret different death and birth rates such as CDR, CBR, etc. • Compute and differentiate between different index numbers such as Laspeyre's index, Pasche's index and Fisher's index. • Compute and understand different scores, reliability of test scores and IQ.	-	-	No change
5.	STAT (code to be generated) Financial Statistics	On completion of the course, the students will be able to, • Understand acquisition of financial data • Describe financial data using distributions • Find relation between two or more financial series	-	**UNIT I** Essential practical familiarization with financial data. Typical challenges with real financial data. Basics on data acquisition, manipulation,filtering,graphicalrepresenta-tion and plotting. **UNIT II** Statistical distribution of returns. Moments of	

		• Understand the concept of stochastic process • Apply basic stochastic models in financial data.		the distribution. Non-Normal distributions and fat-tails. Large fluctuations and tail risk. Stable distributions. Generalized extreme value distribution. Estimation methods to characterize the tails of the distributions. Calibration and validation. Applications to measures of risk. **UNIT III** Measures of dependency: linear and non-linear correlations. Lagged correlations and causality. Information theoretic perspective: mutual information, transfer entrophy. Spurious correlations. Correlation filtering through networks. Calibration, validation and application issues. **UNIT IV** Stochastic Process: Concept, types, properties. Discrete Stochastic Processes, Binomial processes, Gaussian Process. Random walk, General random walks, Geometric random walks, Binomial models with state dependent increments. **UNIT V** Stochastic Models in Finance: Discrete time process- binomial model with period one. Stochastic Models in Finance: Continuous time process- geometric Brownian motion.	

				Suggested Books: 1. Franke, J., Hardle, W.K. And Hafner, C.M. (2011): Statistics of Financial Markets: An Introduction, 3rd Edition, Springer Publications. 2. Stanley L. S. (2012): A Course on Statistics for Finance, Chapman and Hall/CRC. 3. Casella G. & Berger R. L. (2002). *Statistical Inference*, Brooks/Coles. 4. Bouchaud, J.- P. & Potters, M. (2003). *Theory of Financial Risk and Derivative Pricing: from Statistical Physics to Risk Management*, Cambridge University Press. 5. Lehmann, E. L. & Romano, J. P. (2006). *Testing Statistical Hypotheses*, Springer, 2006. **Reference Books** 1. Coles, S. (2001). *An Introduction to Statistical Modeling of Extreme Values*, Springer. 2. Gumbel, E. J. (2013). *Statistics of Extremes*, Echo Point Books & Media.	
6.	STAT (code to be generated) Financial Statistics Lab	On completion of this course, the students will be able to, • Understand the behavior of financial data through graphs • Describe the nature of financial data • Calculate risk through financial data		(Using spreadsheet/ R) 1. Graphical representation of financial data 2. Fit non-normal distributions to financial data 3. Obtain characteristics of the distribution	

		• Find relationship between financial series • Model financial data using some simple stochastic models.		4. Find measures of risk 5. Measure relationships between financial series. 6. Apply stochastic processes for a financial data	
7.	STAT (code to be generated) Health Statistics And Population Dynamics	On completion of this course, the students will be able to, • Understand different measures related to health statistic, • Able to calculate morbidity measures, • Identify principle sources of demographic data and assess their strengths and weaknesses. • Discuss the demographic significance of age and sex structures and the implications of variations in age & sex structure. • Construct and interpret life tables. • Calculation and interpretation of the principal demographic measures, and standardize these measures for comparison. • Understand the components of population change, including the effects of changing birth, death and migration rates, and demonstrate their influences on age structure. • Estimate and project the population by different methods.		**Unit 1** Health statistics: Introduction, utilization of basic data, sources of health statistics, problems in the collection of sickness data, measurement of sickness, hospital statistics and the international classification of diseases, different measures: incidence rates, prevalence rate, attack rate, case fatality rate. Measures of accuracy or validity, sensitivity index, specificity index. **Unit 2** Sources of demographic data in India: census, vital events, registration, survey, extent of under registration, Population pyramids and its use. Population growth rates: arithmetic, geometric and exponential growth rates, population estimation and projection. **Unit 3** Mortality and its measures: Crude, direct and indirect standardization of death rates, age specific death rate, infant mortality rate, neo-natal mortality rate, definitions and their evaluation. Fertility and its measures: CBR, ASBR, measures of reproduction: GFR, TFR,GRR, NRR, cohort fertility analysis.	

				Unit 4 Measures of migration crude, specific and standardized rates survival ratio and national growth rate method. Urbanization - Growth and distribution of rural - urban population in developed and developing countries. **Unit 5** Life tables and their application: construction of complete and abridged life tables and their interrelationship, force of mortality, evaluation of probabilities of survival and death from life table. **Text Books** 1. Rao, P.S.S.Sundar, & Richard, J. (2004). *An introduction to Biostatistics (A manual for students in health sciences)*, Prentice Hall of India, Pvt. Ltd. 2. Misra, B.D. (2004). *An introduction to the study of population,* South Asian Publishers Pvt. Ltd. 3. Ramkumar, R. (2006). *Technical Demography*. New Age International. 4. Pathak, K.B.& Ram, F. (2019). *Techniques of Demographic Analysis* (2nd. ed.). Himalaya Publishing House. **Reference Books** 1. Keyfitz.N. (2013). *Applied Mathematical*	

				Demography, New York: John Wiley. 2. Bhinde, A. A. & Kanitker, T. (2018). *Principles of Population Studies* (19th. ed.). Himalaya Publishing House. **Suggested E- Learning Material** 1. Demographic data; Platform: National Family Health Survey, India http://rchiips.org 2. Population Studies; Platform; e-PG Pathshala https://epgp.inflibnet.ac.in 3. Demography ; Platform: University Library - The University of Adelaide https://www.adelaide.edu.au/library/ 4. Demography; Platform: MITOPENCOURSEWARE https://ocw.mit.edu/index.htm	
8	STAT (code to be generated) Health Statistics And Population Dynamics Lab	On completion of this course, the students will be able to, • Calculate various measures of morbidity and their accuracy • Construct population pyramid and identify its features • Estimate population growth rates and project for future • Calculate measures of mortality and fertility for a given population		(Using spreadsheet/ R) 1. Measures of morbidity 2. Measures of accuracy or validity, sensitivity index, specificity index 3. Construction of population pyramid 4. Population growth rate 5. Measures based on mortality	

		• Calculate simple measures of life table and analyze it.		6. Measures based based on fertility 7. Construction of Life table	

Name of the Programme: M.Sc. (Mathematical Science)

Programme Educational Objectives:

Banasthali's education ideology is to nurture women leaders in all walks of life with strong value base. Mathematical Sciencesis the most important discipline in today's world which open doors in engineering, business, finance, computing, data science, health sciences and environmental sciences. The educational objective of the M.Sc. Mathematical Sciencesprogramme is to provide high quality education in mathematics, statistics, operations research and theoretical computer science in order to prepare students for professional careers in mathematical sciences and related fields.

The aim of the programme is to equip students with mathematical and statistical knowledge to define mathematical concepts, calculate quantities, estimate solutions, design data collection, analyze data appropriately and interpret to draw conclusions from these data.It emphasizes on both theory and applications of mathematics and 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 main objectives of the M.Sc. (Mathematical Sciences) programme are:

- To develop an understanding of the mathematics, statistics, operations research and theoretical computer science as a unifying language of science.
- To use mathematical and statistical techniques to solve well-defined real-world problems and understand the limitations.
- To provide exposure to various mathematical and statistical software packages, including analysis and programming.
- To develop communication and technical writing skills which enables them to present mathematical and statistical ideas clearly in oral and written forms using appropriate technical terms and deliver data analysis results.
- To nurture skills in effective multidisciplinary teamwork and adherence to principles of professional accountability and ethics.

Programme Outcomes:

PO1: Knowledge Domain: Demonstrate an understanding of the basic concepts in mathematics, statistics, operations research and theoretical computer science and their importance in the solution of some real-world problems.

PO2: Problem Analysis: Analyze and solve the well-defined problems in mathematics statistics, operations research and theoretical computer science. Utilize the principles of scientific enquiry, thinking analytically, clearly and critically, while solving problems and making decision. Find, analyze, evaluate and apply information systematically and shall make defensible decisions.

PO3:Presentation and Interpretation of Data: Demonstrate the ability to manipulate and visualize data and to compute standard statistical summaries.

PO4: Modern tool usage: Learn, select, and apply appropriate methods and procedures, resources, and computing tools such as Excel, MATLAB, MATHEMATICA, SPSS, R etc. with an understanding of the limitations.

PO5: Technical Skills: Understand tools of modeling, simulation, and data analysis to bear on real-world problems, producing solutions with the power to predict and explain complex phenomena.

PO6: Ethics: Analyze relevant academic, professional and research ethical problems and commit to professional ethics and responsibilities with applicable norms of the data analysis and research practices.

PO7: Communication: Effectively communicate about their field of expertise on their activities, with their peer and society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations.

PO8: Project Management: Apply knowledge and understanding of principles of mathematics and statistics effectively as an individual, and as a member or leader in diverse teams to manage projects in multidisciplinary environment.

PO9: Research Proposal: Define, design and deliver a significant piece of research work that is clear and concise. Demonstrate the necessary skills and knowledge of deeper understanding of their chosen research area. Understand the philosophy of research in mathematical sciences and appreciate the value of its development.

PO10: Life- long learning: Demonstrate the ability to read and learn mathematical and statistical tools on their own that encourage independent exploration in the specific area of mathematics, statistics, operations research and theoretical computer science. Continue to acquire mathematical and statistical knowledge and skills appropriate to professional activities in the context of technological change.

Annexure V

Programme Scheme: (With specialization in pure mathematics)

Semester I

Existing					
Course Code	**Course Name**	**L**	**T**	**P**	**C**
MATH 401	Algebra-I	6	0	0	6
MATH 403	Analysis-I	6	0	0	6
MATH 405	Discrete Mathematics	6	0	0	6
STAT 402	Probability and Statistics	4	0	0	4
CS 415	Computer Programming	4	0	0	4
STAT 402L	Probability and Statistics Lab	0	0	4	2
CS 415L	Computer Programming Lab	0	0	4	2
	Total:	**26**	**0**	**8**	**30**

Proposed					
Course Code	**CourseName**	**L**	**T**	**P**	**C**
	Algebra-I	5	0	0	5
	Analysis-I	5	0	0	5
	Discrete Mathematics	4	0	0	4
STAT 402	Probability and Statistics	4	0	0	4
CS 415	Computer Programming	4	0	0	4
CS 415L	Computer Programming Lab	0	0	4	2
	Computational Lab-I	0	0	4	2
	Total:	**22**	**0**	**8**	**26**

Semester II

Existing					
Course Code	**Course Name**	**L**	**T**	**P**	**C**
MATH 402	Algebra-II	6	0	0	6
MATH 404	Analysis-II	6	0	0	6
MATH 410	Ordinary Differential Equations	6	0	0	6
MATH 411	Topology	6	0	0	6
MATH 409	Numerical Analysis	4	0	0	4
MATH 409L	Numerical Analysis Lab	0	0	4	2
	Total:	**28**	**0**	**4**	**30**

Proposed					
Course Code	**CourseName**	**L**	**T**	**P**	**C**
	Algebra-II	5	0	0	5
	Analysis-II	5	0	0	5
	Ordinary Differential Equations	4	0	0	4
	Topology	4	0	0	4
MATH 409	Numerical Analysis	4	0	0	4
MATH 409L	Numerical Analysis Lab	0	0	4	2
	Computational Lab-II	0	0	4	2
	Total:	**22**	**0**	**8**	**26**

Annexure V

Semester III

Existing					
Course Code	**Course Name**	**L**	**T**	**P**	**C**
MATH 502	Advanced Calculus	6	0	0	6
MATH 508	Functional Analysis	6	0	0	6
MATH 511	Integral Transform and Special Functions	6	0	0	6
MATH 515	Mathematical Programming	6	0	0	6
	Elective-I	4	0	0	4
MATH 528P	Term Paper	0	0	4	2
	Total:	**28**	**0**	**4**	**30**

Proposed					
Course Code	**CourseName**	**L**	**T**	**P**	**C**
	Advanced Calculus	4	0	0	4
	Functional Analysis	4	0	0	4
	Operations Research	4	0	0	4
	Discipline Elective-I	4	0	0	4
	DisciplineElective-II	4	0	0	4
	Reading Elective-I	0	0	0	2
MATH 528P	Term Paper	0	0	8	4
	Total:	**20**	**0**	**8**	**26**

Semester IV

Existing					
Course Code	**Course Name**	**L**	**T**	**P**	**C**
MATH 518	Operations Research	6	0	0	6
MATH 505	Differential Geometry	6	0	0	6
MATH 519	Partial differential Equations	6	0	0	6
	Elective-II	4	0	0	4
	Elective-III	4	0	0	4
MATH 523P	Research Paper	0	0	8	4
	Total:	**26**	**0**	**8**	**30**

Proposed					
Course Code	**CourseName**	**L**	**T**	**P**	**C**
	Differential Geometry	4	0	0	4
	Partial Differential Equations	4	0	0	4
	DisciplineElective-III	4	0	0	4
	Open Elective	4	0	0	4
	Reading Elective-II	0	0	0	2
	Dissertation	0	0	16	8
	Total:	**16**	**0**	**16**	**26**

Student can opt a course as an open elective from any discipline with prior permission of respective heads and time table permitting.

List of Discipline Electives

Annexure V

CourseCode	Course	L	T	P	C
CS 315	Theory of Computation	4	0	0	4
CS 528	Modeling and Simulation	4	0	0	4
ELE 304	Digital Signal Processing	4	0	0	4
MATH 501	Advanced Analysis (Analysis on abstract spaces)	4	0	0	4
MATH 503	Advanced Functional Analysis	4	0	0	4
MATH 504	Analytic and Algebraic Number Theory	4	0	0	4
MATH 510	Integral equations and Calculus of Variations	4	0	0	4
MATH 517	Number Theory and Cryptography	4	0	0	4
MATH 527	Tensor Analysis and Geometry of Manifolds	4	0	0	4
MATH 529	Theory of Games	4	0	0	4
MATH 530	Viscous Fluid Dynamics	4	0	0	4
	Fuzzy Logic and Belief Theory	4	0	0	4
	Inventory Theory	4	0	0	4
	Queuing Theory	4	0	0	4
	Integral Transforms and Special Functions	4	0	0	4
	Measure Theory and Advanced Probability	4	0	0	4
	Time series and Stochastic Process	4	0	0	4
	Coding Theory	4	0	0	4
	Fixed Point Theory	4	0	0	4
	Introduction to Dynamical System	4	0	0	4
	Bio Mathematics	4	0	0	4
	Algebraic Topology	4	0	0	4
	Combinatorial Optimization	4	0	0	4
	Transportation System Analysis	4	0	0	4
	Fields and Galois Theory	4	0	0	4

List of Reading Electives

CourseCode	Course	L	T	P	C
	Network Biology	0	0	0	2
	Fractional Calculus	0	0	0	2
	Quantum Graphs	0	0	0	2
	Point set topology	0	0	0	2
	Operational Research Applications	0	0	0	2

Annexure V

Programme Scheme: (With specialization in Statistics)

Semester I

Existing					
Course Code	**Course Name**	**L**	**T**	**P**	**C**
MATH 401	Algebra-I	6	0	0	6
MATH 403	Analysis-I	6	0	0	6
MATH 405	Discrete Mathematics	6	0	0	6
STAT 402	Probability and Statistics	4	0	0	4
CS 415	Computer Programming	4	0	0	4
STAT 402L	Probability and Statistics Lab	0	0	4	2
CS 415L	Computer Programming Lab	0	0	4	2
	Total:	**26**	**0**	**8**	**30**

Proposed					
Course Code	**CourseName**	**L**	**T**	**P**	**C**
	Algebra-I	5	0	0	5
	Analysis-I	5	0	0	5
	Discrete Mathematics	4	0	0	4
STAT 402	Probability and Statistics	4	0	0	4
CS 415	Computer Programming	4	0	0	4
CS 415L	Computer Programming Lab	0	0	4	2
	Computational Lab-I	0	0	4	2
	Total:	**22**	**0**	**8**	**26**

Semester II

Existing					
Course Code	**Course Name**	**L**	**T**	**P**	**C**
MATH 402	Algebra-II	6	0	0	6
STAT 403	Statistical Inference	6	0	0	6
STAT 401	Measure Theory & Advanced Probability	6	0	0	6
MATH 409	Numerical Analysis	4	0	0	4
CS 417	Database Management Systems	4	0	0	4
MATH 409L	Numerical Analysis Lab	0	0	4	2
CS 417L	Database Management Systems Lab	0	0	4	2
	Total:	**26**	**0**	**8**	**30**

Proposed					
Course Code	**CourseName**	**L**	**T**	**P**	**C**
	Analysis-II	5	0	0	5
	Statistical Inference	5	0	0	5
	Measure Theory & Advanced Probability	4	0	0	4
MATH 409	Numerical Analysis	4	0	0	4
CS 417	Database Management Systems	4	0	0	4
MATH 409L	Numerical Analysis Lab	0	0	4	2
CS 417L	Database Management Systems Lab	0	0	4	2
	Total:	**22**	**0**	**8**	**26**

Annexure V

Semester III

Existing					
Course Code	**Course Name**	**L**	**T**	**P**	**C**
MATH 515	Mathematical Programming	6	0	0	6
STAT 517	Time Series and Stochastic Process	6	0	0	6
STAT 507	Design of Experiments and Linear Models	4	0	0	4
STAT 506	Demography and Advanced Sampling	4	0	0	4
STAT 507L	Design of Experiments and Linear ModelsLab	0	0	4	2
STAT 506L	Demography and Advanced Sampling Lab	0	0	4	2
	Elective-I	4	0	0	4
STAT 514S	Seminar	0	0	4	2
	Total:	**24**	**0**	**12**	**30**

Proposed					
Course Code	**CourseName**	**L**	**T**	**P**	**C**
	Survey Sampling	4	0	0	4
	Time Series and Stochastic Process	4	0	0	4
STAT 507	Design of Experiments and Linear Models	4	0	0	4
	Computational Lab-III	0	0	4	2
	DisciplineElective-I	4	0	0	4
	DisciplineElective-II	4	0	0	4
	Reading Elective-I	0	0	0	2
	Seminar	0	0	4	2
	Total:	**20**	**0**	**8**	**26**

Semester IV

Existing					
Course Code	**Course Name**	**L**	**T**	**P**	**C**
MATH 518	Operations Research	6	0	0	6
STAT 501	Advanced Inference	6	0	0	6
STAT 502	Bayesian & Multivariate Analysis	4	0	0	4
STAT 502 L	Bayesian & Multivariate Analysis Lab	0	0	4	2
	Elective-II	4	0	0	4
	Elective-III	4	0	0	4
STAT 512P	Project	0	0	8	4
	Total:	**24**	**0**	**8**	**30**

Proposed					
Course Code	**CourseName**	**L**	**T**	**P**	**C**
	Advanced Inference	4	0	0	4
STAT 502	Bayesian and Multivariate Analysis	4	0	0	4
STAT 502L	Bayesian & Multivariate Analysis Lab	0	0	4	2
	DisciplineElective-III	4	0	0	4
	Open Elective	4	0	0	4
	Reading Elective-I	0	0	0	2
	Project	0	0	12	6
	Total:	**16**	**0**	**16**	**26**

Student can opt a course as an open elective from any discipline with prior permission of respective heads and time table permitting.

Annexure V

List of DisciplineElectives

Course Code	Course Name	L	T	P	C
CS 523	Emerging Programming Paradigms	4	0	0	4
CS 528	Modeling and Simulation	4	0	0	4
MATH 516	Network Analysis and Goal Programming	4	0	0	4
MATH 529	Theory of Games	4	0	0	4
STAT 504	Clinical Trials	4	0	0	4
STAT 505	Decision Theory	4	0	0	4
STAT 508	Distribution Theory	4	0	0	4
STAT 510	Econometric Models	4	0	0	4
STAT 511	Non-Parametric Inference and Sequential Analysis	4	0	0	4
STAT 513	Regression Analysis	4	0	0	4
STAT 515	Statistical Computing	4	0	0	4
	Queuing Theory	4	0	0	4
	Stochastic Models	4	0	0	4
	Demography	4	0	0	4
	Actuarial Statistics	4	0	0	4
	Survival Analysis	4	0	0	4
	Reliability and Renewal Theory	4	0	0	4
	Operations Research	4	0	0	4
	Inventory Theory	4	0	0	4

List of ReadingElectives

Course Code	Course Name	L	T	P	C
	Step-Stress Modelling	0	0	0	2
	Categorical Data Analysis	0	0	0	2
	Official Statistics	0	0	0	2
	Robust Estimation in Non-Linear Models	0	0	0	2
	Operational Research Applications	0	0	0	2

Annexure V

Programme Scheme: (With specialization in operations research)

Semester I

Existing					
Course Code	**Course Name**	**L**	**T**	**P**	**C**
MATH 401	Algebra-I	6	0	0	6
MATH 403	Analysis-I	6	0	0	6
MATH 405	Discrete Mathematics	6	0	0	6
STAT 402	Probability and Statistics	4	0	0	4
CS 415	Computer Programming	4	0	0	4
STAT 402L	Probability and Statistics Lab	0	0	4	2
CS 415L	Computer Programming Lab	0	0	4	2
	Total:	**26**	**0**	**8**	**30**

Proposed					
Course Code	**Course Name**	**L**	**T**	**P**	**C**
	Algebra-I	5	0	0	5
	Analysis-I	5	0	0	5
	Discrete Mathematics	4	0	0	4
STAT 402	Probability and Statistics	4	0	0	4
CS 415	Computer Programming	4	0	0	4
CS 415L	Computer Programming Lab	0	0	4	2
	Computational Lab-I	0	0	4	2
	Total:	**22**	**0**	**8**	**26**

Semester II

Existing					
Course Code	**Course Name**	**L**	**T**	**P**	**C**
MATH 402	Algebra-II	6	0	0	6
MATH 404	Analysis-II	6	0	0	6
CS 209	Data Structures	4	0	0	4
MATH 409	Numerical Analysis	4	0	0	4
CS 417	Database Management Systems	4	0	0	4
CS 209L	Data Structures Lab	0	0	4	2
MATH 409L	Numerical Analysis Lab	0	0	4	2
CS 417L	Database Management Systems Lab	0	0	4	2
	Total:	**24**	**0**	**12**	**30**

Proposed					
Course Code	**CourseName**	**L**	**T**	**P**	**C**
	Algebra-II	5	0	0	5
	Analysis-II	5	0	0	5
	Ordinary Differential Equations	4	0	0	4
MATH 409	Numerical Analysis	4	0	0	4
CS 417	Database Management Systems	4	0	0	4
MATH 409L	Numerical Analysis Lab	0	0	4	2
CS 417L	Database Management Systems Lab	0	0	4	2
	Total:	**22**	**0**	**8**	**26**

Annexure V

Semester III

Existing					
Course Code	**Course Name**	**L**	**T**	**P**	**C**
MATH 509	Fuzzy logic and Belief Theory	6	0	0	6
MATH 522	Queuing Theory	6	0	0	6
STAT 507	Design of Experiments and Linear Models	4	0	0	4
MATH 515	Mathematical Programming	6	0	0	6
STAT 507L	Design of Experiments andLinear Models Lab	0	0	4	2
	Elective-I	4	0	0	4
MATH 525S	Seminar	0	0	4	2
	Total:	**26**	**0**	**8**	**30**

Proposed					
Course Code	**Course**	**L**	**T**	**P**	**C**
	Queuing Theory	4	0	0	4
CS 209	Data Structures	4	0	0	4
	Inventory Theory	4	0	0	4
CS 209L	Data Structures Lab	0	0	4	2
	DisciplineElective-I	4	0	0	4
	DisciplineElective-II	4	0	0	4
	Reading Elective-I	0	0	0	2
	Seminar	0	0	4	2
	Total:	**20**	**0**	**8**	**26**

Semester IV

Existing					
Course Code	**Course Name**	**L**	**T**	**P**	**C**
STAT 516	Theory of Reliability	6	0	0	6
MATH 512	Inventory Theory	6	0	0	6
MATH 516	Network Analysis& Goal Programming	4	0	0	4
MATH 516L	Network Analysis & Goal ProgrammingLab	0	0	4	2
	Elective-II	4	0	0	4
	Elective-III	4	0	0	4
MATH 520P	Project	0	0	8	4
		24	**0**	**8**	**30**

Proposed					
Course Code	**Course**	**L**	**T**	**P**	**C**
	Reliability and Renewal Theory	4	0	0	4
MATH 516	Network Analysis & Goal Programming	4	0	0	4
MATH 516L	Network Analysis & Goal Programming Lab	0	0	4	2
	DisciplineElective-III	4	0	0	4
	Open Elective	4	0	0	4
	Reading Elective-II	0	0	0	2
	Project	0	0	12	6
		16	**0**	**16**	**26**

Student can opt a course as an open elective from any discipline with prior permission of respective heads and time table permitting.

Annexure V

List of Electives

Course Code	Course Name	L	T	P	C
CS 523	Emerging Programming Paradigms	4	0	0	4
CS 528	Modeling and Simulation	4	0	0	4
MATH 507	Financial Mathematics	4	0	0	4
MATH 513	Marketing Management	4	0	0	4
MATH 529	Theory of Games	4	0	0	4
STAT 401	Measure Theory and Advanced Probability	4	0	0	4
STAT 505	Decision Theory	4	0	0	4
STAT 510	Econometric Models	4	0	0	4
STAT 517	Time Series and Stochastic Process	4	0	0	4
	Combinatorial Optimization	4	0	0	4
	Transportation System Analysis	4	0	0	4
	Stochastic Models	4	0	0	4
	Fuzzy logic and Belief Theory	4	0	0	4
	Partial Differential Equations	4	0	0	4

List of Reading Electives

CourseCode	Course Name	L	T	P	C
	Selected Applications of Stochastic Models	0	0	0	2
	Operational Research Applications	0	0	0	2
	Step-Stress Modelling	0	0	0	2
	Categorical Data Analysis	0	0	0	2

Annexure V

Programme Scheme: (With specialization in theoretical computer science)

Semester I

Existing					
Course Code	**Course Name**	**L**	**T**	**P**	**C**
MATH 401	Algebra-I	6	0	0	6
MATH 403	Analysis-I	6	0	0	6
MATH 405	Discrete Mathematics	6	0	0	6
STAT 402	Probability and Statistics	4	0	0	4
CS 415	Computer Programming	4	0	0	4
STAT 402L	Probability and Statistics Lab	0	0	4	2
CS 415L	Computer Programming Lab	0	0	4	2
	Total:	**26**	**0**	**8**	**30**

Proposed					
Course Code	**Course**	**L**	**T**	**P**	**C**
	Algebra-I	5	0	0	5
	Analysis-I	5	0	0	5
	Discrete Mathematics	4	0	0	4
STAT 402	Probability and Statistics	4	0	0	4
CS 415	Computer Programming	4	0	0	4
CS 415L	Computer Programming Lab	0	0	4	2
	Computational Lab-I	0	0	4	2
	Total:	**22**	**0**	**8**	**26**

Semester II

Existing					
Course Code	**Course Name**	**L**	**T**	**P**	**C**
MATH 402	Algebra-II	6	0	0	6
MATH 404	Analysis-II	6	0	0	6
CS 209	Data Structures	4	0	0	4
MATH 409	Numerical Analysis	4	0	0	4
CS 417	Database Management Systems	4	0	0	4
CS 209L	Data Structures Lab	0	0	4	2
MATH 409L	Numerical Analysis Lab	0	0	4	2
CS 417L	Database Management Systems Lab	0	0	4	2
	Total:	**24**	**0**	**12**	**30**

Proposed					
Course Code	**Course**	**L**	**T**	**P**	**C**
	Algebra-II	5	0	0	5
	Analysis-II	5	0	0	5
	Ordinary Differential Equations	4	0	0	4
MATH 409	Numerical Analysis	4	0	0	4
CS 417	Database Management Systems	4	0	0	4
MATH 409L	Numerical Analysis Lab	0	0	4	2
CS 417L	Database Management Systems Lab	0	0	4	2
	Total:	**22**	**0**	**8**	**26**

Annexure V

Semester III

Existing					
Course Code	**Course Name**	**L**	**T**	**P**	**C**
MATH 515	Mathematical Programming	6	0	0	6
CS 315	Theory of Computation	4	0	0	4
CS 213	Design and Analysis of Algorithms	4	0	0	4
CS 308	Operating Systems	4	0	0	4
CS 213L	Design and Analysis of Algorithms Lab	0	0	4	2
CS 308L	Operating Systems Lab	0	0	2	1
	Elective-I	4	0	0	4
MATH 526S	Seminar	0	0	4	2
	Total:	**22**	**0**	**10**	**27**

Proposed					
Course Code	**Course**	**L**	**T**	**P**	**C**
CS 315	Theory of Computation	4	0	0	4
CS 209	Data Structures	4	0	0	4
CS 308	Operating Systems	4	0	0	4
CS 528	Modeling and Simulation	4	0	0	4
CS 209L	Data Structures Lab	0	0	4	2
	DisciplineElective-I	4	0	0	4
	Reading Elective-I	0	0	0	2
MATH 526S	Seminar	0	0	4	2
	Total:	**20**	**0**	**8**	**26**

Semester IV

Existing					
Course Code	**Course Name**	**L**	**T**	**P**	**C**
CS 313	Software Engineering	4	0	0	4
CS 528	Modeling and Simulation	4	0	0	4
MATH 518	Operations Research	6	0	0	6
	Elective-II	4	0	0	4
	Elective-III	4	0	0	4
MATH 521P	Project	0	0	8	4
		22	**0**	**8**	**26**

Proposed					
Course Code	**Course**	**L**	**T**	**P**	**C**
CS 315	Software Engineering	4	0	0	4
CS 213	Design and Analysis of Algorithms	4	0	0	4
CS 213L	Design and Analysis of Algorithms Lab	0	0	4	2
	DisciplineElective-II	4	0	0	4
	Open Elective	4	0	0	4
	Reading Elective-II	0	0	0	2
	Project	0	0	12	6
		16	**0**	**16**	**26**

Student can opt a course as an open elective from any discipline with prior permission of respective heads and time table permitting.

List of Electives

CourseCode	Course Name	L	T	P	C

CS 419	Distributed Computing	4	0	0	4
CS 427	Parallel Computing	4	0	0	4
CS 431	Real Time Systems	4	0	0	4
CS 433	Soft Computing	4	0	0	4
CS 436	Web Development and .Net Framework	4	0	0	4
CS 436L	Web Development and .Net Framework Lab	4	0	0	4
CS 502	Advanced Communications and Networks	4	0	0	4
CS 502L	Advanced Communications and Networks Lab	0	0	4	2
CS 507	Artificial Intelligence	4	0	0	4
CS 510	Client-Server Computing and Applications	4	0	0	4
CS 517	Data Communication and Networking	4	0	0	4
CS 517L	Data Communication and Networking Lab	0	0	4	2
CS 527	Mobile Computing	4	0	0	4
ELE 304	Digital Signal Processing	4	0	0	4
MATH 529	Theory of Games	4	0	0	4
STAT 401	Measure Theory and Advanced Probability	4	0	0	4
STAT 517	Time series and Stochastic Process	4	0	0	4

List of Reading Electives

CourseCode	**Course Name**	**L**	**T**	**P**	**C**
	Operational Research Applications	0	0	0	2
	Categorical Data Analysis	0	0	0	2
	Network Biology	0	0	0	2
	Fractional Calculus	0	0	0	2
	Quantum Graphs	0	0	0	2

Name of Programme: M.Sc. (Mathematical Science)
Course Details:
Note: 1. Black Shaded part is shifted. 2. Strikeout is deleted. 3. Italic and Underline is rewritten., 4.Grey shaded part is added.

First Semester

S.N.	Course List	Learning Outcomes	Existing Syllabus	Suggested Syllabus	Remark
1.	MATH (To be generated) Algebra-I	Oncompletion of the course, students will be able to • Analyze finite and infinite dimensional vector spaces and subspaces over a field and their properties, including the basis structure of vector spaces. • Understand the properties of linear transformations, matrices of linear transformations and change of basis, including kernel, range and isomorphism. • Compute inner products and determine orthogonality on vector spaces, including Gram-Schmidt orthogonalization. • Identify operators in inner product spaces. • Identify bilinear forms, canonical forms for symmetric and skew-symmetric forms.	**Section A** Groups: Dihedral groups, symmetric groups, matrix groups; subgroups generated by subsets of a group, Homomorphism and Normal Subgroups, Isomorphism theorems,~~group actions, stabilizers and kernals of group actions,cycle Decomposition~~, Conjugates, Conjugacy in S_n, Class equation for a Group, Sylow's theorem; Applications of Sylow's theorem, Simplicity of Alternating Group A_n for n>5,~~Commutator, Series of Subgroups, Jordan Holder Theorem, Solvable Groups.~~ **Section B** Rings homomorphism and quotient rings, Ideals: Prime and Maximal, rings of fractions, Divisibility, Euclidean and Principal Ideal Domains; Unique Factorization Domains; Polynomial Rings over fields, irreducibility criteria,~~polynomial in several variables, Noetherian ring, Hilbert basis theorem, Grobner basis, solving algebraic equation.~~ **Section C** Field Theory: characteristic of a field, prime subfield, extension fields, Algebraic Extensions, Splitting fields and algebraic closures, Normal and Separable Extensions, Fundamental Theorem of Galois Theory.	**Section A** Vector spaces, subspaces, linear span, bases, quotient spaces, coordinate vectors, change of basis, linear transformations, isomorphism, range and kernel of a linear transformation, matrix of a linear transformation, algebra of L(U, V), invertible transformations and matrices, Linear functionals and dual spaces. **Section B** Linear operator, annihilating polynomials, invariant subspaces of linear operator, direct sum decomposition, cyclic operator, maximal vector, indecomposable linear operators, invariant factors, canonical forms, operators on real and complex vector spaces. **Section C** Inner Product Spaces, Orthonormal Sets, Gram–Schmidt Process, Orthogonal Complements and Projections, Adjoints , self-adjoints and normal operators, unitary and orthogonal operators, Forms on inner product spaces, Bilinear forms, symmetric bilinear forms and quadratic form. **Suggested Books:** 1. Hoffman, K., & Kunze, R. A. (2010). *Linear algebra*. New Delhi: PHI Learning. 2. Cooperstein, B. N. (2015). *Advanced linear algebra*. (Advanced Linear Algebra, Second Edition.) Boca	Shaded part in Black from section A and B is shifted in Algebra II and from section C is shifted in Fields and Galois Theory. **Change in Credit**

			Text Book: 1. Dummit, D. S. and Foote, R. M.: Abstract Algebra, 3rd Ed., Wiley, 2004. **Reference Books:** 1. Herstein, I. N.: Topics in Algebra, 2nd Ed., Wiley Eastern, New Delhi, 1991. 2. Gallian, J. A.: Contemporary Abstract Algebra, 8th Ed. Cengage Learning, 2006. 3. Jacobson, N.: Lectures in Abstract Algebra, D. Van Nostrand, New York, 1964. 4. Jacobson, N.: Basic Algebra-I, Hindustan Publishing, Delhi, 1984. 5. Bhattacharya; P. B. Jain S.K. and Nagpal S.R. : Basic Abstract Algebra. 2nd Ed. Cambridge University Prees, 1990.	Raton: CRC Press. 3. Lang, S. (2011). *Linear algebra*. (3rd Ed.). New York: Springer. 4. Halmos, P. R. (2013). *Finite dimensional vector spaces*. (2nd Ed.). S.l.: Literary Licensing, LLC. **5.** Yang, Y. (2015) *Advanced linear algebra*. Cambridge : Cambridge University Press. **Suggested E-learning Material:** 1. Lecture Notes: https://nptel.ac.in/downloads/111102011/# 2. Video Lectures & Notes: https://onlinecourses.nptel.ac.in/noc17_ma04/preview	
2.	MATH (To be generated) Analysis-I	On completion of the course, the student will be able to, • understand modern theory of set and real numbers. • investigate different metric spaces and their properties. • master the technique of calculating the Lebesgue integral and understand the applications measurable functions. • explain construction and investigate properties of Lebesgue measure. • derive the Fourier series of integrable functions. • discuss the point-wise and uniform	**Section A** Countable & Uncountable Sets, ~~Statements of Axiom of Choice,~~ Well Ordering Principle, ~~Zorn's Lemma~~, ~~Transfinite Induction~~. Field of Real Numbers as a Complete Ordered Field, Metric Space, Compact Set, Heine-Borel Theorem, Bolzano Weierstrass Theorem, ~~Taylor's Theorem.~~ **Section B** Construction & Properties of Lebesgue Measure, Borel Sets, Measurable Sets, Measurable Functions, Lebesgue Integration & its Properties, Dominated & Monotone Convergence Theorems, Fatou's Lemma. **Section C** Fourier Series of Integrable Functions. Discussion of Pointwise & Uniform Convergence of Series,	**Section A** Countable & Uncountable sets, well ordering principle, Field of real numbers as a complete ordered field, Metric space, Sequences in metric spaces, complete metric space, Compact set, Heine-Borel Theorem, Bolzano Weierstrass Theorem, **Section B** Construction & Properties of Lebesgue measure, Borel sets, Measurable sets, Measurable functions, Lebesgue integration & its properties, Dominated & Monotone convergence theorems, Fatou's Lemma. **Section C** Fourier series of integrable functions. Discussion of pointwise & uniform convergence of series, Fejer's Theorem for continuous periodic functions,	**Change in Credit**

		convergence of series.	Fejer'sTheorem for Continuous Periodic Functions, Orthogonality, Parseval's Theorem. Riesz Fischer theorem. **Suggested Text Books:** 1. H. L. Royden, **Real Analysis**, 3rd Ed., Pearson Education Pvt. Limited, Singapore, 2003. (for Sec. A &B) 2. G. D. Barra, **Measure Theory &Integration**, 2nd Ed. Wiley Eastern Limited, New Delhi, 1991. (for Sec. B) 3. H. S. Carslaw, **An Introduction to the Theory of Fourier Series and Integrals**, 3rd Revised Edition Dover Pub., New York, 1950. (for Sec. C) **Suggested Reference Books:** 1. W. Rudin, **Principles of Mathematical Analysis,** 3rd Ed. McGraw- Hill, Auckland, 1985. 2. T.M. Apostol, **Mathematical Analysis**, 2nd Ed, Narosa Publishing House, New Delhi, 1974. 3. E.C. Tichmarch, **Theory of Functions**, Oxford University Prees, 1962. 4. E. Hewitt and K. Stromberg, **Real and Abstract Analysis: A modern treatment of the theory of functions of a real variable,**Narosa Publishing House, New Delhi, 1978. 5. G. Das and S. Pattanaik, **Fundamentals of Mathematical Analysis**, T.M.H,New Delhi, 1989. 6. Richard R. Goldberg, **Methods of Real Analysis**, Oxford & IBH, New Delhi, 1970.	Orthogonality, Parseval's Theorem. Riez Fischer theorem. **Suggested Text Books:** 1. Royden, H. L. (2011). *Real analysis*. (3rd Ed.). New Delhi: Prentice hall of India. 2. Barra, G. D. (2008). *Measure theory and integration*. New Delhi: New Age International. 3. Carslaw, H. S. (1959). *Introduction to the theory of Fourier's series and integrals*. New York: Dover Publications. **Suggested Reference Books:** 1. Rudin, W. (2017). *Principles of mathematical analysis*. (3rd Ed.). Chennai: McGraw Education (india) Private Limited. 2. Apostol, T. M. (1974) *Mathematical analysis*. (2nd Ed.). New Delhi: Narosa Publishing House. 3. Titchmarsh, E. C. (1968). *The theory of functions*. London: Oxford Univ. Press. 4. Hewitt, E., & Stromberg, K. R. (2009). *Real and abstract analysis: A modern treatment of the theory of functions of a real variable*. New York: Springer. 5. Goldberg, R. R. (2019). *Methods of real analysis*. New Delhi: Blaisdell Pub. Co.; Oxford and IBH. **Suggested E-learning material** 1. A Basic Course in Real Analysis; NPTL:https://nptel.ac.in/courses/111105069/ 2. Fourier Series Part-1;NPTL: https://nptel.ac.in/courses/122107037/24	
3.	MATH (To be generated)	After completing the course, students will be able to	**Section A** Sets and Multisets, Partial Order Relations, Chains	**Section A** Logic, Propositional Equivalences, Predicates and	

	Discrete Mathematics	• Understand logical arguments and logical constructs. Have a better understanding of sets, functions and relations. • Apply logical reasoning to solve a variety of mathematical problems. • Understand and apply the fundamental concepts in graph theory. • Acquire ability to apply graph theory-based tools in solving practical problems. • Improve the proof writing skills and able to develop mathematical maturity.	and Antichains. *Permutation and Combination of Multisets. Pigeon hole Principle, Inclusion-Exclusion Principle.* ~~Derangements.~~ *Discrete Numeric Functions, Generating Functions, Recurrence Relations, linear Recurrence Relation with Constant Coefficients and their Solutions, Solution by the method of Generating Functions.* Boolean Algebra, Lattices, Uniqueness of Finite Boolean Lattices, Boolean Functions and Boolean Expression. ~~Propositional Calculus~~. **Section B** *Basic Concepts of Graph Theory. Directed Graph. Euler Graph. Hamiltonian Graph. Matrix Representation of Graphs. Shortest Path in a Weighted Graph.* ~~K-connected and K-edge-connected Graphs~~. Planar Graphs. ~~Coloring of Graphs~~, Vertex Coloring of Graphs, ~~Edge Coloring of Graphs, Vizing's Theorem~~. *Trees: Rooted Trees, Spanning Tree and Cut Set, Minimum Spanning Tree.* ~~Flow Network in a Graph, Max Flow Min Cut Theorem.~~ **Section C** ~~Types of Enumeration, Counting Labeled Trees, Burnside's Lemma, Polya's Counting Theorem, Graph Enumeration with Polya's Theorem.~~ ~~Matchings in Bipartite Graphs, Hall's Matching Theorem, Min-Max Theorem, Independent Sets, Factorization, 1-Factorization, 2-Factorization, Arboricity.~~ **Suggested Text/Reference Books:** 1. C.L. Liu, **Elements of Discrete Mathematics,** Mc-Graw Hill, International Edition, 1985.	Quantifiers, Nested Quantifiers, Methods of Proof, Multi-set, Relations and Functions, Introduction to Algorithms, The growth of functions, Complexity of Algorithms. Partially ordered sets, Chains and Anti-chains, Lattices, Complete lattices, Distributive lattices, Complements, Boolean Algebra, Uniqueness of Finite Boolean Algebras, Boolean expressions and Boolean functions, Normal forms. **Section B** Basic counting Principles, Permutations and Combinations, Permutations and Combinations on multi-sets, Generation of permutations and Combinations, Pigeon-hole principle, Principle of inclusion and exclusion. Discrete numeric functions, Generating Functions, Combinatorial problems. Recurrence relations, linear recurrence relation with constant coefficients and their solutions, Solution by the method of generating Functions. **Section C** Graphs, Vertices of graphs, degrees, Sub-graphs, Paths, Walks and cycles, Connected graphs, Connected components, Weighted graphs, Directed graphs. Matrix representations of graphs. Shortest path Problem Operations on graphs. Blocks, Cut-points, bridges Block graphs and Cut-point graphs. Euler tours, Euler graphs Hamiltonian paths, Hamiltonian graphs. Closure of a graph. Isomorphism in graphs. Euler's formula, Planar graphs, Vertex colouring , Chromatic number, Chromatic polynomial, R - Critical graphs, Acyclic graphs- Trees , Elementary properties of trees, Center, Connectivity, Connectivity and line connectivity,	

			2. N. Deo, **Graph Theory**, Prentice Hall of India, 2002. 3. K.H. Rosen, **Discrete Mathematics and it's Applications**, 7th Ed. Mc-Graw Hill, 2013. 4. K.D. Joshi, **Foundation of Discrete Mathematics**, Wiely Eastern Ltd., 1989. 5. D.B. West, **Introduction to Graph Theory**, 2nd Ed. Pretince Hall of India, 2001.	Partitions, Cut edges - Cut vertices, Spanning tree and minimum Spanning tree. **Suggested Books:** 1. Liu, C. L. (1985) *Elements of discrete mathematics*. Mc-Graw Hill, International edition. 2. Deo, N. (2012). *Graph theory: With applications to engineering and computer science*. New Delhi: PHI Learning Private Limited.. 3. Rosen, K. H. (2013). *Discrete mathematics and its applications: Seventh edition*. New York: McGraw-Hill. 4. Joshi, K. D. (1089) *Foundation of discrete mathematics*. Wiely Eastern Ltd. **Suggested E-learning Material:** 1. Lecture notes: https://nptel.ac.in/downloads/111104026/ 2. Lecture notes: http://home.iitk.ac.in/~arlal/book/mth202.pdf 3. Lecture notes: https://ocw.mit.edu/high-chool/mathematics/combinatorics-the-fine-art-of-counting/lecture-notes/MITHFH_lecturenotes_8.pdf 4. Lecture notes: http://www.math.kit.edu/iag6/lehre/graphtheo2015w/media/lecture_notes.pdf 5. Online Course: https://swayam.gov.in/courses/4926-discrete-mathematics 6. Online Course: https://swayam.gov.in/course/3795-graph-theory	

4.	STAT 402 Probability and Statistics	On completion of the course, the student will be able to: õ Understand the meaning of probability and probabilistic experiment and all approaches to probability theory and particularly, the axiomatic approach. õ Understanding the meaning of conditional probability,conditioning, and reduced sample space. õ Understand the concepts of random variables, sigma-fields generated by random variables, probability distributions and independence of random variables related to measurable functions. õ Distinguish between independent and uncorrelated random variables. õ Distinguish between discrete, continuous, and mixed random variables and be able to represent them using probability mass, probability density, and cumulative distribution function. õ Understand the concepts of sampling distributions and use of sampling distribution in hypothesis testing.	-	**Suggested E-learning material:** **1.** Probability and Statistics; Platform: NPTEL nptel.ac.in/courses/111105041/. **2.** Probability; Platform: e-PGPathshalahttps://epgp.inflibnet.ac.in/ahl.php?csrno=34. **3.** Introduction to Probability- https://ocw.mit.edu/resources/res-6-012-introduction-to-probability-spring-2018/	No change in the syllabus

5.	CS 415 Computer Programming	On successful completion of the course students will be able to • Understanding the concepts of computer basics and programming. • Understanding of the organization and operations of a computer system. • Understanding of Binary logic in design of electronic circuits. • Students would have logical thinking for Analyzing problems, designing and implementing algorithmic solutions. • Students would get the skills for the use of the C programming language to implement the real world applications.	-	**Suggested E-learning material:** 1. Introduction to Programming in C https://nptel.ac.in/courses/106104128/ 2. Introduction to Programming in C Specialization by Duke University https://www.coursera.org/specializations/c-programming 3. Computer Fundamentals by P. K. Sinha https://www.edutechlearners.com/computer-fundamentals-p-k-sinha-free-pdf/	No change in the syllabus
6.	MATH (To be generated) Computatio-nal Lab-I	On completion of the course, the student will be able to, • Perform basic mathematical operations in MATLAB. • Create vectors, arrays, matrices and perform fundamental matrix operations. • Visualize basic mathematical functions. • Solve linear equations and	-	1. Introduction to MATLAB 2. Defining Vectors, Array, Matrices and their mathematical operations 3. Special variables and Numeric display formats 4. Matrix Functions: Norm, rank, determinant, transpose, inverse, g-inverse, diagonal, trace, etc. 5. Finding roots of a polynomial, characteristic equation, eigen values and eigen vectors 6. Solving system of linear equations: Gauss elimination Method, Matrix Decomposition:	New Course

		system of linear equations. • Import/export data, summarize and visualize the data. • Fit some standard distributions and test hypothesis.		Cholesky, LU, and QR factorizations, diagonal forms, singular value decomposition. 7. 2D plots for Cartesian, parametric and polar curves 8. Evaluating and plotting: Trigonometric functions, hyperbolic functions, complex functions, Logarithms, exponentials, etc. 9. 3D plots: surfaces, contour plot, mesh 10. Data import and export 11. Building frequency tables: Univariate, Bivariate. 12. Finding descriptive statistics: averages, dispersion, skewness, kurtosis. 13. Data visualization: Dot plots, Histogram, Box plots, bar diagram, pie diagrams, etc. 14. Fitting and visualization of Probability distributions: Binomial, Poisson and Normal. 15. Empirical cumulative distribution function plot, Histogram based on empirical cumulative distribution function, Histogram with a distribution fit, Normal probability plot, Probability plots, Quantile-quantile plot. 16. Hypothesis Tests: t-test, F-test, chi-square goodness-of-fit test 17. Introduction to M-files and programming in MATLAB, **Suggested Books:** 1. D. Duffy, Advanced Engineering mathematics with MATLAB, 3rd Ed, Taylor & Francis, 2010 **2.** A. Knight, Basics of Matlab and beyond, CRC Press, 1999	

				Suggested E-learning material: 1. PDF Documentation for MATLAB: https://in.mathworks.com/help/pdf_doc/matlab/index.html	

SECOND SEMESTER

S.N.	Course List	Learning Outcomes	Existing Syllabus	Suggested Syllabus	Remark
1.	MATH (to be generated) Algebra-II	After completing the course, students will be able • To demonstrate the mathematical maturity of understanding the proof. • To understand the algebraic structures groups, rings, modules. • To grasp the significance of the concepts of homomorphism & isomorphism and be able to check a given function is one of these. • To understand the class equation for a finite group and its applications in Sylows theorems. • To classify groups up to isomorphism. • To really understand the special types of rings and be	**SectionA** Vector spaces, subspaces, quotient spaces, span and *independence*, bases (finite and infinite), coordinate vectors, linear transformations, projection map, range and kernel of a linear transformation, isomorphism,~~correspondence theorem~~, *isomorphismtheorems*, matrix of a linear transformation, algebra of L(U, V), *singular and nonsingular mappings,* Linear functionals and dual spaces,~~Transpose of a linear mappings~~. **SectionB** ~~Determinant function,Properties of determinant, modules, multilinear functions~~, characteristic values, annihilating polynomials, invariant subspaces, direct sum, invariant direct sum, primary decomposition theorem, cyclic operator, Cyclic Decomposition Theorem,~~Generalized Cayley Hamilton theorem~~, indecomposable linear operator, invariant factors,*Jordan form, Normal form*. **SectionC** Inner product, orthogonal sets, orthogonal complement and projections, adjoints, self adjoints,	**Section A** Review of groups, direct product of groups, normal subgroups, quotient groups, isomorphism theorems, Conjugates, Conjugacy in S_n, Class equation for a Group, Sylow's Theorems, Applications of Sylow's theorem, Simplicity of Alternating Group A_n for n>5, **Section B** Rings, Ring homomorphism and quotient rings, Ideals: Prime and Maximal, fields of fractions, Divisibility, Euclidean and Principal Ideal Domains, Unique Factorization Domains, Polynomial Rings over fields, irreducibility criteria. **Section C** Modules, Quotient modules, module homomorphisms, generation of modules, direct sums, free modules, modules over PID's, Chain conditions, Artinian modules, Northerian modules, Composition series, Modules of finite length, Jordan Holder Theorem, Artinian rings, Northerian rings, Hilbert Basis Theorem, I.S.Cohen's Theorem, Introduction of Nil radical and Jacobson radical. **Suggested Books:**	Shaded in Black from section A, B and C is shifted in Algebra I. Shaded in Grey is added. **Change in Credit**

		able to construct new examples from the old ones. • To check a subset of a ring is an ideal or not and be able to identify proper and maximal ideal. • To understand the concept of unique factorization domain and able to write a polynomial as the product of irreducible factors • To describe as a generalization of vector space and able to understand types of modules. • To grasp the concept of Artinian modules, Northerian modules, Artinian rings and Northerian rings.	spectral theorems, normal operators, unitary and orthogonal operators, ~~polar and singular values decomposition~~, Bilinear maps, symmetric bilinear maps and quadratic form. **Text Books:** 1. Hoffman and Kunze: Linear Algebra, 2nd Ed. Pearson, 1998. 2. Bruce N. Cooperstein: Advanced Linear Algebra, 2nd Ed., CRC Press,2015 **Reference Books:** 1. S. Lang: Linear Algebra, 3rd Ed., Springer Verlag, New York, 1987. 2. P.R. Halmos: Finite Dimensional Vector Spaces, 2nd Ed., Van Nostrand, New York, 1965. 3. Yisong Yang: Advanced linear algebra, Cambridge University Press, 2015	1. Gallian, J. A. (2013). *Contemporary abstract algebra*. (8th Ed.). Boston, MA: Brooks/Cole Cengage Learning. 2. Dummit, D. S. & Foote, R. M. (2004) *Abstract algebra* (3rd Ed.). New Jersey: Wiley. 3. Musili, C. (1994) *Introduction to Rings and Modules* (2ndEd.). New Delhi:.Narosa Publishing House. 4. Hungerford, T. W. (2014) *Abstract algebra: An introduction* (3rd Ed.). Australia: Brooks/Cole Cengage Learning. 5. Hillman A. P. &Alexandersor, G. L. (2015) *Abstract algebra: A first undergraduate course* (5th Ed.). CBS Publishers & Distributors Pvt. Ltd. 6. Fraleigh, J. B. (2003) *A first course in abstract algebra* (7th Ed.). Harlow: Pearson. 7. Sen, M. K., Ghosh, S., Mukhopadhyay, P. &Maity, S. K. (2019) *Topics in abstract algebra* (3rd Ed.). University Press. 8. Herstein, I. N. (1991) *Topics in algebra* (2nd Ed.). New Delhi: Wiley Eastern. **Suggested E-learning Material:** 1. Lecture Notes on Groups and Rings: https://ocw.mit.edu/courses/mathematics/18-703-modern-algebra-spring-2013/related-resources/ 2. Video Lectures on Algebra: https://www.extension.harvard.edu/open-	

				learning-initiative/abstract-algebra Open Source Book Abstract algebra: Theory and applications by Thomas W. Judson http://abstract.ups.edu/download/aata-20110810.pdf	
2.	MATH (To be generated) Analysis-II	On completion of the course, the student will be able to, • demonstrate understanding of the basic and advanced concepts underlying complex analysis. • demonstrate familiarity with a range of examples of these concepts. • prove advanced results/theorems in complex analysis. • apply the methods of complex function theory to evaluate integrals and infinite series of complex functions. • demonstrate understanding and appreciation of a deeper aspects of complex function theory. • demonstrate skills in communicating mathematics orally and in writing.	-	**Suggested E-learning material** 1. Complex Analysis; NPTL: https://nptel.ac.in/courses/111103070/	No change in syllabus. **Change in Credit.**
3.	MATH (To be generated) Ordinary Differential Equations	On completion of the course, students will be able to • Understand the existence and uniqueness of IVPs and their solution	**Section A** *First order differential equations: Method of successive approximation, Lipschitz condition, convergence of successive approximation*, ~~non-local existence of solutions.~~	**Sections A** Existence and Uniqueness of solutions: Introduction, Picard's Successive Approximations, Picard's theorem, Continuation and dependence of initial conditions, Existence of solutions in the large, Existence and	

		• Understand method of successive approximations, variation of constants, annihilator method, and reduction of order of a homogeneous equation. • Solve linear differential equations of higher order with variable coefficients. • Solve boundary value problems for second order equations. • Solve Boundary Value problems for second order equations by Green's function, Strum-Liouville Boundary Value problem. • Grasp the concept of the stability of system of differential equations • Solve system of linear differential equations and study the qualitative behavior of these systems.	*System of differential equations: solution by general method and matrix exponentials, Two Dimensional Autonomous Systems and Phase Space Analysis: critical points, proper and improper nodes, spiral points and saddle points.* **Section B** Linear Differential Equations: Existence and uniqueness theorems ~~constantand~~ variable coefficients ~~(2nd order and nth order),~~ Linear dependence and independence of solutions, Wronskian, variation of constants, ~~annihilator method,~~ reduction of the order of a homogeneous equation. **Section C** Homogeneous equation with analytic coefficients, Legendre equation, Euler equation, method of Frobenius, Bessel's equation, Boundary Value Problems for Second Order Equations: Green's function, Sturm-Liouville boundary value problem, eigenvalue Problem. **Text Books:** 1. E. A. Coddington: An Introduction to Ordinary Differential Equations, Dover Publication Inc., 1961. 2. S. Ahmad and A. Ambrosetti: A text book on Ordinary Differential Equations, 2nd Ed. Springer 2015. **Reference Books:** 1. S. A. Wirkus and R. J. Swift: Ordinary Differential Equation, 2nd Ed., CRC Press, 2015.	Uniqueness for systems, fixed point technique for nonlinear differential equations. **Section B** Linear Differential equations of higher order with variable coefficients: Introduction, Existence and Uniqueness theorem, linear dependence and Wronskian. Solution; Method of variation of parameters, Method of undetermined coefficients, Reduction of order. Boundary Value Problems for second order equations: Introduction, Green's function, Sturm Liouville problem. Applications of BVPs. **Section C** System of linear differential equations: Introduction, Existence and Uniqueness theorem, Solution of the system; Eigenvalue–Eigenvector Method and Fundamental Matrix Method. Matrix Exponential Function, Non-homogeneous linear systems. Phase Portrait in R^2. Plane Autonomous Systems: critical points and types of critical points and stability. **Text Books:** 1. Deo, S. G., Raghavendra, V., Kar, R. &Lakshmikantham, V. (2015) Textbook of ordinary differential equations (3rd Ed.). New Delhi: Mc Graw Hill Education. 2. Ahmad, S. &Ambrosetti, A. (2015). A Textbook on Ordinary Differential Equations (2nd Ed.). Switzerland: Springer. **Reference Books:** 1. Wirkus, S.A. & Swift, R.J. (2015). Ordinary Differential Equations, (2nd Ed.). USA: CRC	

			2. William E. Boyce and Richard C. Di Prima, Elementary Differential Equations and Boundary Value Problems, 10th Ed., 2012 3. Shepley L. Ross, Differential Equations, 3rdEd., Wiley Publication, 1989. 4. P. Hartman; Ordinary Differential Equations; John Wiley and sons, New York, 1964. 5. TynMyint-U, Ordinary Differential Equations, Elsevier North-Holland, 1978.	Press. 2. Birkhoff, G. & Rot, G.C. (1989). Ordinary Differential Equation (4th ed.), India: John Willey. 3. Braun, M. (1975). Differential Equations & their Applications. New York: Springer Verlag. 4. Codington, E.A. & Levinson, N. (1955). Theory of ordinary differential equation. New York: Mcgraw Hill. 5. Ross, S. L. (1984). Differential Equations (3rd ed.). India: Wiley Publication. 6. William E. B., & Richard C. D. (2012). Elementary Differential Equations and Boundary Value (10th ed.). New York: Wiley Publication. 7. Coddington, E. A. (1961). An Introduction to Ordinary differential equations. New Jersey, USA: Dover Publication Inc. 8. Hartman, P. (1964). Ordinary Differential Equations. New York; John Wiley and sons. **Suggested E-learning material** 1. Lecture notes: http://www.math.ust.hk/~machas/differential-equations.pdf 2. NAPTEL: https://nptel.ac.in/courses/111106100/ 3. Lecture Notes: http://home.iitk.ac.in/~sghorai/TEACHING/MTH203/ode.html	
4.	MATH (to be generated)	Upon successful completion of this course, student will be able to	**Section A** Infinite sets and axiom of choice, well ordered sets,	**Section A** Infinite sets and axiom of choice, Well-ordered sets, The	

	Topology	• Define and illustrate the concept of topological spaces and continuous functions. • Define and illustrate the concept of product topology and quotient topology. • Calculate simple topological invariants, such as the number of path components. • Define and illustrate the concepts separation axioms. • Use continuous functions and homeomorphisms to understand structure of topological spaces.	the maximum principle, Topological spaces, Bases for a Topology, The order Topology, The Product Topology, The Subspace Topology, Closed sets and Limit points, Continuous function. Continuity of a function, Homeomorphism, Construction of continuous functions, Metric Topology, The quotient Topology (Introduction only). **Section B** *Connectedness and Compactness: Connected Spaces, Connected sets in the Real line, Components and path components,* Local Connectedness, Compact spaces, Compact sets in the Real line, ~~limit point compactness.~~ **Section C** The Tietze extension Theorem, ~~The UrysohnMetrization Theorem. The Tychnoff Theorem,~~ The completely regular spaces, ~~The Stone-Cech compactification (Statement only),Complete Metric Spaces and Function spaces: Complete Metric Spaces, Compactness in Metric spaces, Pointwise convergence, The Compact Open Topology, Baire Spaces.~~ **Suggested Text/Reference Books:** 1. J.R. Munkres, **Topology- A First Course**, Prentice Hall of India, New Delhi, 1975. (The scope is indicated by the chapters 1, 2, 3, 4, 5, 6 & 7). 2. K.D. Joshi, **Introduction to General Topology**, Wiley Eastern, Delhi, 1986. 3. Mangesh G. Murdeshwar, **General Topology**, Wiley Eastern, New Delhi, 1983. 4. George F. Simmons, **Introduction to Topology**	maximum principle, Topological spaces, Bases for a topology, The order topology, The product topology, The subspace topology, Closed sets and limit points, Continuity of a function, Homeomorphism, Construction of continuous functions. **Section B** Metric topology, The quotient topology (Introduction only), Connected spaces, Path connected spaces, Connected sets in the real line, Components, Path components, Local connectedness, Local path connectedness, Compact spaces. **Section C** First countability axiom, Second countability axiom, Lindelof space, Regular space, Normal spaces, The Urysohn Lemma, Completely regular space. The Tietze extension theorem. **Suggested Books:** 1. Munkres, J. R. (1975) *Topology: A first course***.** New Delhi: Prentice Hall of India. 2. Singh, T. B. (2013) *Elements of topology*. CRC Press. 3. Joshi, K. D. (1986) *Introduction to general topology*. New Delhi: Wiley Eastern. 4. Murdeshwar, M. G. (1983) *General topology*.New Delhi: Wiley Eastern. 5. Simmons, G. F. (1963) *Introduction to topology & modern analysis.* Auckland: McGraw Hill. 6. Dugundji, J. (1990) *Topology,* New Delhi: Universal Book Stall. **Suggested E-learning Resources:** 1. Video Lectures:	

			&Modern Analysis, McGraw Hill, Auckland, 1963. 5. James Dugundji, **Topology**, Universal Book Stall, New Delhi,1990.	https://nptel.ac.in/courses/111106054/	
5.	MATH 409 Numerical Analysis	On completion of the course, the student will be able to, • Demonstrate numerical methods to obtain approximate solutions to mathematical problems. • Derive numerical methods for various mathematical operations and tasks, such as interpolation, differentiation, integration, the solution of linear and nonlinear equations, and the solution of ordinary differential equations. • Analyze the appropriate numerical method to find the Eigen values and corresponding eigenvectors of a system. • Use rational approximation of a function like Padé approximant for power series. • Solve the boundary value problems using shooting method and finite difference method. • Define and use the concepts accuracy, consistence, stability and convergence.	**Section A** Accuracy and approximate calculations: Different types of errors and their computations; ~~Finite differences: forward, backward and divide difference tables,propagation of error in difference table, missing data calculation~~, ~~errors in polynomial interpolation,~~Newton-Gregory forward and backward interpolation,~~central differences: central difference table~~, ~~Gauss formula, Stirling's formula, Bessel's formula. Interpolation with unequal intervals;~~Lagrange's formula,~~divided differences and their properties, Newton's general Interpolation formula,~~inverse interpolation, computation errors in these formulae and analysis of errors. **Section B** Numerical solutions of algebraic and transcendental equations: polynomial, transcendental equations, intermediate value theorem, Bisection method, Iterative method, ~~method of false position, secant method,~~ Newton-Raphson method, ~~Stability and~~ Convergence analysis of these methods, ~~Curve fitting (method of least squares, cubic splines interpolation), approximation of functions: Chebyschev'spolynomials.Taylor's series~~	**Section A** **Accuracy and approximate calculations:** Different types of errors and their computations. **Numerical solution of system of linear equations:** Direct methods: Gauss elimination method and Crout's (factorization) methods, Iterative methods: Jacobi method, Gauss-Seidel method, Vector and matrix norm, Condition number and ill-conditioning, condition of convergence in iterative methods. **Eigen values and Eigen vectors:** Singular value decomposition, Power method, Aitken's acceleration, Inverse Power method. **Section B** **Numerical solutions of algebraic and transcendental equations**: Polynomial and transcendental equations, intermediate value theorem, Bisection method, Iterative method, Newton-Raphson method, Convergence analysis of these methods. **Interpolation:** Newton-Gregory forward and backward interpolation, Lagrange's formula, inverse interpolation, computation errors in these formulae and analysis of errors, **Approximation of function:** Padé approximation. **Numerical Differentiation:** Maximum and minimum value of a tabulated function, Solution of difference	1. Shufflin g of the topics has been done to maintain the flow of syllabus. 2. Some advance d topics and numeric al methods have been added to benefit the students .

			~~approximation~~, Solution of linear systems of equations: Direct method,~~matrix inversion~~, Gauss elimination, Gauss-Jordan ~~and Crout's(factorization) methods,~~ iterative method, Jacobi and Gauss-Seidel methods, condition of convergence in iterative methods. **Section C** Numerical Differentiation: Maximum and minimum value of a tabulated function, Solution of difference equations, Numerical integration: Trapezoidal, Simpson's 1/3 and Simpson's 3/8 and Weddle's rules, Newton-cotes' integration formula, Gaussian quadrature formula. Numerical solution of ordinary differential equations: solution by Taylor's series method, Euler's method & modified Euler's method, Picard's method, Runge Kuttamethod(forth order), Predictor Corrector Method; Miline's method, estimation of errors, ~~Introduction to simultaneous and higher order equations,Solution of PDE (using finite difference approximation to derivatives).~~ **Text Books:** 1. S.S. Sastry, **Introductory Methods of Numerical Analysis**, 4th ed., PHI Learning Private Limited, New Delhi, 2005. **Reference Books:** 1. V. Rajaraman, **Computer Oriented Numerical Methods**, 2nd ed., Prentice Hall of India, New Delhi,1984. 2. S.D. Conte and C.D. Boor, **Elementary Numerical Analysis: An Algorithmic Approach**,	equations, **Numerical Integration:** Newton-cotes' integration formula, Trapezoidal, Simpson's 1/3 and Simpson's 3/8 and Weddle's rules, Gaussian quadrature formula. **Section C** **Numerical solution of ordinary differential equations: Initial value problems:**Lipschittzcondition for initial value problems, solution by Taylor's series method, Euler's method, Picard's method, Runge-Kutta methods, Runge-Kutta-Fehlberg method, Predictor corrector methods: Milne's method, estimation of errors, **Boundary value problems**: Shooting Method, Finite difference method, Rayleigh-Ritz method. **Stability analysis of these numerical methods.** **Suggested Text Books:** 1. Cheney, E. W., & Kincaid, D. (2008). *Numerical mathematics and computing* (5th ed.). Thomson Brooks/Cole. 2. Jain, M. K., Iyengar, S. R. K., & Jain, R. K. (2007). *Numerical methods for scientific and engineering computation* (5th ed.). New Delhi: New Age International. 3. Sastry, S. S. (2012). *Introductory methods of numerical analysis* (5th ed.). New Delhi: Prentice-Hall of India. **Suggested Reference Books:** 1. Burden, R. L., &Faires, J. D. (2005). *Numerical analysis* (7th ed.). Thomson Brooks/Cole. 2. Chauhan, D. S., Vyas, P., &Soni, V. (2014). *Studies in numerical analysis* (Reprint ed.), Jaipur Publishing	

			3rd ed., McGraw Hill, Auckland, 1981. 3. M. K. Jain, S. R. K. Iyengar and R. K. Jain, **Numerical Methods for Scientific and Engineering Computations**, 4th ed., New Age International, New Delhi, 2003. 4. Kendall E. Atkinson, **An Introduction to Numerical Analysis**, John Wiley, New York, 2nd ed., 2001. 5. G.M. Phillips and Peter J. Taylor, **Theory and Applications of Numerical Analysis**, 2nded.,Elsevier, 1996. 6. John R. Rice, **Numerical Methods, Software and Analysis**, MGH, Auckland, 1983. 7. P.K. De, **Computer Based Numerical Methods and Statistical Techniques**, CBS Publication, New Delhi, 1st ed., 2006.	House. 3. Rao, K. S. (2005), *Numerical methods for scientists and engineers* (2nd ed.). New Delhi: Prentice-Hall of India. 4. Phillips, G. M., & Taylor, P. J. (1996). *Theory and applications of numerical analysis* (2nd ed.). Elsevier. **Suggested E-learning material:** 1. Introduction to Numerical Analysis for Engineering, Platform: MIT open courseware https://ocw.mit.edu/courses/mechanical-engineering/2-993j-introduction-to-numerical-analysis-for-engineering-13-002j-spring-2005/index.htm 2. Numerical Analysis, Platform: nptelhttps://nptel.ac.in/courses/111107062/ 3. Elementary Numerical Analysis, Platform: nptel https://nptel.ac.in/courses/111101003/	
6.	MATH 409L Numerical Analysis Lab	On completion of the course, the student will be able to, • Implement numerical methods in MATLAB to solve systems of linear equations, compute quadrature, solve ordinary differential equations and various computational problems. • Write efficient, well-documented MATLAB code and present numerical results in an informative way.	Using MATLAB: Command window computations, M-files, Programming in MATLAB, Basic Mathematical Operations in MATLAB: Scalar addition and multiplication, Matrix addition and multiplication etc. 1. An M-file to implement the bisection method 2. MATLAB M-file to implement Newton-Raphson method for nonlinear systems of equations ~~3. Using MATLAB to Manipulate Polynomials and Determine Their Roots~~	1. A review of basic MATLAB functions on command window. 2. Writing Scripts and functions in MATLAB (m-files). 3. Flow control commands (If-else, for, while, switch). 4. An M-file to implement Gauss elimination method with partial pivoting for solving system of linear equations. 5. An M-file to implement Gauss-Seidel method.	List of Practicals is revised according to the syllabus of Computational lab-1 (New Course)

		• Show logical thinking in coding a mathematical problem in algorithmic form. • Use their knowledge of a programming in MATLAB to learn more easily any other programming language like Mathematica, Python etc.	~~4. MATLAB Matrix Manipulations~~ ~~5. Solving Linear Algebraic Equations Using MATLAB~~ 6. An M-file to implement Gauss elimination 7. Solving linear systems with Gauss elimination with partial pivoting 8. LU Factorization with MATLAB 9. MATLAB M-file to implement Gauss-Seidel. ~~10. Eigenvalues and Eigenvectors with MATLAB~~ 11. MATLAB Implementation for fitting a least-squares nth-order polynomial to data ~~12. Fitting a straight line with linear regression~~ ~~13. Polynomial Regression with MATLAB~~ ~~14. Nonlinear Regression with MATLAB~~ 15. An M-file to implement Newton interpolation 16. An M-file to implement Lagrange interpolation. 17. M-file to implement the composite trapezoidal rule 18. M-file to implement the trapezoidal rule for unequally spaced data ~~19. Calculating Differentiation using MATLAB~~ 20. An M-file to implement Euler's method for ordinary differential equations	6. An M-file to implement the bisection method. 7. An M-file to implement Newton-Raphson method for nonlinear equations. 8. An M-file to implement Newton's interpolation. 9. An M-file to implement Lagrange's interpolation. 10. Curve fitting: least-squares n^{th} order polynomial to data (liner and Quadratic). 11. An M-file to implement the trapezoidal and Simpson's rules. 12. An M-file to implement Euler's method for solving ordinary differential equations with a plot of exact and numerical solutions. 13. An M-file to implement Runge-Kutta methods (ode23 and ode45) for solving ordinary differential equations with a plot of exact and numerical solutions. 14. An M-file to implement finite difference method for solving ordinary differential equations with a plot of exact and numerical solutions. **Text Books/ Reference Books:** 1. Fausett, L. V. (2008). *Applied numerical analysis using MATLAB* (2nd ed.). Pearson Education. 2. Chapra,S. (2006). *Applied numerical methods with MATLAB for engineers and scientists*, McGraw-Hill Higher Education. **Suggested E-learning material:** 1. Introduction to Numerical Methods and	and revised syllabus of Numerical Analysis (MATH 409).

				MATLAB Programming for Engineers, Platform: Ohio University; http://www.ohiouniversityfaculty.com/youngt/IntNumMeth/ 2. Using numeric approximations to solve continuous problems, Platform: MathWorks; https://in.mathworks.com/discovery/numerical-analysis.html	
7.	**MATH** (code to be generated) Computational Lab-II	On successful completion of the course, the students will be able to, • Understand the fundaments of procedural and functional programming with Mathematica software; • Efficiently use these technical computing systems in one's studies and research. • Set up simple engineering problems such that they can be solved and visualized using basic codes.	-	1. Introduction to Wolfram Mathematica: Entering input, variables, assignment, execution, and evaluation of mathematical functions, rules and replacement, Notebooks in Mathematica. 2. Basic commands of Mathematica, Trigonometry. 3. Calculus: Roots of polynomials, partial fractions, differentiation, limits and expansions, integration, Optimization. 4. Lists and Matrices: Matrix Operations, transpose, determinant, inverse of a matrix, Index Notation. 5. Linear Algebra: Characteristic equation, Eigen values and Eigenvectors, Row reduced echelon form and normal form, Vector Spaces, Linear Transformations, Solutions to system of linear equations. 6. Graphics: Plotting of simple functions, Two- and Three-dimensional Plotting (Cartesian, parametric and polar equations, Vector plots), Graphics Primitives, and Formatting. 7. Differential equations: analytic and numerical solutions of ODEs, Plotting of second order	New Course

				solution family of differential equation, System of ODEs (critical points, phase portrait diagrams and time series plots). 8. Plotting of recursive sequences. 9. Study the convergence of sequences through plotting. 10. Verify Bolzano-Weierstrass theorem through plotting of sequences and hence identify convergent subsequences from the plot. 11. Study the convergence/divergence of infinite series by plotting their sequences of partial sum. Cauchy's root test by plotting nth roots. 12. Ratio test by plotting the ratio of n^{th} and $(n+1)^{th}$ term. **Suggested Readings:** 1. The Mathematica Book, Fifth Edition by Stephen Wolfram; https://www.wolfram.com/language/elementary-introduction/2nd-ed/ 2. Lecture Notes on Mathematics for Materials Scientists and Engineers; https://ocw.mit.edu/courses/materials-science-and-engineering/3-016-mathematics-for-materials-scientists-and-engineers-fall-2005/lecture-notes/	
8.	STAT (To be generated) Statistical Inference	After successful completion of this course, student will be able to: • Apply various parametric, non-parametric and sequential estimation techniques and testing procedures to deal with real life	-	**Suggested E-Learning Material:** 1. Statistical Inference; Platform: MITOPENCOURSEWARE https://ocw.mit.edu/index.htm 2. Statistical Inference; Platform: Coursera https://www.coursera.org	No change in syllabus. **Change in credit.**

		problems. • Understand confidence interval, Neyman-Pearson fundamental lemma, UMP test, Interval estimation. • Understand SPRT, OC and ASN function. • Understand non-parametric methods, U-statistic.		3. Statistical Inference: Platform: e-PG Pathshalahttps://epgp.inflibnet.ac.in	
9.	STAT (To be generated) Measure Theory & Advanced Probability	On successful completion of this unit, students will be able to: • Understand the basic concepts of measure and integration theory. • Understand of the theory on the basis of examples of application. • Use abstract methods to solve problems and to use a wide range of references and critical thinking. • Use weak and strong law of large numbers in statistical theory.	**Section A** Measure Theory - Fields, Sigma Fields, Monotone Classes, Set Functions, Measure, Outer Measure, Carotheodory's Extension Theorem. Probability Measure, Lebesgue Measure, Lebesgue Stieljes Measure. Measurable Functions, Monotone and Dominated Convergence Theorem. Product Spaces, Fubini's Theorem (without proof), ~~Signed Measure, Radon Nikodym Theorem (without proof).~~ **Section B** Inequalities-Cauchy-Schwartz Inequalities, Holder Inequalities, Minkowski Inequality, Jensen Inequality,~~Hajek Renyi Inequality~~. Sequences of Distribution Function, Helly Bray Theorem. Almost sure Convergence, Convergence in Probability, Convergence in Mean Square. Borel-Cantelli Lemma and Zero One Law. Characteristics Function. Inversion and Continuity Theorem. **Section C** Weak and Strong Law of Large Numbers-Khintchine, Kolmogorov Theorem. One Dimensional	**Section A** Measure Theory-Fields, Sigma Fields, Monotone Classes, Set Functions, Measure, Outer Measure, Carotheodory's Extension Theorem. Probability Measure, Lebesgue Stieljes Measure. Measurable Functions, Monotone and Dominated Convergence Theorem. Product Spaces, Fubini's Theorem (without proof). **Section B** Sequences of Distribution Function, convergence: convergence in distribution, convergence in probability, almost sure convergence, convergence in Mean Square. Helly Bray theorem, Borel-Cantelli lemma and zero one law. Characteristics function, inversion and continuity theorem. **Section C** Inequalities: Cauchy-Schwartz inequality, Chebychev's inequality, Holder Inequality, Minkowski Inequality, Jensen Inequality. Weak and strong Law of Large Numbers-Khintchine, Kolmogorov theorem. One Dimensional Central Limit theorem- Lindeberg Levy, Lyapunov, Lindeberg Feller theorem.	**Change in credit.**

			Central Limit Theorem- Lindeberg Levy, Lyapunov, Lindeberg Feller Theorem. ~~Representation of Distribution Function as a mixture of Discrete and Continous Distribution Function, Convolutions, Marginal and Conditional Distributions of Bivariate Distributions.~~ **Suggested Text/ Reference Books:** 1. W. Feller, **An introduction to Probability Theory and Applications**, **Vol I & Vol II**, John Wiley & Sons. 2. K.L. Chung, **A Course in Probability Theory**, Academic Press. 3. B.R. Bhatt, **Modern Probability Theory**. 4. V.K. Rohtagi, **An Introduction to Probability Theory and its Applications**, John Wiley & Sons. 5. P.R. Halmos, **Measure Theory**, Springer-Verlag. 6. H. Bauer, **Probability Theory and Elements of Measure Theory**, Academic press.	**Suggested Text/ Reference Books:** **1.** Feller, W. (2008). *An Introduction to probability theory a applications* (Vol. I & Vol. I). John Wiley & Sons. **2.** Chung, K. L. (2011). *A Course in Probability Theory* (3 ed.). San Diego, Academic Press. 3. Bhatt, B. R. (2019). *Modern Probability Theory* (4th ed London, UK : New Academic Science. 4. Rohatgi, V. K. (2000). *An Introduction to probability theo and mathematical statistics* (2nd ed.). Wiley series probability and statistics. 5. Halmos, P. R. (2013). *Measure Theory* (Vol. 18). N York: Springer. 6. Bauer, H. (1981). *Probability theory and element of measu theory* (2nd ed.).London: Academic Press. **Suggested E-Learnings Material:** 1. Measure Theory: www.math.tifr.res.in/~publ/ln/tifr12.pdf 2. Measure Theory and probability: https://www.math.ucdavis.edu/~hunter/measure_theory/ 3. CLT and applications: https://newonlinecourses.science.psu.edu/stat414/node/133/	
10.	CS 417 Database Management Systems	On successful completion of the course students will be able to • Describe data models and schemas in DBMS • Understand the features of database management system and Relational databases.	-	**Suggested E-Learnings Material:** 1. Data Base Management System https://nptel.ac.in/courses/106105175/ 2. Database Management Essentials by University of Colorado https://www.coursera.org/learn/database-management	

		• Use SQL -the standard language of relational databases. • Understand the functional dependencies and design of the database. • Understand the concept of Transaction and Query processing.		3. Database System Concepts by Abraham Silberschatz, Henry F. Korth and S. Sudarshan https://kakeboksen.td.org.uit.no/Database%20System%20Concepts%206th%20edition.pdf	

THIRD SEMESTER

S.N.	Course List	Learning Outcomes	Existing Syllabus	Suggested Syllabus	Remark
1.	MATH (to be generated) Advanced Calculus	On completion of the course, the student will be able to, • Analyze vector functions to find derivatives, tangent lines, integrals, and arc length. • Evaluate integrals of functions or vector-related quantities over curves, surfaces, and domains in two- and three-dimensional space. • Use the Lagrange multiplier method to find extrema of functions with constraints. • Solve problems involving tangent planes and normal lines.	**Section A** Euclidean Space R^n, Basic Topology on R^n, Functions on Euclidean spaces, continuity Uniform Continuity, Differentiability; Partial and directional derivatives. Affine functions, First order approximation of Real Valued functions, quadratic Functions Hessian Matrices, second order approximation and second derivative test. **Section B** Linear mappings and Matrices, The Derivative matrix, First order approximation Theorem for mappings, Chain Rule, Inverse Function Theorem, Implicit Function Theorem, Lagrange Multipliers. **Section C** Riemann Integral of real-valued functions on ~~Euclidean spaces~~, Integration of functions on Jordan Domains, Fubini's Theorem, Change of Variables,	**Section A** Euclidean Space R^n, Basic Topology on R^n, Functions on Euclidean spaces, continuity, Uniform Continuity, differentiability; partial and directional derivatives. Affine functions, First order approximation of Real valued functions, quadratic functions, Hessian Matrices, second order approximation and second derivative test. **Section B** Linear mappings and Matrices, The derivative matrix, First order approximation Theorem for mappings, Chain Rule, Inverse Function Theorem, Implicit Function Theorem, Lagrange Multipliers. **Section C** Riemann Integral of real-valued functions on Generalized rectangles, Continuity and integrability, Integration of functions on Jordan Domains, Fubini's Theorem, Change of Variables. **Suggested Text Book:**	**Change in credit.**

			~~Line and Surface Integrals, Green and Stokes Theorem.~~ **Text Book :** 1. Patrick M. Fitzpatrick, Advanced Calculus, Second edition, AMS. **Suggested Text/Reference Books:** 1. J.R. Munkres, Analysis on Manifolds, Addison-Wesley, 1991. 2. GB Folland, Advanced Calculus, Pearson. 3. V. Guillemin and A. Pollack, Differential Topology, Prentice-Hall Inc., Englewood Cliffe, New Jersery, 1974. 4. W. Fleming, Funcetions of Several variables, 2nd Edition, Springer-Verlag, 1977. 5. W. Rudin, Principles of Mathematical Analysis, 3rd Edition, McGraw-Hill, 1984. 6. M. Spivak, Calculus on Manifolds, A Modern Approach to Classsical Theorems of Advanced Calculus, W.A. Benjamin, Inc., 1965.	1. Fitzpatrick, P. (2009). *Advanced calculus*. Providence, R.I: American Mathematical Society. **Suggested Reference Books:** 1. Munkres, J. R. (2018). *Analysis on manifolds*. Boca Raton, FL: CRC Press/Taylor & Francis Group/Advanced Book Program. 2. Folland, G. B. (2009). *A guide to advanced real analysis*. Washington, D.C.: Mathematical Association of America. 3. Rudin, W. (2017). *Principles of mathematical analysis*. Chennai: McGraw Education (India) Private Limited. **Suggested E-learning material** 1. Lecture Notes on Multivariable Calculus; Platform: NPTEL https://nptel.ac.in/courses/111107108/	
2.	MATH (to be generated) Functional Analysis	On completion of the course, the student will be able to, • explain the basic concepts of Functional Analysis, including the study of operator theory and the study of topological function spaces. • describe how to illustrate the abstract notions in functional analysis via examples.	-	**Suggested E-learning material** 1. Introduction to Functional Analysis; Platform: MITOPENCOURSEWARE https://ocw.mit.edu/courses/mathematics/18-102-introduction-to-functional-analysis-spring-2009/ 2. Functional Analysis; Platform; NPTELhttps://nptel.ac.in/courses/111105037/ 3. Functional Analysis; Platform: Free video lectureshttps://freevideolectures.com/course/3	No change in Syllabus. **Change in credit.**

		• apply Hilbert space-theory, including Riesz' representation theorem and weak convergence, and methods in problem solving. • solve the problems appear in PDEs via the powerful tools from functional analysis, • study in a range of other fields, e.g. Quantum Theory, Stochastic calculus and Harmonic analysis.		145/functional-analysis	
3.	MATH (to be generated) Operations Research	On completion of the course, the student will be able to, • Build a mathematical programming model of a real-life situation • Write a report that describes the formulation of a linear and nonlinear programming problem, and presents and interprets the solutions. • Understand the basic theory in linear and nonlinear programming • Apply a suitable method in research to develop the theories which will be applicable in the real-life problems. • Understand the concepts of	**Section A** Network Analysis, Introduction of Network analysis, shortest path problem PERT & CPM Updating of PERT charts, ~~project planning and scheduling with CPM & PERT.~~ **Section B** Queuing Theory, Probability description of arrivals and service times, objectives and different characteristics of a queuing system, deterministic queuing system, steady-state behaviour of Markovian and Earlangian Models (M/M/1, M/M/C, M/Ek/1). ~~Introduction to discrete time queuing system.~~ **Section C** Inventory Theory, Deterministic economic lot size models and their extensions, models with lost sales and partially backlogged, continuous production with varying demand rates. ~~Probabilistic model time~~	**Section A** Linear Programming: Simplex method, Theory of simplex method, Duality in linear programming. Dual simplex method. Assignment and Transportation Problem. **Section B** Dynamic Programming: Introduction, characteristics of dynamic programming, dynamic programming algorithm, solution of discrete dynamic programing problem. Sequencing Problem: Introduction, processing n jobs through two machines, processing n jobs through k machines, processing two jobs through k machines. Network Analysis, Introduction of Network analysis, shortest path problem PERT & CPM. Updating of PERT charts. **Section C** Queuing Theory, Probability description of arrivals and	**Change in Credit.**

		dynamic programming, job sequencing, network analysis. • Understand the basic concepts and need of inventory theory and queuing theory.	~~independent and time dependent with and without lead time.~~ **Suggested Text/ Reference Books:** 1. J.C. Pant, **Introduction to Optimization: Operations Research**, 2nd ed., Jain brothers, New Delhi, 1988. 2. Hamdy A. Taha, **Operations Research**, Machmillan& Co, 9th ed., New York, 2010. 3. Frederick S. Hiller & Gerald J. Lieberman, **Operations Research**, 2nd ed., Holden-San Francisco, 1974. 4. Kanti Swaroop, **Operations Research**, S.Chand, New Delhi, 1977. 5. S.D. Sharma, **Operations Research**, Kedarnath Ramnath, Meerut, 1994. 6. Nirmal Singh Kambo, **Mathematical Programming Techniques**, Affiliated East-West, New Delhi, 1991.	service times, objectives and different characteristics of a queuing system, deterministic queuing system, steady-state behaviour of Markovian and Earlangian Models (M/M/1, M/M/C, M/Ek/l). Inventory Theory, Deterministic economic lot size models and their extensions, models with lost sales and partially backlogged, continuous production with varying demand rates. **Suggested Books:** 1. Swarup, K., Gupta, P. K., & Mohan, M. (1977). *Operations Research (Answers to problems)*. New Delhi: Sultan Chand & Sons. 2. Pant, J. C. (2004). *Introduction to optimization: Operations Research*. New Delhi: Jain Brothers. 3. Taha, H. A., & Pearson Education. (2017). *Operations research: An introduction*. Harlow [i 21 pozostałych: Pearson. 4. Hillier, F. S., & Lieberman, G. J. (1972). *Introduction to operation research*. San Francisco: Holden-Day. 5. Sinha, S. M. (2006). *Mathematical programming: Theory and methods*. New Delhi: Elsevier. **Suggested E-learning material:** 1. Tutorial: https://ibmdecisionoptimization.github.io/tutorials/html/Linear_Programming.html 2. Tutorial: Sophia Learning: https://www.sophia.org/tutorials/linear-programming--5 3. Lectures – NPTEL:	

				https://nptel.ac.in/courses/111102012/ 4. Nonlinear Programming – MIT http://web.mit.edu/6.252/www/. 5. Nonlinear Programming: https://ocw.mit.edu/courses/sloan-school-of-management/15-084j-nonlinear-programming-spring-2004/lecture-notes/	
4.	STAT (to be generated) Survey Sampling	On completion of the course, the student will be able to, • Understand the distinctive features of sampling schemes and its related estimation problems. • Learn about various approaches (design based and model-based) to estimate admissible parameters; with and without replacement sampling scheme, sampling with varying probability of selection. • Learn about the methods of post–stratification (stratified sampling) and controlled sampling and also double sampling procedure with unequal probability of selection. • Learn about the applications of sampling methods; systematic, stratified and cluster sampling. • Understand the cluster and two stages sampling with varying sizes of clusters/first stage units. • Understand the super population	-	**Section A** Review of Simple random Sampling, Stratified Sampling, Cluster sampling with equal/unequal sample sizes, double sampling, Post and deep stratification, Sampling with varying probability of selection with replacement and without replacement, Midzuno Sen and Narain methods of sampling. **Section B** Horwitz-Thompson estimates, Desraj ordered estimator, Lahiri's method and cumulative total, Yates and Grandy estimate of variance its non-negativity. Auxiliary variable: Ratio, product and regression method of estimation, Quenouille's techniques of bias reduction,Hortley and Ross unbiased ratio type estimator. Ratio and Regression estimators with combined and separate type estimates, two phase sampling (double sampling) in Ratio and Regression estimation. **Section C** Non-sampling errors: Incomplete samples effect of non response, Hensen and Hurvitz technique, Politz – Simmon's "not at home" method, Interpenetrating samples. Randomized response techniques – both qualitative and quantitative.	New Course

		approach to estimation. • Understand non sampling error and estimation techniques in presence of non response.		**Suggested Readings** 1. Cochran, W. G. (2007). *Sampling techniques(3rd. ed.)*. John Wiley & Sons. 2. Raj, D., &Chandhok, P. (1998). *Sample survey theory*. Narosa. 3. Chaudhuri, A. (2014). *Modern survey sampling*. CRC Press. 4. Chaudhuri, A. (2016). *Randomized response and indirect questioning techniques in surveys*. Chapman and Hall/CRC. 5. Sukhatme, P. V. (1963). *Sampling theory of surveys with applications.* The Indian Society Of Agricultural Statistics; New Delhi. 6. Murthy, M.N. (1967). *Sampling Theory and Methods. (2nd ed.)*. Statistical Publishing Society, Calcutta. 7. Singh, D. & Chaudhary, F.S. (2018). *Theory and Analysis of Sample Survey Design*. New Age International (P) Ltd. 8. Goon, A. M., Gupta, M. K., & Dasgupta, B. (2016). *Fundamental of Statistics Vol. II*. World Press. 9. Chaudhuri, A. (2016). *Randomized response and indirect questioning techniques in surveys.* Chapman and Hall/CRC. 10. Chaudhuri, A. (2013): *Essentials of Survey Sampling*, PHI Learning Pvt. Ltd, Delhi. **Suggested E-learning Resources** 4. Design of experiment and sample surveys; Platform: e-PG Pathshala https://epgp.inflibnet.ac.in	

				5. Survey Sampling; Platform: University Library - The University of Adelaide https://www.adelaide.edu.au/library/ 6. Survey Sampling; Platform: MITOPENCOURSEWARE https://ocw.mit.edu/index.htm	
5.	STAT (to be generated) Time Series and Stochastic Process	On the successful completion of the course the students should be able to • Plot a time series and interpret the components. • Identify and estimate cyclical fluctuations in the time series. • Examine the relationship between the lagged values of the series. • Test for the stationarity of the series. • Estimate ARIMA(p,d,q) model for the series. • Define stochastic process and identify its type . • Understand the concept of Markov chain and its basic properties using some theorems. • Define and understand the concept and application martingale. • Define Poisson process and understand its properties with some applications. • Apply gamblers ruin problem for	**Section A** Time series as a stationary or non stationary stochastic process, Time domain analysis based on correlogram, Sample autocovariance function and autocorrelation function at lag K, Lag correlation. Measurement of cyclic fluctuations: Periodogram and its relation with acvf, Harmonic analysis. Measurement of irregular component: Variate difference method. AR(p) process, MA(q) process, mixed ARMA(p, q) process, Stationarity and inevitability conditions, ARIMA (p, d, q) model, Estimation of parameters, Tests for stationarity Stochastic – Process. **Section B** Markov Chain having two states, n-step transition probabilities, Classification of states, Recurrent and transient states, Chapman-Kolmogorov equations, Stationary probability theorems and limit theorem for ergodic chains, Martingales. **Section C** Poisson process, birth and death process, Random walk and Gambler's Ruin problem, Wiener process, Renewal theory and its application, Branching chains: Discrete Process (Galton-Watson),	**Section A** Time series as a stationary or non stationary stochastic process, Time domain analysis based on correlogram, Sample autocovariance function and autocorrelation function at lag K, Lag correlation. Measurement of cyclic fluctuations: Periodogram and its relation with acvf, Harmonic analysis. Measurement of irregular component: Variate difference method. AR(p) process, MA(q) process, mixed ARMA(p, q) process, Stationarity and inevitability conditions, ARIMA (p, d, q) model, Estimation of parameters, Tests for stationarity Stochastic – Process. **Section B** Markov Chain having two states, n-step transition probabilities, Classification of states, Recurrent and transient states, Chapman-Kolmogorov equations, Stationary probability theorems and limit theorem for ergodic chains, Martingales. **Section C** Poisson process, birth and death process, Random walk and Gambler's Ruin problem, Wiener process, Renewal theory and its application, Branching chains: Discrete	**Change in Credit.**

		some problems. • Understand the basic concept and applications of Weiner process, Renewal theory and branching process.	~~Continuous process (Markov Branching), Fundamental theorem of Extinction.~~ **Suggested Text/ Reference Books:** 1. P.G.Hoel, S.C. Port, C.J. Stone, **Introduction to Stochastic Processes**, Universal Book Store, New Delhi. 2. S.K. Srinivasan, K.M. Mehata, **Stochastic Processes**, Tata McGraw-Hill Publishing Company limited, New Delhi, 1988. 3. J. Medhi, **Stochastic Processes**.New Age international, 1982. 4. G.E.P. Box, G.M. Jenkins, and Gregory C. Reinset **Time Series Analysis: Forecasting and Control**, John Wiley 4th edn 2008. 5. C. Chatfield, **The Analysis of Time Series: Theory and Practice**, Chapman and Hall in 1975.	Process (Galton-Watson). **Suggested Text/Reference Books** 1. Hoel, P. G., Port, S. C., & Stone, C. J. (1971). *Introduction to probability theory*, Universal Book Store, New Delhi. 2. Srinivasan, S. K., &Mehata, K. M. (1988). *Stochastic Processes*. New Delhi: Tata McGraw Hill. 3. J. Medhi, J. (1994). *Stochastic processes*. New Age International Publications. 4. Box, G. E. P., Jenkins, G. M., &Reinsel, G. C. (2008). *Time series analysis: Forecasting and control*. Hoboken: Wiley. 5. Chatfield, C. (1975). *The Analysis of Time Series: Theory and Practice*. Boston, MA: Springer US. **Suggested E-learning material:** 1. Lecture Notes and Videos on "Stochastic Hydrology": https://nptel.ac.in/courses/105108079/ 2. Course material on "Time Series Analysis": http://hdl.handle.net/1721.1/46343 3. Lecture Notes on "Introduction to Stochastic Processes": https://ocw.mit.edu/courses/mathematics/18-445-introduction-to-stochastic-processes-spring-2015/lecture-notes/ 4. Lecture Notes on "Discrete Stochastic Processes": https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-262-	

				discrete-stochastic-processes-spring-2011/course-notes/	
6.	STAT 507 Design of Experiments and Linear Models	After successful completion of this course, student will be able to: • Identify what design was followed and its features, describe what assumptions are appropriate in modelling the data. • Analyse the results of a designed experiment in order to conduct the appropriate statistical analysis of the data. • Interpret statistical results from an experiment and report them in non-technical language. • Compare efficiency of the experimental designs.	-	**Suggested E-learning Resources** 1. Lecture notes on Design of Experiments http://www.iasri.res.in/ebook/EB_SMAR/e-book_pdf%20files/Manual%20III/2-Basic%20Experiments.pdf	No change in Syllabus.
7.	STAT (to be generated) Computational Lab-III	On completion of the course, the student will be able to, • Analyze 2^n- factorial experiments. • Apply ANCOVA with one and two concomitant variable • Execute analysis and understanding of Split-plot designs and strip-plot design • Appraise Narain, Horwitz-Thompson estimator, Des Raj's ordered estimator. • Employ AR (p) process,MA (q)	-	Design of Experiment and Linear Models. 1. Analysis of Completely randomized design (CRD) and Randomised block design (RBD). 2. 2-square factorial experiment. 3. 2- cube factorial experiment without confounding. 4. 2- cube factorial experiment with partial confounding. 5. 2- cube factorial experiment with complete confounding. 6. Split-plot designs 7. Strip plot designs. 8. ANCOVA with one concomitant variable.	New Course

		process, Mixed ARMA (p, q) process.		9. ANCOVA with two concomitant variable. 10. BIBD Survey sampling: 1. Estimation of mean and variance of sampling mean in cluster sampling. 2. Estimation of mean and variance using combined and separate ratio type estimators. 3. Estimation of population mean and total by ration and regression method of estimation. 4. Double sampling for ratio and regression methods of estimation. 5. Narain, Horwitz-Thompson estimator and its variance. 6. Des Raj's ordered estimator and the estimate of their variances. Time Series and Stochastic Process: 1. Decomposition of time series. 2. Correlogram analysis. 3. Testing for stationarity. 4. Estimation of ARMA (p, q) process. 5. Estimation of ARIMA (p, d, q) model. **Suggested E-learning Material:** 1. Lawson, J. (2014). *Design and Analysis of Experiments with R*. Chapman and Hall/CRC. 2. Book on Design of Experiment with R https://cran.r-project.org/doc/contrib/Vikneswaran-ED_companion.pdf **3.** Statistics: An introduction using	

				R:https://bit.ly/30deSj5	
8.	MATH (To be generated) Queuing Theory	On completion of the course, the student will be able to • Understand the principles and objectives of model building based on Markov chains. • Analyze the queueing situations. • Understand the mathematical tools that are needed to solve queueing problems. • Identify and develop queueing models from the verbal description of the real system.	**Section A** *Concept of stochastic processes*. Markov Chains *discrete and continuous time parameter.* Objectives and different characteristics of a Queueing system. Performance measures. Steady state solution of Markovian Models (M/M/1, M/M/c, M/Ek/1, Ek/M/1). **Section B** *Analytical method and use of randomization technique to find the transient solution of M/M/1,* ~~M/M/c and M/M/μ~~ queuing models including busy period distribution. **Section C** Imbedded markov chain technique and its use to the queueing models: M/G/1, GI/M/1 ~~and M/D/c~~, *Bulk queuing models*. Different design and control policies ((O, N) and vacation policies) for Markovian Queuing models. ~~Introduction to discrete time queuing system.~~ Simulation procedures: Data generation and Book-keeping aspects. **Suggested Text Books:** 1. D. Gross and C.M. Harris, **Fundamentals of Queueing Theory**, 2nd Ed., John Wiley, 1985. 2. Michel E. Woodward, **Communication and Computer Networks Modeling with Discrete Time Queues**, IEEE Computer Society Press, 1994. (Chapter 4)	**Section A** Introduction of stochastic processes, Markov process, Markov Chain, Poisson process with its properties and related distributions (without proof) and birth-death process. Objectives and different characteristics of a Queueing system. Performance measures. Steady state solution of Markovian queueing models: M/M/1 and M/M/c. and their performance measures. **Section B** Steady State solution of $M/E_k/1$ and $E_k/M/1$ queueing models with their performance of measures. The transient solution of M/M/1 and $M/M/\infty$ Queueing models including busy period distribution. **Section C** Imbedded Markov chain technique and its use to solve the Queueing models: M/G/1 and GI/M/1. Bulk queuing models: $M^{[X]}/M/1$ and $M/M^{[Y]}/1$. Different design and control policies for Markovian Queueing models. Simulation procedures: Data generation and Book- keeping aspects. **Suggested Text Books:** **1.** Gross, D., & Harris, C. M. (1985). *Fundamental of Queueing Theory*. (2nd ed.). John Wiley. **2.** Michel, E. W. (1994). *Communication and Computer Networks Modeling with discrete Time queues*. IEEE Computer Society Press. (Chapter 4) **Suggested Reference Books:** 1. Cooper, R. B. (1981). *Introduction to Queuing*	**Change in Credit.**

			Suggested Reference Books: 1. R.B. Cooper, **Introduction to Queuing Theory**, 2nd Ed., North Holland, 1981 2. D.R. Cox and W.L. Smith, **Queues**, Mathuen, 1961. 3. L. Kleinrock, **Queuing Systems, Vol. I**, John Wiley, 1975. 4. J. Medhi, **Stochastic Model in Queuing theory**, Academic Press, 1991. 5. T.L. Satty, **Elements of Queuing Theory with Applications**, Mc-Graw Hill, 1961.	*Theory*. (2nd ed.). North Holland, Elsevier. 2. Cox, D. R. & Smith, W. l. (1961). *Queues*. Mathuen& Co. Ltd. 3. Kleinrock, L. (1975). *Queuing System*. (Vol. 1). John Wiley. 4. Medhi, J. (1991). *Stochastic Models in queuing Theory*. Academic Press. 5. Satty, T. L. (1961). *Elements of Queuing Theory with Applications*. Tata McGraw Hill. **Suggested E-learning Material:** 1. Queuing Systems, NPTEL https://nptel.ac.in/courses/117103017/1 2. Introduction to stochastic process and applications, NPTEL https://nptel.ac.in/courses/110104024/1 3. Stochastic Process and Time series, ePATHSHALAhttps://epgp.inflibnet.ac.in/ahl.php?csrno=34	
9.	CS 209 Data Structures	On successful completion of the course students will be able to • Develop knowledge of basic data structures for storage and retrieval of ordered or unordered data. Data structures include: arrays, linked lists, stacks, queues, binary trees, heaps. • Develop knowledge of applications of data structures including the ability to implement algorithms for the creation,	-	**Suggested E-learning material:** 1. Programming and Data Structures https://swayam.gov.in/course/1407-programming-and-data-structures 2. Data Structures and Program Methodology https://nptel.ac.in/courses/106103069/	

		insertion, deletion, searching, and sorting of each data structure. • Learn to analyze and compare algorithms for efficiency using Big-O notation. • Understand the concept of Dynamic memory management, data types, algorithms, Big O notation. • Apply Algorithm for solving problems like sorting, searching, insertion and deletion of data			
10.	MATH (to be generated) Inventory Theory	On completion of this course, students will be able to: • Comprehend the dynamics of inventory management's principles, concepts, and techniques as they relate to the entire supply chain (customer demand, distribution, and product transformation processes), • Understand the methods used by organizations to obtain the right quantities of stock or inventory, • Familiarize themselves with inventory management practices. • Optimize different case studies requires efficient methods and practices to address inventory management problems.	**Section A** *Analytical structure of production and Inventory problems, Inventory related costs, properties of inventory systems, Factors influencing inventories.* *Deterministic inventory models and extensions without and with lead time, Inventory models with partial backlogging and sales, Models with continuous production and non-constant demand with known production capacity, Inventory models with constraints,Quantity discounts; All units and incremental, Sensitivity of the lot size system,*~~N-products and M-Machines model.~~ **Section B** Stochastic Inventory Models and Extensions without and with lead time, ~~Use of transformation from time-dependent for continuous and discrete demand,~~ Power demand pattern Inventory Model~~, Safety stock and Buffer stock.~~	**Section A** Concepts of Inventory, Classification of inventory models, EOQ model, EPQ model, EOQ model with shortages, EPQ model with shortages, EOQ model with constraints: Quantity discounts, Floor Constraints, Investment Constraint. Sensitivity analysis in inventory models. **Section B** Stochastic Inventory Models and Extensions without and with lead time. Power demand pattern inventory model, Introduction to Just In Time (JIT) and Vendor Managed Inventory (VMI). **Section C** Simulation in Inventory system, Classification of items viz: ABC, VED, FNSD, HML, SDE, XYZ,Case studies in inventory control. **Suggested Books:** 1. Hadley, G., Whitin, T. M.. (1963). *Analysis of inventory systems.* Englewood Cliffs, N.J.: Prentice-Hall. 2. Naddor, E. (1984). *Inventory systems*. Malabar, Fla:	Change in Credits

		• Understand the behavior of the inventory parameters after some time using simulation techniques.	**Section C** Simulation in Inventory system, Production scheduling, Classification of items viz: ABC, VED, (FNSD, HML, SDE, XYZ), Case studies. **Books Recommended:** **Text Books:** 1. Kanti Swarup, **Operation Research**, Sultan Chand & Sons, 2010. 2. Sharma S.D., **Operations Research**, Kedarnath Ramnath, Meerut, 1972. **Reference Books:** 1. G. Hadley, T. Whitin, **Analysis of Inventory Systems**, Prentice Hall, 1963. 2. E.Naddor, **Inventory System**, John Wiley, New York, 1966.	R.E. Krieger. 3. Waters, D. (2008). *Inventory Control And Management, 2Nd Ed*. Wiley India Pvt. Limited. **Suggested E-learning material:** 1. Inventory Models costs, EOQ model(Lecture PDF) https://nptel.ac.in/courses/110106045/9 2. Inventory management(PDF) https://ocw.mit.edu/courses/engineering-systems-division/esd-260j-logistics-systems-fall-2006/lecture-notes/	
11.	CS 315 Theory of Computation	On successful completion of the course students will be able to • Explain basic concepts in formal language theory, grammars, automata theory, computability theory, and complexity theory. • Understand abstract models of computing, including deterministic (DFA), non-deterministic (NFA), Push Down Automata(PDA) andTuring (TM) machine models and their power to recognize the languages. • Understand the application of	-	**Suggested E-learning material:** 1. Theory of Computation https://nptel.ac.in/courses/106104028/ 2. An Introduction to Formal Languages and Automataby Peter Linz http://almuhammadi.com/sultan/books/Linz.5ed.pdf	No Change

		machine models and descriptors to compiler theory and parsing. • Relate practical problems to languages, automata, computability, and complexity. • Apply mathematical and formal techniques for solving problems in computer science. • Understand the relationship among language classes and grammars with the help of Chomsky Hierarchy.			
12.	CS 308 Operating Systems	On successful completion of the course students will be able to • Learn the fundamentals of Operating Systems. • Learn the mechanisms of OS to handle processes and threads and their communication • Learn the mechanisms involved in memory management in contemporary OS • Gain knowledge on Mutual exclusion algorithms, deadlock detection algorithms and agreement protocols • Know the components and management aspects of concurrency management • Learn Case study of Unix OS.	-	**Suggested E-learning material:** 1. Operating Systems https://nptel.ac.in/courses/106108101/ 2. Linux for Developers by The Linux Foundation https://www.coursera.org/learn/linux-for-developers	No Change

13.	CS 528 Modeling and Simulation	On successful completion of the course students will be able to • Define basic concepts in modeling and simulation (M&S). • Classify various simulation models and give practical examples for each category. • Construct a model for a given set of data and perform its validity. • Generate and test random number and apply them to develop simulation models. • Analyze output data produced by a model and test validity of the model. • Explain parallel and distributed simulation methods. • Know how to simulate any discrete system using queuing systems.	-	**Suggested E-learning material:** 1. Modelling and Simulation of Descrete Event System https://nptel.ac.in/courses/112107220/ 2. Simulation and modeling of natural processes by University of Geneva https://www.coursera.org/lecture/modeling-simulation-natural-processes/modeling-and-simulation-F7vas	No Change
14.	MATH (to be generated) Fields and Galois Theory	On completion of this course, students will be able to • Understand the concepts of field extension and appreciate its importance. • Understand different types of extensions. • Find the Galois group for some extension fields. • Know the link between field theory	-	**Section A** Fields, prime subfields, Extension fields, algebraic extensions, simple extensions, transcendental extension, minimal polynomial, Kronecker's Theorem, splitting fields, uniqueness of splitting fields and algebraic closures. **Section B** Finite fields, existence and uniqueness of finite fields, Normal and separable extensions, perfect fields, Automorphisms of field, fixed fields, Galois group, F–	New Course

		and group theory. • Demonstrate the solvability of quadratic, cubic and quartic equations by radicals.		conjugate, Frobenius map, character, linear independence of characters. **Section C** Fundamental theorem of Galois theory, cyclotomic extensions and abelian extensions, cyclotomic polynomials, cyclic extension, radical extension, solution of quadratic, cubic and quartic equations by radicals. **Suggested Books:** 1. Howie, J. M. (2006). *Fields and Galois theory*. London: Springer. 2. Escofier, J.-P. (2001). *Galois theory*. New York: Springer. 3. Gallian, J. A. (2013). *Contemporary abstract algebra*. (8th Ed.). Boston, MA: Brooks/Cole Cengage Learning. 4. Dummit, D. S. & Foote, R. M. (2004) *Abstract algebra* (3rd Ed.). New Jersey: Wiley. 5. Sen, M. K., Ghosh, S., Mukhopadhyay, P. &Maity, S. K. (2019) *Topics in abstract algebra* (3rd Ed.). University Press. 6. Morandi, P. J. (2003). *Field and Galois theory*. Beijing: Beijing World Pub. **Suggested E-learning Material:** 1. Notes on Galois Theory: www.math.iitb.ac.in/~srg/Lecnotes/*galois*.pdf 2. Lecture Notes: https://nptel.ac.in/courses/111101001/	

FOURTH SEMESTER

S.N.	Course List	Learning Outcomes	Existing Syllabus	Suggested Syllabus	Remark
1.	MATH (to be generated) Differential Geometry	On completion of the course, the student will be able to • Compute Reparameterization, Curvature and Torsion of smooth curves of curves. • Discuss about Osculating circle, Osculating sphere, Involutes and Evaluates, Bertrand curves, and Helices. • Compute quantities of geometric interest such as curvature, as well as develop a facility to compute in various specialized systems, such as semi geodesic coordinates or ones representing asymptotic lines or principal curvatures. • Develop arguments in the geometric description of curves and surfaces in order to establish basic properties of geodesics.	**Section A** Curves in Plane and Space : Parameterized curves, Tangent vector, Arc length, Reparametrization, Regular curves, Curvature and Torsion of smooth curves, Frenet-Serret formulae, arbitrary speed curves, Frenet approximation of a space curve. Osculating circle, Osculating sphere, Involutes and Evolutes, Bertrand curves, Spherical indicatrices, Helices, ~~Intrinsic equations of space curves, Fundamental theorem of space curves, Isomeries of R^3, Global Properties of Curves.~~ **Section B** Surfaces in R^3: Smooth surfaces, Tangents, Normals and Orientability. Examples of surfaces: Generalized cylinder and cone, Ruled surfaces and Surface of revolution.Inverse function theorem and its applications, First fundamental form, Isometry of surfaces, Conformal mapping of surfaces, Surface Area, Equiareal maps and a Theorem of Archemedes, Second fundamental form, Curvature of curves on a surface, Normal and Principal curvatures, Meusnier's theorem, Euler's theorem, Classification of points on a surface, Geometric interpretation of principal curvatures, Umbilical points. **Section C**	**Section A** Curves in Plane and Space: Parameterized curves, Tangent vector, Arc length, Reparametrization, Regular curves, Curvature and Torsion of smooth curves, Frenet-Serret formulae, Osculating circle, Osculating sphere, Involutes and Evolutes, Bertrand curves, Spherical indicatrices, Helices. **Section B** Surfaces in R^3**:** Smooth surfaces, Tangent, Normal and Orientability. Examples of surfaces: Generalized cylinder and cone, ruled surfaces, Surface of revolution, First fundamental form, Isometries of surfaces, Conformal mapping of surfaces, Surface Area, Equiareal maps and Theorem of Archemedes, Second fundamental form, Curvature of curves on a surface, Normal and Principal curvatures, Meusnier's theorem, Euler's theorem, Classification of point on surface, Geometric interpretation of principal curvatures, Umbilical points. **Section C** Gaussian and Mean curvature, Pseudo sphere, Flat surfaces, Surfaces of constant mean curvature, Gaussian curvature of compact surfaces, Gauss map. Geodesics: Definition and basic properties, Geodesic equations, Geodesics on a surface of revolution, Clairaut's theorem, Geodesics as shortest paths, Geodesic coordinates,	**Change in Credit.**

			Gaussian and Mean curvature, The Pseudosphere, Flat surfaces, Surfaces of constant mean curvature, Gaussian curvature of compact surfaces, Gauss map. Geodesics: Definition and basic properties, Geodesic equations, Geodesics on a surfaces of revolution, Clairaut's theorem, Geodesics as shortest paths, Geodesic coordinates, Geodesic curvature of a curve, ~~Gauss TheoremaEgregium (Statement only), Gauss equations, Codazzi Mainardi equations, Gauss-Bonnet Theorem (Statement only).~~ **Text book:** • Pressley, **Elementary Differential Geometry**, Springer (Undergraduate Mathematics Series), 2001. **Reference books:** 1. M. P. Do Carmo, **Differential Geometry of Curves and Surfaces**, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1976. 2. A. Gray, **Differential Geometry of Curves and Surfaces**, CRC Press, 1998. 3. B. O' Neill, **Elementary Differential Geometry**, Academic Press, 1997. 4. C. Bär, **Elementary Differential Geometry**, Cambridge University Press, 2001. 5. J. A. Thorpe, **Elementary Topics in Differential Geometry,** Springer (Undergraduate Texts in Mathematics), 1979. 6. D. Somasundaram, **Differential Geometry, A First Course**,Narosa Publishing House, New Delhi, 2005.	Geodesic curvature of a curve. **Suggested Text Book** 1. Pressley, A. (2012). *Elementary differential geometry*. London: Springer. **Suggested Reference Books:** 1. Carmo, M. P. (1980). *Differential geometry of curves and surfaces*. Englewood Cliffs, N.J: Prentice-Hall. 2. O'Neill, B. (2006). *Elementary differential geometry*. London: Elsevier/Academic Press. 3. Gray, A. (2000). *Modern differential geometry of curves and surfaces*. FL: CRC Press. 4. Somasundaram, D. (2010). *Differential geometry: A first course*. Harrow: Alpha Science International. **Suggested E-learning material:** 1. NOC:Differential Calculus in Several Variables: https://nptel.ac.in/courses/111104092/ 2. NOC:Curves and Surfaces: https://nptel.ac.in/courses/111104095/	

2.	MATH (to be generated) Partial differential Equations	On completion of the course, the student will be able to • apply the techniques for solving partial differential equations. • describe the most common partial differential equations that appear in problems concerning e.g. heat conduction, flow, elasticity and wave propagation • solve simple first order equations using the method of characteristics and classify second order equations. • describe, compute and analyse wave propagation and heat conduction in mathematical terms • formulate maximum principles for various equations and derive consequences. • evaluate and assess the results of various problems in other subjects based on these concepts.	**Section A** *Mathematical classification of Partial Differential Equation, Illustrative examples of elliptic, parabolic and hyperbolic equations. Physical examples of elliptic, parabolic and hyperbolic partial differential equations, Formulation of partial differential equations.* Partial Differential equation of the first order, Lagrange's linear equation, different forms of non-linear partial differential equations, Charpit's method. Linear partial differential equations with constant coefficients. Homogeneous equations, Non-homogeneous equation. **Section B** Partial Differential equations of second order with variable coefficients, Monge's Methods, Separation of variables, canonical forms, Cauchy's problem. The Wave equation (one and two dimensional) Fourier series solutions of the Wave equations (homogeneous and non-homogeneous), Numerical solution of the wave equation.~~Wave motion along infinite and semi-infinite strings. Characteristics and d' Alembert's solution. Normal modes of Vibration of a circular elastic membrane and rectangular membrane.~~ **Section C** Heat equations (homogeneous and non-homogeneous). Numerical approximation of solution ofstandard heat condition problem.	**Section A** Mathematical classification and Formulation of partial differential equations, Partial Differential equation of the first order, Lagrange's linear equation, different forms of non-linear partial differential equations, Charpit's method. Linear partial differential equations with constant coefficients. Homogeneous equations, Non-homogeneous equation. **Section B** Partial Differential equations of second order with variable coefficients, Monge's Methods, Separation of variables, The Wave equation (one and two dimensional) Fourier series solutions of the Wave equations (homogeneous and non-homogeneous), Numerical solution of the wave equation. **Section C** Heat equations (homogeneous and non-homogeneous), Numerical approximation of solution of standard heat condition problem, Harmonic Functions and Dirichlet Problem, Green's Functions and Properties. Existence theorem by Perron's Method. **Suggested Text Books:** 1. John, F. (1991). *Partial differential equations*. New York: Springer. 2. Bansal, J. L., &Dhami, H. S. (2004). *Differential equations Vol II*. Jaipur: JPH. 3. O'Neil, P. V. (2012). *Advanced engineering*	**Change in Credit.**

			Harmonic Functions and Dirichlet Problem, Green's Functions and Properties. Existence theorem by Perron's Method. ~~Heat Equation, Maximum Principle. Uniqueness of Solutions via Energy Method. Uniqueness of Solutions of IVPs for Heat Conduction Equation.~~ **Text Books:-** 1. JohnF. Partial Differential Equations, Springer Verlag, New York, 1991. 2. J. L. Bansal and H. S. Dhami: Differential Equations Vol.11, 2004, JPH, India. 3. P. V. 0' Neil: Advanced Engineering Mathematics, Cengage Learning, India, 2011. 4. I. N. Sneddon: Elements of Partial Differential Equations, Mc-Graw Hill New Delhi 1957 **References Books:-** 1. H.F. Weinberger: A First Course in Partial Differential Equations, John Wiley New York,1965. 2. W.E. William: Partial Differential Equations, Clarendan .Press, Oxford, 1980. 3. Folland G. B. Introduction to partial differential equations, Princeton University Press1996 4. K.SankaraRao.-Introduction to Partial Differential Equations, PHI learning Pvt Ltd 2010. 5. P Prasad and R Ravindran: Partial Differential Equations, New Age International, 2011. 6. T. Amaranath : An Elementary Course in Partial Differential Equations, Jones &	*mathematics*. India: Cengage Learning. 4. Sneddon, I. N. (1981). *Elements of partial differential equations*. New York MacGraw-Hill. **Suggested References Books:** 1. Weinberger, H. F. (1995). *A first course in partial differential equations with complex variables and transfrom methods*. New York: Dover Publications. 2. Williams, W. E. (1980). *Partial differential equations*. Oxford [Eng.] : New York : Clarendon Press ; Oxford University Press 3. Folland, G. B. (2003). *Introduction to partial differential equations*. New Delhi: Prentice Hall of India. 4. Rao, K. S. (2010). *Introduction to Partial differential equations*. New Delhi: Prentice Hall of India. 5. Amaranath, T. (2009). *An elementary course in partial differential equations*. Sudbury, Mass: Jones and Bartlett Publishers. 6. Sharma, J. N., & Singh, K. (2009). *Partial differential equations for engineers and scientists*. Oxford: Alpha Science International Ltd. **Suggested E-learning material:** 1. Partial Differential Equation; Platform: https://ocw.mit.edu/courses/mathematics/18-02-multivariable-calculus-fall-2007/video-lectures/lecture-15-partial-differential-equations/ 2. Introduction to partial differential equation; Platform: NPTEL https://nptel.ac.in/courses/111103021/	

			Bartlett Learning, 2009 7. J N Sharma and K Singh: Partial Differential Equations for engineers and scientists.Narosa New-Delhi, India.2014.	3. **Video Lectures for Partial Differential Equations; Platform: LAMAR** http://www.math.lamar.edu/faculty/maesumi/PDE1.html#pdeRESOURCES	
3.	STAT (to be generated) Advanced Inference	After successful completion of this course, student will be able to • Apply various estimation and testing procedures to deal with real life problems. • Understand Fisher Information, Lower bounds to variance of estimators, MVUE. • Understand consistency, CAN estimator, MLE. • Understand Neyman-Pearson fundamental lemma, UMP test. • Apply Likelihood Ratio test in real life testing problems. • Understand invariant and similar test.	**Section A** Consistency and asymptotic relative efficiency of estimators, Consistent asymptotic normal (CAN) estimator, Method of MLE and its large sample properties, Best Asymptotic normal (BAN) for one parameter, ~~MLE in Pitman family and exponential of distribution.~~ **Section B** *Best critical region (BCR),* Generalized *Peyman* Pearson lemma, UMP tests for distribution with monotone likelihood ratio (MLR), Unbiased tests, *Locally most powerful test*, Similar regions and test of Neymann structure. **Section C** Invariance tests and UMP invariant tests, *Asymptotic distribution of* Likelihood ratio test (LRT) statistics, *Asymptotic distribution of log likelihood ratio,*~~Consistency of large sample test, Asymptotic power of large sample test.~~ **Text Book:** 1. Ferguson, T.S. (1996) : A Course in Large Sample Theory, Chapman & Hall, London. 2. Goon, A.M. Gupta, M.K. Dasgupta, B. (1973). An Outline of Statistical Theory, vol. 2, World Press. **Reference Books:** 1. Gupta, A.D. (2008), Asymptotic Theory of	**Section A** Consistency and asymptotic relative efficiency of estimators, Consistent asymptotic normal (CAN) estimator, Best asymptotic normal (BAN) for one parameter, Method of MLE and its large sample properties. **Section B** Generalized Neyman- Pearson lemma, UMP tests for distribution with monotone likelihood ratio (MLR), Unbiased tests, Similar regions and test of Neyman structure. **Section C** Invariance tests and UMP invariant tests, Likelihood ratio test. Consistency of Likelihood ratio test. Asymptotic properties of likelihood ratio test. **Text Books** 1. Ferguson, T. S. (1996). *A course in Large sample Theory*. London, Chapman and Hill. 2. Goon, A. M., Gupta, M. K. & Gupta, B. D. (1973). *Fundamental of Statistics* (Vol. II), The world Press Pvt. ltd. **Reference Books:** 1. Gupta, A. D. (2008). *Asymptotic Theory of Statistics and Probability*. New York, Springer. 2. Kale, B. K. (1999). *A first course on parametric inference*. Narosa Publication.	Change in Credit.

			Statistics and Probability, Springer, NewYork. 2. Kale, B.K. (1999), A First Course in Parametric Inference, Narosa, Publication. 3. Lehmann, E.L. and Casella, G. (1998), Theory of Point Estimation, Springer, New York. 4. Rao, C.R. (1995), Linear Statistical Inference and its Applications, Wiley, New York. 5. Lehman, E. (1986), Theory of Point Estimation, John Wiley & Sons. 6. Lehman, E. (1986), Testing Statistical Hypotheses, John Wiley & Sons.	3. Lehman, E. L. &Cesella, G. (1998). *Theory of Point estimation.*New York, Springer. 4. Rao, C. R. (1995). *Linear Statistical Inference and Its Applications.* Wiley Eastern Ltd. 5. Lehman, E. L. (1986). *Testing of Point Estimation*, John Wiley & Wiley eastern. 6. Lehman, E. L.(1986). *Testing of Statistical Hypothesis*, John Wiley & Wiley eastern. **Suggested E-learning Resources** 1. Statistical Inference, NPTEL, https://nptel.ac.in/courses/111105043/ 2. Statistical Inference, ePATHSHALAhttps://epgp.inflibnet.ac.in/ahl.php?csrno=34	
4.	STAT 502 Bayesian and Multivariate Analysis	On the successful completion of the course, student will be able to, • Find posterior distribution of a parameter. • Identify the nature of the prior. • Understand various types of loss functions and their nature. • Use Bayesian theory to draw inferences in simple problems. • Define multivariate normal distribution and understand its properties. • Estimate the mean vector and covariance matrix of the multivariate normal population.	-	**Suggested E-learning material:** 1. Video lecture on 'Bayesian statistics without tears' https://podcasts.ox.ac.uk/bayesian-statistics-without-tears	No Change in Syllabus.

		• Test the significance of single mean vector and difference in the two mean vectors. • Perform PCA and factor analysis on real data set. • Classify and discriminate the observations in two populations. • Perform correlation analysis between two multivariate populations.			
5.	STAT 502L Bayesian & Multivariate Analysis Lab	On completion of this course, the student will be able to • Differentiate between the nature of prior and posterior densities by means of their plots • Find Bayes estimator, Bayes Risk and perform Bayes testing • Estimate mean vector and covariance matrix of given data set • Perform testing of significance of single mean vector and difference of two mean vectors • Reduce dimension of the data using principal component analysis and factor analysis • Classify and discriminate observations in two or more populations • Observe correlation between two	-	**Suggested E-learning Material** 1. Using R for Multivariate Analysis https://little-book-of-r-for-multivariate-analysis.readthedocs.io/en/latest/src/multivariateanalysis.html	No Change in Syllabus

		sets of multivariate data sets.			
6.	STAT (to be generated) Reliability and Renewal Theory	On successful completion of the course, the students will be able to: • Understand the importance of validity and reliability assessment and the link between the two. • Estimate the reliability function and mean time to failure for different types of systems • Analyze statistical experiments leading to reliability modeling. • Estimate life length distributions, using complete or censored data. • Identify reliability testing components. • Apply reliability theory to assessment of reliability in engineering design. • Analyze non-repairable systems of independent components, with and without redundancy • First look at what a random process is and then explain what renewal processes are. • Describe, derive, and prove important theorems and formulas for renewal theory • Use renewal theory to solve problems where Poisson is not a	-	**Section A** Concept of Reliability. Classes of Life time distributions. Evaluation of Reliability function, Shape of Reliability function. System, Reliability Evaluation : Series & Parallel system, partially redundant system, standby system with perfect switching/imperfect switching, (k,n) system, Bridge Structure. Availability theory and its molding for various configurations. Introduction to Software Reliability. **Section B** Reliability models of maintained systems. Reliability Allocation Problems, Discrete Replacement Policies : Age, Block, Policies, Preventive Maintenance Policies, Corrective Maintenance Policies, Concept of minimal repair, Notions of aging. **Section C** Renewal Theory, Distribution of number of renewals & moments, Recurrence time & its limiting distribution. Application of Renewal Theory, Solutions of Renewal type equations, Optimization problem with respect to system reliability. **Text Books** 1. Sinha, S. K. (1986). *Reliability and life testing*. New York: Wiley. 2. Gert s bakh, I. B. (2009). *Reliability theory: With applications to preventive maintenance*. New Delhi: Springer.	New Course

		realistic process		3. Cox, D. R. (1982). *Renewal theory*. London: Chapman and Hall. 4. Lewis, E. E. (1996). *Introduction to reliability engineering*. New York, NY: Wiley. **Reference Books** 1. Barlow, R. E., &Proschan, F. (1975). *Statistical theory of reliability and life testing*. New York: Holt, Rinehart and Winston. 2. Jardine, A.K.S. (1973). *Maintenance, Replacement andReliability*. UK: Pitman Publication. 3. Medhi, J. (2009). *Stochastic Process* (3rd Ed.). New Age International, 2009. **Suggested E-learning material:** 1. 2011 Lecture 17: Modules, Systems, and Reliability: https://ocw.mit.edu/courses/mechanical-engineering/2-627-fundamentals-of-photovoltaics-fall-2013/lecture-videos-slides/2011-lecture-17-modules-systems-and-reliability/ 2. Probability Theory and Applications: Lecture 40-Reliability of Systems: https://nptel.ac.in/courses/111104079/40	
7.	MATH 516 Network Analysis & Goal Programming	On completion of this course, students will be able to: • Plan and structure a project. • Understand basic techniques for quality improvement, • Apply the PERT & CPM techniques	-	**Suggested E-learning material:** 1. Critical path method (PDF) http://textofvideo.nptel.ac.in/112106131/lec34.pdf 2. Project Management(Video Lecture) https://nptel.ac.in/courses/110104073/21	No Change in Syllabus.

		to optimize the project goals. • Solve network models like the shortest path, minimum spanning tree, and maximum flow problems. • Understand how to model and solve problems using Goal Programming			
8.	MATH 516L Network Analysis & Goal Programming Lab	On completion of the course, the student will be able to, • Implement optimization methods in software to solve shortest path problem, spanning tree problem, programming problems etc. • The science learning goals of laboratory experiences include enhancing mastery of science subject matter, developing scientific reasoning abilities, increasing understanding of the complexity and ambiguity of empirical work, developing practical skills, increasing understanding of the nature of science, cultivating interest in science and science learning. • Write efficient, well-documented code and present numerical results in an informative way.	-	Practical/Lab to be performed on a computer using OR (TORA, LINGO, MATLAB etc.)/Statistical packages. 1. Determines the Flow of commodity in a network 2. Solution of Shortest path problem as a LPP 3. Shortest Path Problem using Dijkstra's algorithm 4. Problem based on Minimal Spanning Tree 5. Project planning (Deterministic case-CPM) 6. Project planning (Probabilistic case-PERT) 7. Problem based on Project management with Crashing 8. Solution of Flow Shop Problem 9. Solution of Job Shop Problem 10. To solve Goal Programming Problem using Graphical Method 11. Graphical solution of weighted Goal programming 12. Graphical solution of pre-emptive Goal programming 13. Solution of Goal Programming Problem with simplex method	List of Practical is added.

				Text Books/ Reference Books: 1. Winston, W. L. (2009). *Operations research: Applications and algorithms*. Belmont, Calif: Brooks/Cole, Cengage Learning. 2. Hillier, F. S., & Lieberman, G. J. (2016). *Introduction to Operations Research*. Boston: McGraw-Hill. **Suggested E-learning material:** 1. Optimization Toolbox https://in.mathworks.com/help/optim/index.html **2.** LINGO http://swmath.org/software/4942	
9.	CS 313 Software Engineering	On successful completion of the course students will be able to • Understand the system development lifecycle. • Understand the software-development process, including requirements analysis, design, programming, testing and maintenance. • Model object-oriented software systems. • Investigate and improve the specification of a software system. • Specify, design and construct CASE tools and application software. • Develop and apply testing	-	**Suggested E-learning material:** 1. Software Engineering https://nptel.ac.in/courses/106101061/ 2. Software Engineering by Roger S. Pressman http://qiau.ac.ir/teacher/files/911610/13-11-1387-17-31-03.pdf	No Change

		strategies for software applications. • Identify some of the main risks of software development and use. • Effectively participate in team-based activities.			
10.	CS 213 Design and Analysis of Algorithms	On successful completion of the course students will be able to • Analyze the performance of various algorithms in terms of time and space. • Solve recurrence relation using various methods. • Compute complexity of various iterative and recursive algorithm. • Understand the concept and design algorithm using data structures including threaded binary tree, B-Tree and hashing techniques. • Understand numerous algorithm design techniques including divide& conquer, greedy, dynamic programming, backtracking and branch& bound. • Choose appropriate algorithm design techniques for solving real world problems. • Understand how the choice of the algorithm design methods impact	-	**Suggested E-learning material:** 1. Design and Analysis of Algorithms https://nptel.ac.in/courses/106101060/ 2. Algorithms Specialization by Stanford University https://www.coursera.org/specializations/algorithms 3. Introduction to Algorithms by Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest and Clifford Stein https://mcdtu.files.wordpress.com/2017/03/introduction-to-algorithms-3rd-edition-sep-2010.pdf	No Change

		the performance of programs			

THIRD/FOURTH SEMESTER (Electives)

S.N.	Course List	Learning Outcomes	Existing Syllabus	Suggested Syllabus	Remark
1.	MATH 501 **Advanced Analysis (Analysis on Abstract Spaces)**	On completion of the course, students will be able to, • Explain when Normed space become Banach space. • Define the Hilbert spaces. • Define multi linear mappings. • Check whether the function is bounded or not? • What is directional derivative? • Explain the difference between partial derivative and directional derivative. • Tell about the Lipschitz's constant and conditions • Related the analysis and differential equation	-	**Suggested E-learning material** 1. Normed space, Banach space and Hilbert spaces and its properties; Platform: https://nptel.ac.in/courses/111105037/	No change in the syllabus
2.	MATH 503 **Advanced Functional Analysis**	On completion of the course, students will be able to, • Check whether a sequence of operators convergence or divergences? • Explain how continuous function on a closed and bounded interval can be	-	**Suggested E-learning material** 1. Normed space, Banach space and Hilbert spaces and its properties; Platform: https://nptel.ac.in/courses/111105037/	No change in the syllabus

		uniformly approximated on that interval by polynomials to any degree of accuracy. • Explain how you will apply the Banach fixed point theorem. • Relate the fixed point with solution of differential and Integral equation. • Check the spectral properties of bounded linear operators • Check whether the operator is compact or not? • Explain and use of the properties of compact linear operators.			
3.	MATH 504 **Analytic and Algebraic Number Theory**	On completion of the course, students will be able to, • Demonstrate the knowledge of arithmetic functions and their property. • Know the prime number theorem and its analytic proof. • Understand basic concepts of algebraic number theory such as conjugates, discriminants, algebraic integers, integral basis, norms and traces. • Understand prime factorization of ideal and unique factorization. • Know some important theorem in algebraic number theory.	-	-	No change in the syllabus
4.	MATH 510	On completion of the course, students	-	**Suggested E-learning material**	No change

	Integral Equations and Calculus of Variations	will be able to, • Acquire ability to recognize difference between Volterra and Fredholm Integral Equations, First kind and Second kind, homogeneous and inhomogeneous. • Be thorough with different types of integral equations and apply these methods to solve Integral Equations. • Students will have much better and deeper understanding of the fundamental concepts of the space of admissible variations and concepts of a weak and a strong relative minimum of an integral. • Solve isoperimetric problems of standard type. • Solve simple initial and boundary value problems by using several variable calculus.		1. Open course in Integral equations, calculus of variation and its applications (all Topics) https://nptel.ac.in/courses/111107103/ 2. Volterra and Fredholm Integral Equations http://staff.ul.ie/mitchells/Final_notes.pdf 3. Green's Functions http://www.maths.manchester.ac.uk/~wparnell/MT34032/34032_IntEquns.pdf 4. Neumann series, resolvent kernels and variational problem https://swayam.gov.in/courses/4824-july-2018-integral-equations-calculus-of-variations-and-its-applicati 5. Open course in integral equations: https://ocw.mit.edu/courses/mathematics/18-307-integral-equations-spring-2006/	in the syllabus
5.	MATH 517 **Number Theory and Cryptography**	On completion of the course, students will be able to, • Understand the basic concepts of number theorem and their applications in cryptography. • Know the need of security of digital data. • Demonstrate the application of mathematics in computer science. • Appreciate the historical	-	**Suggested E-learning material:** 1. Lecture Notes on Number Theory: https://nptel.ac.in/courses/111103020/ 2. Video Lecture on Number Theory: https://bit.ly/2ToTdjZ 3. Video Lecture on Cryptography: https://nptel.ac.in/courses/106105031/	No change in the syllabus

		cryptosystems and the development of modern cryptography. • Demonstrate the knowledge of mathematics behind RSA cryptosystem, ElGamal Cryptosystem and secrete sharing schemes.			
6.	MATH 527 **Tensor Analysis and Geometry of Manifolds**	On completion of the course, students will be able to, • Discuss different kinds of surfaces, connection and covariant derivatives. • Understand the concepts of manifold and illustrate some examples of manifolds. • Understand the Ricci identity and enable to use it in proving different theorems. • Define and illustrate some examples of Lie group.	-	**Suggested E-learning material:** 1. NOC: Differential Calculus in Several Variables: https://nptel.ac.in/courses/111104092/ 2. NOC: Multivariable Calculus: https://nptel.ac.in/courses/111107108/ 3. NOC: Calculus of One Real Variable: https://nptel.ac.in/courses/109104124/	No change in the syllabus
7.	MATH 529 **Theory of Games**	On completion of the course, students will be able to, • Understand all the basic concepts and results of game theory. • Understand terms like Nash equilibrium, the extensive form (which computer scientists call game trees), Bayesian games (modelling things like auctions), repeated and dynamic games. • Recognize and model strategic	-	**Suggested E-learning material:** 1. Game Theory: Lecture notes(PDF)https://ocw.mit.edu/courses/economics/14-126-game-theory-spring-2016/ 2. Game Theory and Economics: Lecture notes(PDF)https://nptel.ac.in/courses/109103021/	No change in the syllabus

		situations, to predict when and how your actions will influence the decisions of others and to exploit strategic situations for your own benefit. • Understand the game theoretic tools for modelling and solving problems in operations management.			
8.	MATH 530 **Viscous Fluid Dynamics**	On completion of the course, students will be able to, • Understand the fundamental concepts of fluid dynamics. • Derive the fundamental equations governing the flow of a viscous fluid. • Demonstrate the analytical solutions of Navier-Stokes equations by making certain assumptions for certain geometries. • Identify, formulate and solve engineering problems.	-	**Suggested E-learning material** 1. Viscous Fluid Flow, Platform: The University of Manchester; http://www.maths.man.ac.uk/~mheil/Lectures/Fluids/index.html 2. Fluid Mechanics, Platform: nptel; https://nptel.ac.in/courses/112105171/ 3. Introduction to Fluid Mechanics and Fluid Engineering, Platform: FreeVideoLectures; https://freevideolectures.com/course/3513/introduction-to-fluid-mechanics-and-fluid-engineering/28	No change in the syllabus
9.	MATH 507 **Financial Mathematics**	On completion of the course, students will be able to, • Understand financial analysis and planning. • Know the cost of capital, capital structure and dividend policies. • Apply technique of Goal Programming to profit planning and	-	-	No change in the syllabus

		financial budgeting. • Make financing decision onproblem of determining optimal capital structure • Understand the concept of leasing, debt management, analysis of commitment of funds and risk of cash insolvency.			
10.	MATH 513 **Marketing Management**	On completion of the course, students will be able to, • Understand the concept of marketing and its role in business and public organization. • Understand the need for scientific marketing analysis. • To uses Mathematical models in Marketing and understand their limitations. • Understand the concept of promotional decisions in the presence of competition. • Use game theory models for promotional effort. • Make channels of distribution and transportation decision.	-	-	No change in the syllabus

11.	MATH (to be generated) **Fuzzy Logic and Belief Theory**	On completion of the course, students will be able to, • Learn crips and fuzzy set theory. • Decide the difference between crips set and fuzzy set theory. • Make calculation on fuzy set theory. • Recognize fuzzy logic membership function. • Recognize fuzzy logic fuzzy inference systems • Make applications on Fuzzy logic membership function and fuzzy inference systems. • Utilize fuzzy logic approach to problems arising in the field of Operations Research, Computer Science and Engineering. • Formulate logical expressions, fuzzy logic to solve a variety of problems related to real scenarios • Apply defuzzification methods.	-	**Section A** Basic concept of Fuzzy Logic: Introduction to fuzzy set, membership function, Various forms of membership functions, type of fuzzy sets, LR- representations of fuzzy sets, properties of fuzzy sets (support, cardinality, alpha-cut set, convexity).Operations on Fuzzy sets: Union, Intersection, complement, combinations of operations. Fuzzy extension principle, Fuzzy Relations: fuzzy cartesian product and composition, Crisp versus fuzzy relations, binary fuzzy relation, fuzzy equivalence relations, fuzzy compatibility relations, fuzzy ordering relations. Fuzzy graphs, Fuzzy morphism (homomorphism), Fuzzy relation equations.Fuzzy Numbers: Definitions and types of fuzzy numbers, interval analysis in arithmetic, triangular and trapezoidal types, Arithmetic operations on fuzzy numbers. Fuzzy Function: Introduction to fuzzy function, type of fuzzy function, fuzzy extrema of function, differentiation and integration of fuzzy function. **Section B** Fuzzy Logic: Classical logic, logic variable, logic function, truth tables, tautology and inference rule, Linguistic variables. Predicate logic, Quantifier, fuzzy expression, operators in fuzzy expression, fuzzy predicate, fuzzy modifier, fuzzy truth qualifier.Fuzzy if-then rules: Basics of fuzzy rules, fuzzy mapping rules, fuzzy implication rules.Fuzzy Decision Making: Introduction, multistage decision making, fuzzy ranking method, fuzzy linear programming, fuzzy	New elective

				transportation problemsFuzzy System: Introduction to fuzzy system.Defuzzification methods: centre of area (or centre of gravity or centroid), centre of maxima, mean of maxima.Fuzzy controllers: an overview of fuzzy controller.Fuzzy Systems and Neural Network: Introduction to neural network, fuzzy neural networks. **Section C** Probability, Uncertainty and Fuzzy Measures: Probability verses Possibility, Fuzzy event, Crisp probability of fuzzy event and fuzzy probability of fuzzy event, Level of uncertainty, Measure of fuzziness: (i) using Shannon's entropy formula and (ii) using metric distance. Belief Theory: Evidence Theory- Mathematical Theory of evidence, Introduction to Shafer's Belief Theory, Belief representation: mass of belief, belief measure, plausibility measure, properties of belief function-relation between belief and plausibility measure, Dempster's Rule of Combination, Applications of Fuzzy logic and fuzzy set theory in Operations Research, Computer Science and Engineering fields. **Suggested Text Books:** 1. Lee, K. H. (2005). First course on fuzzy theory and applications. Berlin: Springer-Verlag 2. Klir, G. J., & Yuan, B. (2003). Fuzzy sets and fuzzy logic: Theory and applications. New Delhi: Prentice Hall of India. **Suggested Reference Books:** 1. Klir, G. J., & Folger, T. A. (2010). Fuzzy sets,	

				uncertainity and information. New Delhi: PHI Learning Private Ltd. 2. Yen, J., &Langari, R. (2005). Fuzzy logic: Intelligence, control and information. Pearson Education. 3. Shafer, G. (1976). A mathematical theory of evidence. Princeton: Princeton University Press. 4. Mukaidono, M. (2010). Fuzzy logic for beginners. Singapore: World Scientific. 5. Nguyen, H. T., & Walker, E. A. (2006). A first course in fuzzy logic. Boca Raton, Fla: Chapman & Hall/CRC. **Suggested E-learning material:** 1. Introduction to Fuzzy Logic(Videos) https://nptel.ac.in/courses/106105173/2 2. Fuzzy Logic: Introduction (PDF) http://cse.iitkgp.ac.in/~dsamanta/courses/sca/resources/slides/FL-01%20Introduction.pdf	
12.	MATH (to be generated) Coding Theory	On successful completion of this course students will be able to, • Understand the need of coding theory. • Appreciate the applications of abstract and linear algebra in coding theory. • Find the generator and parity check matrix of linear codes. • Understand the main coding		**Section A** Communication channels, maximum likelihood decoding,Hamming distance, minimum distance decoding, distance of a code,finite fields, structure of finite fields, minimal polynomial, linear codes, Hamming weight, bases of linear codes, generator matrix and parity check matrix, encodingand decoding of linear codes, syndrome decoding. **Section B** The coding theory problem, lower bounds, Hamming	New elective

		theory problem. • Derive classical bounds of codes and the distance of the code. • Understand cyclic codes and their decoding.		bounds and perfect codes, singleton bound and MDS codes, nonlinear codes, Reed-Muller codes, subfields codes. **Section C** Cyclic codes: definitions, generator polynomials, generator and parity check matrices, decoding of cyclic codes, Burst-error-correcting codes, BCH codes: definitions, parameters of BCH codes, Decoding of BCH codes. Reed–Solomon codes, generalized Reed–Solomon codes, Goppa codes. **Suggested Text Book:** 1. Ling, S., & Xing, C. (2004). *Coding Theory: A first Course*. Cambridge: Cambridge University Press. **Suggested Reference Books:** 1. MacWilliams, F. J., & Sloane, N. J. A. (2007). *The theory of error-correcting codes*. Amsterdam: North-Holland. 2. Peterson, W. W., & Weldon, E. J. (2008). *Error-correcting codes*. (2nd Ed.). Cambridge, Mass: MIT Press. 3. Berlekamp, E. R. (2015). *Algebraic coding theory*. (Algebraic Coding Theory.) Singapore: World Scientific. 4. Huffman, W. C., &Pless, V. (2010). *Fundamentals of error-correcting codes*. Cambridge: Cambridge Univ. Press. 5. Hill, R. (2001). *A first course in coding theory*. Oxford: Clarendon Press. 6. Rhee, M. Y. (1989). *Error-correcting coding theory*.	

				Singapore: McGraw-Hill. **Suggested E-learning Material:** 1. Online Course on Coding Theory:https://onlinecourses.nptel.ac.in/noc17_ee07 2. Lecture Notes: https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-895-essential-coding-theory-fall-2004/	
13.	MATH (to be generated) Fixed Point Theory	On successful completion of this course students will be able to: • Understand various concepts in metric spaces such as completeness. • Demonstrate standard examples of metric spaces and prove simple results related to them. • Understand the proof of open mapping theorem and Closed graph theorem. • Check the conditions for expansive and Nonexpansive Mappings, contractive and contraction mappings. • Understand standard fixed-point theorems. • To present the basic ideas of the theory, and illustrate them with a wealth of examples and		**Section A** Metrics space, Complete metric space, Convergence, Cauchy sequence and Completeness, Various concept in metric space, Normed linear space, Banach space, normed space and Hilbert space, open mapping theorem and Closed graph theorem, linear operator. **Section B** Lipschitz mapings,expansive and Nonexpansive Mappings, contractive and contraction mappings, Upper and lower semi continuity of maps, contractive and nonexpansive multivalued maps, Banach's contraction principle, Fixed point theorem of Schauder's and Kirk, Tarsiki's Fixed point theorem. **Section C** Banach Fixed point theorem for multivalued maps, Generalized Schauder Fixed point theorem. Existence of solutions of ordinary equations and systems of linear equations in several unknowns, applications in the theory of differential and integral equations. **Suggested Books:** 1. Zeidler, E. (2000). *Nonlinear functional analysis*	New elective

		applications in differential and integral equations.		*and its applications: Vol 1*. New York: Springer. 2. Khamsi, M. A., & Kirk, W. A. (2001). *An introduction to metric spaces and fixed point theory*. New York: John Wiley & Sons. 3. Smart, D. R. (1980). *Fixed point theorems*. Cambridge: Cambridge University Press. 4. Istra tescu, V. I. (1981). *Fixed point theory: An introduction*. Dordrecht, Holland: D. Reidel Pub. 5. Agarwal, R. P., Meehan, M., &O'Regan, D. (2009). *Fixed point theory and applications*. Cambridge, UK: Cambridge University Press. **E-Resources** 1. National Programme for Technology Enhanced Learning (NPTEL) https://nptel.ac.in/courses/111105037/	
14.	MATH (to be generated) An Introduction to Dynamical Systems	On successful completion of this course students will be able to, • Describe the main features of dynamical systems and their realisation as systems of ordinary differential equations. • Identify fixed points of simple dynamical systems, and study the local dynamics around these fixed points, in particular to discuss their stability. • Use a range of specialised analytical techniques which are required in the study of dynamical systems.	-	**Section A** Introduction to Dynamical Systems: Background and examples, dynamical systems, attractors and invariant sets. Non-linear Systems-local analysis: the fundamental existence-uniqueness theorem, The flow defined by a differential equation, Linearization, The stable manifold theorem, The Hartman-Grobman theorem, Stability and Liapunov functions, Saddles, Nodes, Foci, and Centers. **Section B** Non-linear Systems-global analysis: Dynamical systems and global existence theorem, Limit sets and Attractors, Periodic orbits, Limit Cycles, and Seperatrix cycles, the Poincare map, the stable manifold theorem for periodic orbits, the Poincare-Bendixon theory in R2,	New Elective

		• Describe dynamical systems geometrically and represent them graphically via phase plane analysis. • Find fixed points and period orbits of discrete dynamical systems, and find their stability. • Do graphical analysis of 1D discrete dynamical systems. • Understand the basic properties of a chaotic dynamical system.		LineardSystems, Bendixon's Criteria. **Section C** Discrete dynamical systems: finite dimensional maps, limit sets, Stability, Invariant manifolds, Runge-Kutta methods: the framework, linear decay, Lipschitz conditions, Dissipative systems, Generalized dissipative systems, Gradient system. **Suggested Books:** 1. Perko, L. (2009). *Differential equations and dynamical systems*. (3rd Ed.). New York, NY: Springer. 2. Stuart, A. M., & Humphries, A. R. (1998). *Dynamical systems and numerical analysis*. Cambridge: Cambridge University Press. 3. Lynch, S. (2014). *Dynamical systems with applications using MATLAB*. (2nd Ed.). Cham: Birkhäuser.	
15.	MATH (to be generated) Bio Mathematics	On completion of the course, the student will be able to, • model the single species and two species systems. • study the stability of these systems. • Apply harvesting of the species. • to model epidemics and analyse the dynamics		**Section A** Continuous population Models for single species: Basic concepts. Exponential growth model, formulation, solution, interpretation, and limitations. Compensation and depensation. Logistic growth model, Continuous Growth Models, Insect out break Model: Spruce Budworm, Delay models, Linear Analysis of Delay Population Models: Periodic solutions. Harvesting a single Natural Population. **Section B** Continuous Models for interacting Population:Interaction between species: two species models, definition of stability, community matrix	New elective

				approach, Qualitative behavior of the community matrix, Competition: Lotka-Volterra models, Extension to Lotka-Volterra models, Competition in field experiments, Competition for space, Models for Mutualism. Predator-Prey interaction: Lotka-Volterra Models, dynamic of the simple Lotka-Volterra models, Role of density dependent in the Prey, Classic laboratory experiment on predator, predation in natural system. Some predator-prey models. **Section C** Mathematical modeling of epidemics: Basic concepts. Simple epidemic model, formulation, solution, interpretation, and limitations. General epidemic model, formulation, solution, interpretation, and limitations **Suggested Text Books:** 1. Murray, J. D. (2013). *Mathematical Biology*. Berlin: Springer Berlin. 2. Freedman, H. I. (1987). *Deterministic mathematical models in population ecology*. (2nd Ed.). Edmonton, Alta., Canada: HIFR Consulting. **Suggested Reference Books:** 1. Hastings, A. (2010). *Population biology*. New York: Springer. 2. Meerschaert, M. M. (2013). *Mathematical modeling*. (4th Ed.). Amsterdam: Elsevier Academic Press. 3. Meyer, W. J. (1984). *Concepts of mathematical modeling*. New York, N.Y.	

				4. May, R. (1976). *Theoretical ecology. Principles and applications*. United States. 5. Bailey, N. T. J., & Bailey, N. T. J. (1975). *The mathematical theory of infectious diseases and its applications*. New York: Oxford University Press. **Suggested E-learning material** 1. NPTEL: https://nptel.ac.in/courses/102101003/ and https://nptel.ac.in/courses/102101003/# 2. Biomathematics Lectures - UBC Zoology**:** www.zoology.ubc.ca/~bio301/Bio301/Lectures.html	
16.	MATH (to be generated) Algebraic Topology	On completion of the course, the student will be able to, • Generate original solutions to a variety of mathematical problems related to the fundamental group and covering spaces. • Recall all definitions and theorems in this course and use them to construct original proofs and/or counterexamples, even on demand (e.g. in exams or discussions). • Use algebraic invariants of topological spaces to distinguish spaces which otherwise seem similar. • Apply computational algorithms		**Section A** Homotopy, Straight line homotopy, Null homotopy. Contractible spaces and Homotopy type. Retract, Deformation Retract and Strong Deformation Retract. No-Retraction theorem. Fundamental Group and its properties. The Degree map, path homotopy, homotopy class. Simply connected spaces. **Section B** Calculation of Fundamental Groups of Circle, The Cylinder, The Torus, the Punctured Plane And the n-sphere S^n. Brouwer's Fixed-Point Theorem for the Discs, The Fundamental Theorem of Algebra. Covering projections, Properties of covering projection. **Section C** The Path Lifting Property, Homotopy Lifting Property, Applications of Homotopy Lifting Theorem, The	New elective

		to compute algebraic invariants of simple topological spaces.		Monodromy Theorem. The Right Action of the fundamental group. Lifting of an arbitrary map. Lifting theorem. Covering homomorphism. Group of Deck transformation. Universal covering space, The Covering theorem. Borsuk-Ulam theorem. **Suggested Text books:** 1. Deo, Satya. 2003. *Algebraic topology: a primer*. New Delhi: Hindustan Book Agency. 2. Munkres, J. R. (1978). *Topology, a first course*. New Delhi: Prentice-Hall of India. **Suggested Reference books:** 1. Singh, T. B. (2013). *Elements of topology*. CRC Press. 2. Hatcher, Allen. 2002. *Algebraic topology*. New York: Cambridge University Press. 3. Bredon, Glen E. 2006. *Topology and geometry*. New York: Springer. **Suggested E-learning material** 1. Algebraic Topology; Platform: NPTEL **https://nptel.ac.in/courses/111101002/**	
17.	MATH (to be generated) Combinatorial Optimization	On completion of the course, the student will be able to, • define the concept of combinatorial (optimisation or satisfaction) problem • recognize many types of combinatorial optimization problems; • formulate linear and integer	-	**Section A** Combinatorial algorithms for classic discrete optimization problems: Quick Overview of flow problems- Maximum flow, Minimum Cut, Minimum cost flow, Multi-commodity flow, Matching theory - Matchings and alternating paths-Tutte-Berge formula- Maximum cardinality matchings: Bipartite matching via flow, Edmond's blossom algorithm. Introduction to computational complexity.	New elective

		programs, and identify when a problem can be viewed in terms of various "standard" combinatorial optimization problems; understand the mathematical concepts underlying these problems and their solutions; • solve combinatorial optimization problems using suitable algorithms • analyze the performance of simple algorithms, understand and interpret computational complexity, and reduce one problem to another.		Single Source Shortest path algorithms–Bellman Ford algorithm, all pair shortest path algorithms – Floyd Warshall algorithm. **Section B** Algorithmic Perspective to Simplex Method: Introduction to Linear Optimization, Equivalence of optimization and separation, LP Formulation, Geometry of Linear Programs, Theory of Simplex Algorithm, Geometric interpretation of Degeneracy, Avoiding cycles, Methods for obtaining initial Basic Feasible Solutions, Linear Programming formulations of shortest path problem. **Section C** Integer Programing: Integrality gap, Branch and Bound algorithm, Cutting-plane algorithm, Applications of these algorithms on Travelling Salesman Problem Primal-Dual Algorithms: Interpretation of Dual, Optimality conditions for primal and dual, primal-dual algorithms based on complementary slackness, Primal-dual algorithms for shortest path problem, vertex cover and set cover. **Suggested Text Books:** 1. Papadimitriou, C. H., &Steiglitz, K. (2006). *Combinatorial optimization: Algorithms and complexity*. New Delhi: Prentice-Hall of India. 2. Hillier, F. S., & Lieberman, G. J. (1995). *Introduction to mathematical programming; 2nd ed*. New York: McGraw-Hill. 3. Cook, W. J. (2011). *Combinatorial optimization*. New York: Wiley.	

				Suggested References Books: 1. Lange, K. (2004). *Optimization*. New York: Springer. 2. Bazaraa, M. S., Jarvis, J. J., &Sherali, H. D. (2013). *Linear Programming and Network Flows*. Hoboken: Wiley. 3. Taha, H. A., & Pearson Education. (2017). *Operations research: An introduction*. Harlow: Pearson. 4. Korte, B., &Vygen, J. (2012). *Combinatorial Optimization: Theory and Algorithms*. Berlin, Heidelberg: Springer Berlin Heidelberg. 5. Ahuja, R. K., Magnanti, T. L., & Orlin, J. B. (1993). *Network flows: Theory, algorithms, and applications*. Upper Saddle River, N.J: Prentice-Hall. **Suggested E-learning material** 1. Topics in Combinatorial Optimization: Lecture Notes(PDF): https://bit.ly/2MY9MB3 2. Optimization –Introduction(Video Lecture) https://nptel.ac.in/courses/111105039/	
18.	MATH (to be generated) Transportation System Analysis	On completion of the course, the student will be able to, • Use optimal transportation decision-making schemes based on transportation data analysis by establishing, testing and solving transportation models.		**Section A** Introduction of transportation system analysis; characteristics, goal and role of transportation system analysis; applications and methodologies of transportation system analysis; Scope of transportation system analysis; TAF system; Impact of TAF system	New elective

		• Perform simple statistical analysis on transportation field data, sample estimation and hypothesis testing in transportation system. • Design suitable sampling and experimental methods for transportation system analysis and realize error sources.		**Section B** Random variables, applications of probability distributions in transportation system analysis, sample distributions and means in transportation system analysis, Central Limit Theorem, Bayesian Theorem, significance and hypothesis testing in transportation systems. Use of transportation field data and data gathering techniques, sources of errors, considerations of transportation system sample size; experiment design for transportation system demand forecasting and transportation operations analysis. **Section C** Intelligent Transportation System (ITS), components of ITS; Causal Loop Diagramming (CLD) system dynamics approach, conceptualization and development in transportation system policy and scenario analysis; Transportation system scenario generation models and techniques: Delphi technique; Seth Harva model; Multi criteria decision making model. **Suggested Books:** 1. Papacostas,C.S. (1987)*Fundamentals of transportation system analysis*, PHI. 2. Cascetta, Ennio. (2012). *Transportation Systems Analysis: Models and Applications*. Springer Verlag. 3. Edwards, J. D., & Institute of Transportation Engineers. (1999). *Transportation planning handbook*. (2nd Ed.). Washington: Institute of	

				Transportation Engineers. 4. Levin, R. I., & Rubin, D. S. (2008). *Statistics for management*. New Delhi: Prentice Hall of India. 5. Walpole, R. E. (2014). *Essentials of probability and statistics for engineers and scientists*. Pearson. 6. Mohapatra, P. K. J., Mandal, P., & Bora, M. C. (1994). *Introduction to system dynamics modelling*. London: Sangam. 7. Roberts, N. (1998). *Introduction to computer simulation: A system dynamics modeling approach*. Portland, Or: Productivity Press.	
19.	MATH (to be generated) Integral Transform and Special Functions	On completion of the course, the student will be able to, • understand transformations, and their conditions of existence. • carry out integral transformations and inverse transformation of different special functions, including some most useful special functions. • demonstrate understanding of the concepts of recurrence relations, generating functions, series representations pertaining to different special functions and polynomials. • determine some significant properties of special functions and integral transformations. • discuss the nature of special	-	**Section A** Laplace Transform: Definition, Transform of some elementary functions, rules of manipulation of Laplace Transform, Transform of Derivatives, relation involving Integrals, the error function, Transform of Bessel functions, Periodic functions, convolution of two functions, Inverse Laplace Transform of simple function, Tauberian Theorems. Applications of Laplace Transform to solve ordinary differential equations with constant and variable coefficients, initial and boundary value problems. **Section B** Fourier series, Fourier integral Theorem, Fourier Transform, Fourier Cosine Transform, Fourier Sine Transform, Transforms of Derivatives, Fourier transforms of simple Functions, Fourier transforms of Rational Functions, Convolution Integral, Parseval's Theorem for Cosine and Sine Transforms, Inversion	New elective

		functions in different domains.		Theorem, Solution of Partial Differential Equations by means of Fourier Transforms. Mellin transform, Properties, Mellin transform of derivatives and integrals, Mellin inversion theorem, Convolution theorem. **Section C** The Hypergeometric function: An integral representation, differential equation and solutions. F(a,b,c;1) as a function of the parameters, evaluation of F(a,b,c;1), contiguous function relations, Hypergeometric differential equations Legendre polynomials: Solution of Legendre's Equation, Generating function, Rodrigue's formula, Orthogonal properties. Integrals involving Legnedre polynomials, Recurrence relations, Legendre's function of second kind $Q_n(x)$. Bessel functions, solutions of Bessel's equation, Generating function, Integral expressions. Recurrence relations, orthogonal properties. **Suggested Text Books:** 1. Sneddon, I.N. (1974)*The use of integral transforms*, New Delhi: Tata McGraw Hill. 2. Rainville, E. D. (1960)*Special functions*, New York:Chelsea Publishing Company. **Suggested References:** 1. Davies, B. (1978)*Integral transforms and their applications*, New York:Springer. 2. Slater, L. J. (2008). *Generalized hypergeometric*	

				functions. Cambridge: Cambridge University Press. 3. Mathai, A. M., &Haubold, H. J. (2011). *Special functions for applied scientists*. New York: Springer. **Suggested E-learning material** 1. Advanced Engineering Mathematics; NPTL: https://nptel.ac.in/courses/111105035/22	
20.	STAT 505 Decision Theory	On completion of the course, students will be able to, • Understand a decision theoretic approach to the problem, evaluate a utility function, propose a conjugate family of prior distributions, evaluate Bayes and posterior risks and find the optimal solution. • Solve Multilevel Decision Problems, Decision Process with sampling information • Understand Basic Concept of the sampling time Markov decision process, telecommunication and queuing theory.	**-**	**Suggested E-learning Resources** 1. Decision Theory; platform: http://www.utdallas.edu/~mbaron/7330/	No change in syllabus.
21.	STAT 508 Distribution Theory	On completion of the course, students will be able to, • Formulate the statistical models for real data sets arising in various fields in order to analyze in respect of various useful	**-**	**Suggested E-learning Resources** 1. Probability Distribution- nptel.ac.in/courses/111105041/ 2. Distribution Functions- https://epgp.inflibnet.ac.in/ahl.php?csrno=34	No change in syllabus.

		characteristics of the populations • Develop problem-solving techniques needed to accurately calculate probabilities. • Identify the distribution of random variable under various discrete and continuous distributions. • Calculate probabilities, moments and other related quantities based on given distributions. • Determine the probability distribution after transformation. • Understand how to use non-central distributions in real life problems.		3. Introduction to Probability- https://ocw.mit.edu/resources/res-6-012-introduction-to-probability-spring-2018	
22.	STAT 510 Econometric Models	On completion of this course, students will be able to, • Construct econometric models from economic models. • Detect influential observations and perform robust regression. • Estimate regression models when the dependent variable is nominal, ordinal or a quantile. • Fit distributed lag model when the data is time series. • Diagnose the identifiability of a simultaneous equation model.	**Section A** Review of multiple linear regression models, Polynomial Regression, Stepwise Regression, Lasso Regression, Model Selection Methods: AIC, BIC, Mallow's Cp, Cross-validation, Regression regularization methods. **Section B** Distributed lag models: Finite polynomial lags, determination of the degree of polynomial. Infinite distributed lags, adaptive expectations and partial adjustment models, determination of lag	**Section A** Nature of Econometrics, Review of linear regression models, polynomial regression model. Stepwise Regression, Lasso Regression, Model Selection Methods: AIC, BIC, Mallow's Cp, Cross-validation, Regression regularization methods. Influential observations: Standardized and studentized residuals, Cook's distance, DFFITS, DFBETAS, COVRATIO. Robust regression techniques: LAD and LMS regression. **Section B** Logit and Probit models: binary response model, multinomial choice models: ordered and unordered	The existing syllabus is a bit short, so some new topics are added which have good application in analyzing an

		• Estimate a simultaneous equation system.	length. Methods of estimation. ~~*[Introduction to logistic regression and]*~~ Poisson regression. **Section C** Simultaneous equation model: concept of structural and reduced forms, problem of identification, rank and order conditions of identifiability, [~~*indirect least squares; two stage least squares,Maximum likelihood estimation.]*~~ **Text/References Books:** 1. Johnston, J. (1984). Econometric Methods, McGraw Hill Kogakusha Ltd. 2. Judge, G.C., Hill, R,C. Griffiths, W.E., Lutkepohl, H. and Lee, T-C. (1988). Introduction to the Theory and Practice of Econometrics, Second Edition, John Wiley & Sons. 3. Kendall, M.G. and Stuart, A. (1968). The Advanced Theory of Statistics (Vol. III), Second Edition, Charles Griffin.	response models. Censored regression, truncated regression models. Poisson regression: estimation and prediction. Introduction to Generalized linear model. Introduction to quantile regression and non-parametric regression. General non-linear regression: Assumptions, Least squares estimation, Testing. **Section C** Distributed lag models: Finite polynomial lags, determination of the degree of polynomial. Infinite distributed lags, adaptive expectations and partial adjustment models, determination of lag length. Methods of estimation. Simultaneous equation models: concept of structural and reduced forms, problem of identification, rank and order conditions of identifiability. Limited information and full information estimation methods. **Suggested Text/References Books:** 1. Baltagi, B. H. (2007). *Econometrics*. Springer Science & Business Media. 2. Gujarati, D. N. (2003). *Basic econometrics*. McGraw Hill. 3. Johnston, J., & DiNardo, J. E. (2007). *Econometric Methods*. McGraw-Hill. 4. Montgomery, D. C., Peck, E. A., & Vining, G. G. (2006). *Introduction To Linear Regression Analysis, 3rd Ed*. Wiley India Pvt. Limited. 5. Rawlings, J. O., Pantula, S. G., & Dickey, D. A. (1998). *Applied Regression Analysis: A Research Tool* (2nd Ed.). New York: Springer-Verlag.	empirical data.

				6. Wooldridge, J. M. (2008). *Introductory Econometrics: A Modern Approach*. Cengage Learning. 7. William H. Greene (2012). *Econometric Analysis* (7th Ed.). Pearson Education limited. **Suggested E-learning material:** 1. Lecture Notes on Regression Analysis by Shalabh, IITK: http://home.iitk.ac.in/~shalab/course5.htm 2. An article on "Understanding logistic regression analysis" by Sandro Sperandei :https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3936971/ 3. Lecture Notes on "Econometrics": https://ocw.mit.edu/courses/economics/14-382-econometrics-spring-2017/lecture-notes/	
23.	**STAT 504** Clinical Trials	On completion of this course, students will be able to, • Identify and classify different types of trial designs when reading a trial report. • Understand the essential design issues of randomized clinical trials. • Appreciate three possible sources of errors that could lead to erroneous trial results. • Understand the basic statistical principles, concepts, and methods for clinical data analysis and reporting; and	**-**	**Suggested E-learning Resources** 1. Clinical Trials http://www.esourceresearch.org/eSourceBook/ClinicalTrials/1LearningObjectives/tabid/192/Default.aspx 2. Clinical Trials as Research https://newonlinecourses.science.psu.edu/stat509/node/6/	**No change in the syllabus.**

		• Understand some frequently used terms in clinical trials. • Understand the relative contributions of clinical judgment and clinical trials in evaluating new medical therapies.			
24.	STAT 511 Non ParametricInference and Sequential Analysis	On completion of this course, student will be able to, • Solve hypothesis testing problems where the conditions for the traditional parametric inferential tools to be applied are not fulfilled. • Build non-parametric density estimates. • The application of sequential statistical techniques. • Critically examining sequential procedures for appropriate statistical analyses.	**-**	**Suggested E-learning Resources** 1. Statistical Methods for Scientists and Engineers-Non Parametric Methods: https://nptel.ac.in/courses/111105077/29. 2. Statistics for Applications: https://ocw.mit.edu/courses/mathematics/18-650-statistics-for-applications-fall-2016/	**No change in the syllabus.**
25.	STAT 508 Distribution Theory	On successful completion of the course, the students will be able to: • Formulate the statistical models for real data sets arising in various fields in order to analyze in respect of various useful characteristics of the populations • Develop problem-solving techniques needed to accurately calculate probabilities.	**-**	**Suggested E-learning Resources** 1. Probability Distribution-nptel.ac.in/courses/111105041/ 2. Distribution Functions-https://epgp.inflibnet.ac.in/ahl.php?csrno=34 3. Introduction to Probability-https://ocw.mit.edu/resources/res-6-012-introduction-to-probability-spring-2018	**No change in the syllabus.**

		• Identify the distribution of random variable under various discrete and continuous distributions. • Calculate probabilities, moments and other related quantities based on given distributions. • Determine the probability distribution after transformation. • Understand how to use non-central distributions in real life problems.			
26.	STAT 513 Regression Analysis	On completion of the course, the students should be ableto, • Understand the concept of regression and the underlying assumptions. • Estimate least squares estimate of regression coefficients. • Perform testing of complete regression model and subset of regression model. • Measure the goodness of the model. • Check the validity of the assumptions for a real data. • Find a suitable remedy to reduce the effect of violation of any assumption. • Include a qualitative variable as regressors in a regression model		**Suggested E-learning Resources** 1. The resources site for the book 'Introductory Econometrics for Finance, 3rd edition' by Chris Brooks https://www.cambridge.org/us/academic/textbooks/introductory-econometrics 2. Lecture Notes on "Econometric Theory": https://nptel.ac.in/courses/111104072/ 3. Course material on "Econometrics": https://ocw.mit.edu/courses/economics/14-32-econometrics-spring-2007	**No change in the syllabus.**

		using dummy variables. • Check the model for specification errors and its testing. • Understand the concept of outlier, leverages and influential observations. • Understand the concept of a simple logistic regression and make interpretations.			
27.	STAT 515 Statistical Computing	On successful completion of this course, student will be able to: • Generate random numbers from a given distribution. • Perform MCMC simulation. • Understand the basic concepts of statistical theories in depth. • Handle real world problems with large scale data.	**-**	**Suggested E-learning Resources** 1. Statistical computing Platform: MITOPENCOURSEWARE https://ocw.mit.edu/index.htm 2. Statistics: Platform: e-PG Pathshalahttps://epgp.inflibnet.ac.in 3. Exploratory Data analysis ; Platform: Coursera https://www.coursera.org 4. https://ocw.mit.edu/index.htm	**No change in the syllabus.**
28.	STAT (to be generated) Stochastic Models	On completion of this course, the students will be able to: • Acquire skills in handling situations involving more than one random variables. • Understand to analyze the performance of reliability models. • Learn how to analyze a network of queues with Poisson arrivals and exponential service requirements. • Learn how to analyze a network of	**-**	**Section A** Review of Stochastic processes, Markov process, Markov chain, Poisson Process. Birth and Death process. Expression for mean and variance of a birth and death process. Introduction of queues, Queueing system. Components of a queueing system, Measures of effectiveness and Notations. Steady state solution of M/M/1 and M/M/1/N Queueing Models and their measures of effectiveness. **Section B** Steady state solution of M/M/C Queueing Models and	**New elective introduced .**

		queues with Poisson arrivals and general service requirements. • Understand the concept of switching in reliability modeling.		their measures of effectiveness. The transient solution of M/M/1 and M/M/∞ Queueing models including busy period distribution. Imbedded Markov chain technique and its use to solve the M/G/1 queueing models. Measures of Effectiveness of M/G/1 queueing model. **Section C** Reliability Models: Concept of reliability, early age failures, wearout failures and chance failures. Derivation of general reliability function failure rate, failure density functions and mean time between failures (MTBF). System reliability evaluation: series system, parallel system, partially redundant system, standby system with perfect switching / imperfect switching. Effect of spare components (identical / non-identical) on the system reliability. **Text/References books:** 1. Cox, D. R., & Miller, H. D. (1972). *The theory of stochastic processes*. London: Chapman and Hall. 2. Billinton, R., & Allan, R. N. (2013). *Reliability evaluation of engineering systems: Concepts and techniques*. New Delhi: Springer (India). 3. J. Medhi, J. (1994). *Stochastic processes*. New Age International Publications. 4. Bazovsky, I. (2013). *Reliability Theory and Practice*. Dover Publications. 5. Gross, D., &Harris C.M (2002). *Fundamentals of Queueing Theory*. John Wiley & Sons. 6. Allen, A. O. (2014). *Probability, Statistics, and Queueing Theory with Computer Science Applications*.	

				Academic Press. **Suggested E-learning Resources** 1. Introduction to Stochastic Processes and its Applications https://nptel.ac.in/courses/110104024/ 2. Statistics e-PG-pathshala: https://epgp.inflibnet.ac.in/ahl.php?csrno=34 3. Reliability Engineering, NPTEL: **https://nptel.ac.in/courses/105108128/**	
29.	STAT (to be generated) Demography	On completion of the course, students will be able to, • Identify principle sources of demographic data and assess their strengths and weaknesses. • Discuss the demographic significance of age and sex structures and the implications of variations in age & sex structure. • Construct and interpret life tables. • Calculation and interpretation of the principal demographic measures, and standardize these measures for comparison. • Understand the components of population change, including the effects of changing birth, death and migration rates, and demonstrate their influences on age structure. • Understand the concept of		**Section A** Meaning and scope of demography; Sources of demographic data; Census; Population composition and its basic demographic measures: Ratios, Proportions and Percentages; Population pyramids; Quality of demographic data: Population growth rate; Rates of natural increase; Doubling time; Stochastic models for population growth; Intrinsic growth rate models for population growth and their fitting to population data; Coverage and content errors in demographic data; Balancing equations;Chandrasekharan - Deming formula to check completenessof registration data; Adjustment of age data- use of Whipple, Myer and UN indices; Population transitiontheory. **Section B** Mortality: Rates and Ratios; Crude and age-specific death rates;Infant mortality rate (IMR); Child death rate (CDR); Under five, neo-natal and post neo-natal	**New elective introduced**

		urbanization on the economic growth of the contrary. • Estimate and project the population by different methods. • Understand the concept of stable and stationary population.		mortality rate; Maternal mortality rate and Maternal mortality ratio (MMR); Direct and Indirect Standardization; Factors for decline in mortality in recent past; Life tables and their applications; Increment-decrement life tables; Construction of complete and abridged life tables; Model life table. Natality:Fecundity and fertility; Measure of fertility: Cohort fertility; Children ever born (CEB); Current family size (CFS); Age specific martial fertility rate;Birth order and parity; Parity progression ratio; Length of generation, Measures of reproduction: Total fertility rate; Gross reproduction rate; Net reproduction rate; Replacement index; General fertility models; Fertility schedules; Differential fertility; Levels and trends of fertility. **Section C** Migration - Concepts and types; Its effect on population growth and pattern; Differentials of migration; Measures of migration: Migration rates; Volume of migration and its estimation; Migration component; Migration streams; Hamilton's rate; Migration models; Concept of international migration; Concept of morbidity and its measures. Urbanization - Growth and distribution of rural - urban population in developed and developing countries. Nuptiality - Concept and analysis of marital status; Singulate mean age at marriage. Stationary and Stable population theory; Uses of Lotka's stable population theory in estimation of	

				demographic parameters; Population estimates; Population projections and forecasting; Methods of Inter-censal and Post-censal estimation; Methods of population projection. **Suggested Text Books:** 1. Ramkumar, R.(2006). *Technical Demography*. New Age International. 2. Pathak, K.B.& Ram, F. (2019). *Techniques of Demographic Analysis* (2nd. ed.). Himalaya Publishing House. 3. Srinivasan, K., Saxena, P. C., &Kanitkar, T. (1979). *Demographic and Socio-economic Aspects of the Child in India*. Himalaya Publishing House. **Suggested Reference Books:** 1. Cox, P. R. (2009). *Demography* (6th. ed.). GBR Cambridge University Press. 2. Sinha, V. C., & Zacharia, E. (1984). *Elements of demography*. Allied Publishers. 3. Bhinde, A. A. &Kanitker, T. (2018). *Principles of Population Studies* (19th. ed.). Himalaya Publishing House. **Suggested E-learning Resources** 1. Demographic data; Platform: National Family Health Survey, India http://rchiips.org 2. Population Studies; Platform; e-PG Pathshalahttps://epgp.inflibnet.ac.in/loaddata.php?action=loadpaperlist1&maincat=453 3. Demography ; Platform: University Library -	

				The University of Adelaide https://www.adelaide.edu.au/library/ 4. Demography; Platform: MITOPENCOURSEWARE https://ocw.mit.edu/index.htm	
30.	STAT (to be generated) Actuarial Statistics	On completion of this course, the students will be able to: • Understand the applications of Actuarial Statistics in insurance sector. • Understand the concept of utility theory and premium principles. • Construct life tables with various factors. • Understand the concept of compound interest. • Apply various life Insurance models in real life situations.		**Section A** Actuarial science: an overview, Introductory Statistics and Insurance Applications: Discrete, continuous and mixed probability distributions, risk and insurance, insurance products, reinsurance and its different types. Utility theory: Utility functions, expected value principle, expected utility criterion, types of utility function, insurance and utility theory. Principles of Premium Calculation: Properties of premium principles. **Section B** Survival Distribution and Life Tables: Age at death random variable, survival function, time until-death for a person, curate future lifetime, force of mortality, life tables, relation of life table functions to the survival function, deterministic and random survivorship group, life table characteristics, recursion formulas, assumptions for fractional age, analytical laws of mortality, select and ultimate tables. **Section C** Principles of compound interest: Nominal and effective rates of interest and discount, force of interest and discount, compound interest, accumulation factor, continuous compounding, present value of a future payment. Life Insurance models: Models for insurance	**New elective introduced**

				payable at the moment of death and at the end of the year of death - level benefit insurance, endowment insurance, deferred insurance and varying benefit insurance. **Text/Reference Books:** 1. Dickson, C. M. D. (2005). *Insurance Risk and Ruin (International Series no. 1 Actuarial Science)*, Cambridge University Press. 2. Bowers, N.L., Gerber, H.U., Hickman, J.C., Jones, D.A. and Nesbitt, C.J. (1997). *Actuarial Mathematics*. Society of Actuaries, Itasca, Illinois, U.S.A. 3. Rotar, V.I. (2015). *Actuarial Models: The Mathematics of Insurance*, 2nd ed., CRC Press, New York. 4. Deshmukh, S.R. (2009). *Actuarial Statistics: An Introduction Using R*, University Press, India. **Suggested E-learning Resources** 1. Winkel, M. (2003). Actuarial Science http://www.stats.ox.ac.uk/~winkel/o13.pdf	
31.	**STAT (to be generated) Survival Analysis**	On completion of the course, the student will be able to, • Identify characteristics of survival data and problems in their correct analysis • Define and understand the relationship between the survival function, distribution function, hazard function, relative hazard, and		**Section A** Characteristics of survival data and problems, censoring and its types, likelihood and inference of life distributions, relationship between the survival function, distribution function, hazard function, relative hazard, and cumulative hazard, univariate analyses of survival data using the Kaplan-Meier estimator and actuarial estimator, estimation under the assumption of IFR/DFR, tests of exponentiality against non-	**New elective introduced**

		cumulative hazard • Perform and interpret one-sample and two-sample analyses of survival data using common statistical procedures such as the log rank test and Kaplan-Meier estimator • Formulate research questions involving survival data as regression problems • Fit the proportional hazards regression and parametric regression models to survival data and assess the scientific significance, precision, and interpretation of regression coefficients • Use graphical and other methods to assess the adequacy of fitted models and propose alternate solutions when common assumptions are violated • Use time-dependent covariates in the proportional hazards model and interpret the coefficients • Understand and use methods for analyzing correlated survival data • Interpret and critically evaluate survival analyses in biomedical or epidemiologic manuscripts		parametric classes, total time on test. **Section B** Two-sample analyses of survival data using common statistical procedures such as the log rank test and Gehan test, Parametric and semi-parametric regression model to survival data and assess the estimation, scientific significance, precision, and interpretation of regression coefficients, graphical and other methods to assess the adequacy of fitted models and propose alternate solutions when common assumptions are violated, **Section C** Time-dependent covariates in the proportional hazards model and estimate and interpret the coefficients, methods for analyzing correlated survival data, Competing risk model: parametric and non-parametric inference for this model. **Text Books** 1. Collet, D. (2003). *Modeling Survival Data in Medical Research*. London: Chapman and Hall. 2. Hosmer, D. and Lemeshow S. (1999). *Applied Survival Analysis: Regression Modeling of Time to Event Data*. New York: Wiley. **Reference Books** 1. Breslow, N. and Day, N. (1987). *Statistical Methods in Cancer Research, v. 2: The Design and Analysis of Cohort Studies*. Lyon: IARC. 2. Therneau T, and Grambsch, P. (2000). *Modeling Survival Data: Extending the Cox Model*. New	

				York: Springer 3. Kalbfleish, JD. and Prentice, RL. (2002). *The Statistical Analysis of Failure Time Data*. New York: Wiley. **Suggested E-learning Resources** **1.** Lecture Notes on Introduction to Survival Analysis: http://www.stat.columbia.edu/~madigan/W2025/notes/survival.pdf	

THIRD/FOURTH SEMESTER

(Reading Electives)

S.N.	Course List	Learning Outcomes	Existing Syllabus	Suggested Syllabus	Remark
1	MATH (to be generated) Network Biology	On completion of the course, the student will be able to, • Understand the use of graph theory in biology • Build and analyse network of biological systems.	-	Networks in Biology, Graph Theory, Global Network Properties, Network Centralities, Network of Clustering, Network Motifs, Petri Nets, Signal Transduction and Gene Regulation Networks, Protein Interaction Networks, Metabolic Networks, Phylogenetic Networks, Ecological networks, Correlation Network, Network Construction. **Suggested Readings:** 1. Junker, B. H., & Schreiber F. (2008). *Analysis of Biological Networks,*John Wiley & Sons, Inc. 2. Zhang, W. (2013). *Network Biology Theories, Methods and Applications,* Nova Science	New course proposed.

S.N.	Course List	Learning Outcomes	Existing Syllabus	Suggested Syllabus	Remark
				Publishers, Inc.	
2	MATH (to be generated) Fractional Calculus	On completion of the course, the student will be able to, • Understand fractional integrals of some important functions • Understand the concepts of Fractional Derivatives • Carry out research on the topic related to fractional calculus		Origin, Significant contributions, development in different timelines, different aspects, contributors in the field, The Riemann Liouville Fractional Calculus: Fractional Integrals of some functions namely binomial function, exponential, the hyperbolic and trigonometric functions, Bessel's functions, Hyper-geometric function. Dirichlet's Formula, Derivatives of the Fractional Integral and the Fractional Integral of Derivatives. Laplace Transform of the Fractional integral, Leibniz's Formula for Fractional Integrals. Derivatives, Leibniz's Formula of Fractional Derivatives. **Suggested Readings:** 1. Oldham, K.B. &Spanier, J. (2006). The *Fractional Calculus: Theory and Applications of Differentiation and Integration to Arbitrary Order*. Dover Publications Inc. 2. Machado, J.T.A., Virginia, K., &Mainardi, F. (2011). Recent History of Fractional Calculus. *Communications in Nonlinear Science and Numerical Simulation*. 3. Machado, J. A. T., Kiryakova , V. &Mainardi, F. (2010). A poster about the recent history of fractional calculus. *J. Fractional Calculus and Applied Analysis*.	New course proposed.
3	MATH (to be generated) Quantum Graphs	On completion of the course, the student will be able to, • Describe some basic tools in the spectral theory of Schrödinger		Introduction, Operators on graphs, Quantum Graphs, Quantum Graphs: Some Special topics, Spectra of quantum graphs, Spectra of periodic graphs, Spectra of quantum graphs, Quantum Chaos on graphs, Some	New course proposed.

S.N.	Course List	Learning Outcomes	Existing Syllabus	Suggested Syllabus	Remark
		operator on metric graphs • Demonstrate results on the count of zeros of the eigen functions of quantum graphs. • Demonstrate key concepts of general spectral theory.		Applications and generalizations. The Spectral Form Factor for Quantum Graphs with Spin-Orbit Coupling, Approximation of Permutation-Symmetric Vertex Couplings in Quantum Graphs, Determinant of the Schrodinger Operator on a Metric Graphs, Laplacian or Metric Graphs; eigenvalues, resolvents and Semigroups. **Suggested Readings:** 1. Berkolaiko G. and Kuchment Peter (2016), *Introduction to Quantum Graphs*, Indian Edition. 2. Berkolaiko G., Carlson R., Fulling S. A. and Kuchment Peter (2006), *Quantum Graphs and Their Applications*, American Mathematical Society.	
4	MATH (to be generated) Point Set Topology	**Course Outcomes:** On completion of the course, the student will be able to, • Express the notion of metric space, construct the topology by using the metric and using this topology identify the continuity of the functions which are defined between metric spaces. • Define the notion of topology; construct various topologies on a general set which is not empty by using different kinds of techniques. • Define the subspace topology, Construct the product topology on product spaces, and Construct the		Sets, Functions, The Real Numbers, Zorn's Lemma, Countable Sets, Metric Spaces, Sequences and completeness, Continuity, Compactness, Connectedness, The BaireCategory Theorem, Topological Spaces, Base and Subbase for a Topology, Continuous Functions, Compactness and Connectedness, Pathwiseconnectedness, Infinite Products, Nets , Quotient Topology. **Suggested Readings:** 1. Conway, J. B. (2014). *A course in point set topology*. Springer. 2. Körner, T. (2010). Metric and topological spaces. 3. Munkres, J. R. (1978). *Topology, a first course*. New Delhi: Prentice-Hall of India.	New course proposed.

S.N.	Course List	Learning Outcomes	Existing Syllabus	Suggested Syllabus	Remark
		quotient topology.			
5	MATH (to be generated) Operational Research Applications	On completion of the course, the student will be able to, • To have the knowledge of role of O.R. in solving industrial problems. • To introduce the important ideas in operations research which are both fundamental and long lasting. • To prepare and motivate future specialists to continue in their study by having an insightful overview of operations research. • To demonstrate the cohesiveness of operations research methodology. • To identify the resources required for a project and generate a plan and work schedule.		Media allocation problem, Cargo Loading Problem, Production Scheduling Problem, Wood cutting problem, School bus routing problem using spanning tree, Simulation, Knapsack problem, Set Covering Problem, Fixed Charge Transportation Problem, Project Selection Problem. **Suggested Readings:** 1. Taha, H. A. (2010). *Operations Research-An Introduction* (9th Ed.), Prentice Hall. 2. Winston, W. L., &Venkataramanan, M. (2002). *Introduction to Mathematical Programming: Applications and Algorithms* (4th ed.). Duxbury Press. 3. Ravindran, A., Phillips, D. T. & Solberg, J. J. (2005). *Operations Research. Principles and Practice*, John Wiley & Sons. 4. Hadley, G. (1964). *Nonlinear and Dynamic Programming*, Addison-Wesley.	New course proposed.
6	STAT (to be generated) Selected Applications of Stochastic Models	On completion of the course, the student will be able to, • Elucidate the power of stochastic processes and their range of applications. • Demonstrate essential stochastic modelling tools including Markov chains and queuing theory. • Use probabilistic arguments		Markov decision processes: finite and infinite horizon models. Optimality of Markov policies. Computational aspects. Examples from inventory systems, resource allocation, etc. Learning algorithms: Temporal difference methods. Methods based on approximation functions; TD(lambda); Q-learning. Stability of queuing models. Little's law and its extensions. Advanced queuing models in discrete and continuous time.	New course proposed.

S.N.	Course List	Learning Outcomes	Existing Syllabus	Suggested Syllabus	Remark
		including conditional distributions and expectations. • Carry out basic modelling using Markov chains in discrete and continuous time. • Review and apply Markov chains methods based on stationary and asymptotic distributions.		Some classes of stochastic scheduling rules; minimizing mean sum of completion times on a single machine with and without pre-emptions and index policies. Makespan with and without pre-emptions on parallel machines; due date related objectives. **Suggested Readings:** 1. Bertsekas, D. P. (1995). *Dynamic programming and optimal control* (Vol. 1 & 2). Belmont: Athena publications. 2. Wolff, R.W. (1989). *Stochastic modeling and theory of queues*. Englewood Cliffs: Prentice-Hall Inc. 3. Pinedo, M. (1995). *Scheduling: Theory, algorithms and systems*. Englewood Cliffs: Prentice-Hall Inc.	
7	STAT (to be generated) Step-Stress Modelling	On completion of the course, the student will be able to, • Understand statistical models and methods for analyzing accelerated life-test data from step-stress tests. • Understand how to use ALT methods in real life problems.		Deferent Aspects of ALT Models, Accelerated Life Test, Step Stress Test, Acceleration Model, Cumulative Exposure Model, Optimum Step-Stress Accelerated Life Test Models, Optimum Step-Stress Partially Accelerated Life Test Plans with Type-I and Type-II Censoring. **Suggested Readings** 1. Kundu, D. and Ganguly, A. (2017). *Analysis of Step-Stress Models*. Elsevier. 2. Tang, L-C. (2018). *Multiple-steps Step-stress Accelerated Life Test*. Springer. 3. Accelerated Life Test; Platform: http://home.iitk.ac.in/~kundu/seminar25.pdf 4. Different aspects of ALT models; Platform: https://www.worldscientific.com/doi/pdf/10.1142/9789813141261_fmatter	New course proposed.

S.N.	Course List	Learning Outcomes	Existing Syllabus	Suggested Syllabus	Remark
8	STAT (to be generated) Categorical Data Analysis	On completing the course, the student will be able to: • Identify and understand the structure of categorical data and be able to phrase the appropriate scientific questions in terms of parameters of interest. • Understand the various assumptions needed for the various methodologies • Test for independence, and equality of proportions • Fit logistic models for binary data • Check model assumptions and analyze residuals and goodness-of-fit • Conduct inference for model parameters and interpret the output of the models		Categorical Response Data: Nominal/Ordinal scale, statistical inference for a proportion and discrete data. Probability Structures for Contingency Tables. Comparing Proportions in Two-by-Two Tables, Odds Ratio: their properties and relation with relative risk. Tests of Independence of two attributes. Testing Independence for Ordinal Data: Choice of Scores, Trend Tests for $I \times 2$ and $2 \times J$ Tables, Nominal–Ordinal Tables, Exact Inference for Small Samples. Association in Three-Way Tables. Logistic regression model: Interpretations, inferences, model selection, model checking. Logit Models for Nominal Responses, Cumulative Logit Models for Ordinal Responses, Paired-Category Ordinal Logits. Loglinear Models for Two-Way and Three-Way Tables **Suggested Readings** 1. Alan Agresti, An Introduction to Categorical Data Analysis, Second Edition, Wiley Interscience, 2007. 2. Categorical Data Analysis: http://web.pdx.edu/~newsomj/cdaclass/	New course proposed.
9	STAT (to be generated) Robust estimation in Non Linear Models	On completion of this course, student will be able to • Understand the basics of fitting and inference for nonlinear regression methods when the regression function acting on the predictors is not linear in the parameters.		Non Linear Models: Introduction to non Linear models, non-linear least squares estimators, outliers, robustness of models against outliers, robust M-estimation approach, asymptotic properties of robust M-estimators, the asymptotic theoretical properties of M-estimators under different possibilities of the M-estimation function and noise distribution assumptions. It is an important and challenging problem to design	New course proposed.

S.N.	Course List	Learning Outcomes	Existing Syllabus	Suggested Syllabus	Remark
		• Check the robustness of the fitted model. • Carry out research in the area of robust estimation.		robust order estimation techniques for nonlinear nested models and establish their asymptotic optimality properties **Suggested readings:** 1. Cizek, P. (2001).Robust Estimation in Nonlinear Regression Models. https://www.researchgate.net/publication/23737960_Robust_Estimation_in_Nonlinear_Regression_Models 2. Zhu, L., Li, R., & Cui, H. (2013). Robust estimation for partially linear models with large-dimensional covariates. *Science China. Mathematics*, *56*(10), 2069–2088. https://doi.org/10.1007/s11425-013-4675-0 3. Neugebauer, S.P. (1996). Robust Analysis of M-Estimators of Nonlinear Models. *citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.11.2523&rep=rep1...pdf*	
10	STAT (to be generated) Official Statistics	On completion of the course, the students will be able to: • Know the key aspects of Official Statistics, as distinct from other branches of statistics. • Know the legal and ethical constraints on organizations producing Official Statistics. • Know the principal methods for data collection, analysis and interpretation of health, social and economic.		Official statistics provide a picture of a country or different phenomena through data, and images such as graph and maps. Statistical System in India: Central and State Government Organizations, Functions of Central Statistical Organization (CSO), National Sample Survey Organization (NSSO). System of Collection of Agricultural Statistics - Crop forecasting and estimation Productivity, fragmentation of holdings - Support prices - Buffer stocks - Impact of irrigation projects**.** Statistics related to industries, foreign trade - Balance of payment - Inflation - Social statistics. National Income – Measures	

S.N.	Course List	Learning Outcomes	Existing Syllabus	Suggested Syllabus	Remark
		• Know the methods for presenting and preparing commentaries on Official Statistics.		of national income - Income, expenditure and production approaches - Applications in various sectors in India. Measurement of income inequality: Gini's coefficient, Lorenz curves, Application of Pareto and Lognormal as income distribution. **Suggested readings:** 1. Bhaduri, A. (1990). *Macroeconomics: The Dynamics of Commodity Production*, Macmillan India Limited, New Delhi. 2. Branson, W. H. (1992). *Macroeconomic Theory and Policy*.(3rd ed.). Harper Collins Publishers India (P) Ltd., New Delhi. 3. C. S. O. (1990). *Basic Statistics Relating to the Indian Economy*. 4. C.S.O. (1995). *Statistical System in India.* 5. C. S. O. (1999). *Guide to Official Statistics.* 6. Panse, V. G. (1964). *Estimation of Crop Yields (FAO)*. Food and Agriculture Organization of the United Nations. 7. Central Statistical Organization: http://www.mospi.gov.in/central-statistics-office-cso-0 8. National Sample Survey Office (NSSO) http://www.mospi.gov.in/national-sample-survey-office-nsso 9. Agriculture Survey Reports: https://eands.dacnet.nic.in/	

Verified

Offg. Secretary
Banasthali Vidyapith
P.O. Banasthali Vidyapith
Distt. Tonk (Raj.)-304022

Name of Programme: M.Phil (Mathematical Science)
Course Details: (To be provided in the below mentioned table)
Note: 1. Black Shaded part is shifted. 2. Strikeout is deleted. 3. Italic and Underline is rewritten., 4.Grey shaded part is added.

First Semester

S.N.	Course List	Learning Outcomes	Existing Syllabus	Suggested Syllabus	Remark
1.	MATH (to be generated) Research Methodology				New Course
2.	MATH 602 Advanced Analysis	On completion of the course, students will be able to, • Tell what is Normed spaces • Explain when Normed space become Banach space • Define the Hilbert spaces • Define multi linear mappings • Check whether the function is bounded or not? • What is directional derivative? • Explain the difference between partial derivative and directional derivative • Tell about the fixed point • Tell about the Lipschitz's constant and conditions • Related the analysis and differential equation • Explain the fixed point using graph theory		**Suggested E-learning material:** 1. Normed space Banach space and Hilbert spaces and its properties; Platform:https://nptel.ac.in/courses/11110503/	No change in the syllabus
3.	MATH 504 Analytic and	On completion of the course, students will be able to,		--	No change in the

	Algebraic Number Theory	• Demonstrate the knowledge of arithmetic functions and their property. • Know the prime number theorem and its analytic proof. • Understand basic concepts of algebraic number theory such as conjugates, discriminants, algebraic integers, integral basis, norms and traces. • Understand prime factorization of ideal and unique factorization. • Know some important theorem in algebraic number theory.	--		syllabus

Electives

S.N.	Course List	Learning Outcomes	Existing Syllabus	Suggested Syllabus	Remark
1.	MATH 507 Financial Mathematics	On completion of the course, students will be able to, • Understand financial analysis and planning. • Know the cost of capital, capital structure and dividend policies. • Apply technique of Goal Programming to profit planning and financial budgeting. • Make financing decision onproblem of determining optimal capital structure • Understand the concept of leasing, debt management, analysis of			**No change in the syllabus**

		commitment of funds and risk of cash insolvency.			
2.	MATH 527 Tensor Analysis and Geometry of Manifolds	On completion of the course, students will be able to, • Discuss different kinds of surfaces, connection and covariant derivatives. • Understand the concepts of manifold and illustrate some examples of manifolds. • Understand the Ricci identity and enable to use it in proving different theorems. • Define and illustrate some examples of Lie group.	--	**Suggested E-learning material:** 1. NOC: Differential Calculus in Several Variables: https://nptel.ac.in/courses/111104092/ 2. NOC: Multivariable Calculus: https://nptel.ac.in/courses/111107108/ 3. NOC: Calculus of One Real Variable: https://nptel.ac.in/courses/109104124/	**No change in the syllabus**
3.	MATH 601 Advanced Graph Theory	On completion of the course, the student will be able to, • To understand and apply the fundamental concepts in graph theory. • To recognize and express the mathematical ideas graphically. • Acquire ability to apply graph theory based tools in solving practical problems. • To improve the proof writing skills. • To develop mathematical maturity. • Understand some applications of graph theory to practical problems and other areas.		**Suggested E-learning material** 1. Basic concepts in graph theoryhttps://nptel.ac.in/downloads/111104026/ 2. Basic concepts in graph theory http://home.iitk.ac.in/~arlal/book/mth202.pdf 3. Euler graph, Hamiltonian graph, connectivity and coloring http://www.math.kit.edu/iag6/lehre/graphtheo2015w/media/lecture_notes.pdf 4. Ramsey theoryhttp://math.mit.edu/~fox/MAT307-lecture05.pdf 5. Matchinghttp://www-math.mit.edu/~djk/18.310/Lecture-Notes/MatchingProblem.pdf 6. Open course in graph theory (All topics) a. https://swayam.gov.in/course/3795-graph-theory b. https://swayam.gov.in/course/4403-advanced-graph-theory	**No change in the syllabus**

4.	MATH 614 Finsler Geometry	On completion of the course, the student will be able to • Make use of purely metric methods in the investigation of various Finsler metrics that appear naturally in geometry, topology and convexity theory.		**Suggested E-learning material** 1. Lectures on Differential Geometry: https://www.math.iupui.edu/~zshen/Research/papers/lecture.pdf 2. Lectures on Differential Geometry: https://www.worldscientific.com/worldscibooks/10.1142/4619#t=toc	**No change in the syllabus**
5.	MATH 619 Mathematical Cryptography	On completion of the course, students will be able to, • Understand the necessary concepts of number theory and complexity theory. • Understand the need of cryptography and its impact on the society. • Demonstrate the knowledge of one way functions and its concrete examples such as integer factorization and discrete logarithm. • Understand the public key cryptosystems such as RSA and ElGamal. • Know the concept of digital signature.		**Suggested E-learning material:** 1. Lecture Notes on Number Theory: https://nptel.ac.in/courses/111103020/ 2. Video Lecture on Number Theory: https://bit.ly/2ToTdjZ 3. Video Lecture on Cryptography: https://nptel.ac.in/courses/106105031/	**No change in the syllabus**
6.	STAT 504 Clinical Trials	On completion of this course, students will be able to, • Identify and classify different types of trial designs when reading a trial report.		**Suggested E-learning Resources** 1. Clinical Trials http://www.esourceresearch.org/eSourceBook/ClinicalTrials/1LearningObjectives/tabid/192/Default.aspx	**No change in the syllabus.**

		• Understand the essential design issues of randomized clinical trials. • Appreciate three possible sources of errors that could lead to erroneous trial results. • Understand the basic statistical principles, concepts, and methods for clinical data analysis and reporting; and • Understand some frequently used terms in clinical trials. • Understand the relative contributions of clinical judgment and clinical trials in evaluating new medical therapies.		2. Clinical Trials as Research https://newonlinecourses.science.psu.edu/stat509/node/6/	
7.	STAT 505 Decision Theory	On completion of the course, students will be able to, • Understand a decision theoretic approach to the problem, evaluate a utility function, propose a conjugate family of prior distributions, evaluate Bayes and posterior risks and find the optimal solution. • Solve Multilevel Decision Problems, Decision Process with sampling information • Understand Basic Concept of the sampling time Markov decision process, telecommunication and	-	**Suggested E-learning Resources** 1. Decision Theory; platform: http://www.utdallas.edu/~mbaron/7330/	No change in syllabus.

		queuing theory.			
8.	STAT 508 Distribution Theory	On successful completion of the course, the students will be able to: • Formulate the statistical models for real data sets arising in various fields in order to analyze in respect of various useful characteristics of the populations • Develop problem-solving techniques needed to accurately calculate probabilities. • Identify the distribution of random variable under various discrete and continuous distributions. • Calculate probabilities, moments and other related quantities based on given distributions. • Determine the probability distribution after transformation. • Understand how to use non-central distributions in real life problems.		**Suggested E-learning Resources** 1. Probability Distribution- nptel.ac.in/courses/111105041/ 2. Distribution Functions- https://epgp.inflibnet.ac.in/ahl.php?csrno=34 3. Introduction to Probability- https://ocw.mit.edu/resources/res-6-012-introduction-to-probability-spring-2018	No change in syllabus.
9.	STAT 510 Econometric Models	On completion of this course, students will be able to, • Construct econometric models from economic models. • Detect influential observations and perform robust regression. • Estimate regression models when the dependent variable is nominal, ordinal or a quantile. • Fit distributed lag model when the data is time series.	**Section A** Review of multiple linear regression models, Polynomial Regression, Stepwise Regression, Lasso Regression, Model Selection Methods: AIC, BIC, Mallow's Cp, Cross-validation, Regression regularization methods. **Section B** [redacted]	**Section A** Nature of Econometrics, Review of linear regression models, polynomial regression model. Stepwise Regression, Lasso Regression, Model Selection Methods: AIC, BIC, Mallow's Cp, Cross-validation, Regression regularization methods. Influential observations: Standardized and studentized residuals, Cook's distance, DFFITS, DFBETAS, COVRATIO. Robust regression techniques: LAD and LMS regression.	The existing syllabus is a bit short, so some new topics are added which have good application in

		• Diagnose the identifiability of a simultaneous equation model. • Estimate a simultaneous equation system.	[redacted] [redacted] ~~*[Introduction to logistic regression and]*~~ Poisson regression. **Section C** Simultaneous equation model: concept of structural and reduced forms, problem of identification, rank and order conditions of identifiability, [~~*indirect least squares; two stage least squares,Maximum likelihood estimation.]*~~ **Text/References Books:** 1. Johnston, J. (1984). Econometric Methods, McGraw Hill Kogakusha Ltd. 2. Judge, G.C., Hill, R,C. Griffiths, W.E., Lutkepohl, H. and Lee, T-C. (1988). Introduction to the Theory and Practice of Econometrics, Second Edition, John Wiley & Sons. 3. Kendall, M.G. and Stuart, A. (1968). The Advanced Theory of Statistics (Vol. III), Second Edition, Charles Griffin.	**Section B** Logit and Probit models: binary response model, multinomial choice models: ordered and unordered response models. Censored regression, truncated regression models. Poisson regression: estimation and prediction. Introduction to Generalized linear model. Introduction to quantile regression and non-parametric regression. General non-linear regression: Assumptions, Least squares estimation, Testing. **Section C** [redacted] Simultaneous equation models: concept of structural and reduced forms, problem of identification, rank and order conditions of identifiability. Limited information and full information estimation methods. **Suggested Text/References Books:** 1. Baltagi, B. H. (2007). *Econometrics*. Springer Science & Business Media. 2. Gujarati, D. N. (2003). *Basic econometrics*. McGraw Hill. 3. Johnston, J., & DiNardo, J. E. (2007). *Econometric Methods*. McGraw-Hill. 4. Montgomery, D. C., Peck, E. A., & Vining, G. G. (2006). *Introduction To Linear Regression Analysis, 3rd Ed*. Wiley India Pvt. Limited.	analyzing an empirical data.

				5. Rawlings, J. O., Pantula, S. G., & Dickey, D. A. (1998). *Applied Regression Analysis: A Research Tool* (2nd Ed.). New York: Springer-Verlag. 6. Wooldridge, J. M. (2008). *Introductory Econometrics: A Modern Approach*. Cengage Learning. 7. William H. Greene (2012). *Econometric Analysis* (7th Ed.). Pearson Education limited. **Suggested E-learning material:** 1. Lecture Notes on Regression Analysis by Shalabh, IITK: http://home.iitk.ac.in/~shalab/course5.htm 2. An article on "Understanding logistic regression analysis" by Sandro Sperandei :https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3936971/ 3. Lecture Notes on "Econometrics": https://ocw.mit.edu/courses/economics/14-382-econometrics-spring-2017/lecture-notes/	
10.	STAT 511 Non-Parametric Inference and Sequential Analysis	On completion of this course, student will be able to, • Solve hypothesis testing problems where the conditions for the traditional parametric inferential tools to be applied are not fulfilled. • Build non-parametric density estimates. • The application of sequential statistical techniques. • Critically examining sequential procedures for appropriate statistical analyses.		**Suggested E-learning Resources** 1. Statistical Methods for Scientists and Engineers-Non Parametric Methods: https://nptel.ac.in/courses/111105077/29. 2. Statistics for Applications: https://ocw.mit.edu/courses/mathematics/18-650-statistics-for-applications-fall-2016/	**No change in the syllabus.**

11.	STAT 513 Regression Analysis	On completion of the course, the students should be able to, • Understand the concept of regression and the underlying assumptions. • Estimate least squares estimate of regression coefficients. • Perform testing of complete regression model and subset of regression model. • Measure the goodness of the model. • Check the validity of the assumptions for a real data. • Find a suitable remedy to reduce the effect of violation of any assumption. • Include a qualitative variable as regressors in a regression model using dummy variables. • Check the model for specification errors and its testing. • Understand the concept of outlier, leverages and influential observations. • Understand the concept of a simple logistic regression and make interpretations.		**Suggested E-learning Resources** 1. The resources site for the book 'Introductory Econometrics for Finance, 3rd edition' by Chris Brooks https://www.cambridge.org/us/academic/textbooks/introductory-econometrics 2. Lecture Notes on "Econometric Theory": https://nptel.ac.in/courses/111104072/ 3. Course material on "Econometrics": https://ocw.mit.edu/courses/economics/14-32-econometrics-spring-2007	**No change in the syllabus.**
12.	STAT 603 Bayesian Inference	On completion of the course, students will be able to: • Calculate simple likelihood		**Suggested E-learning material** 1. Bayesian Statistics: From Concept to data analysis https://www.coursera.org/learn/bayesian-statistics **2.** Introduction to Bayesian Statistics	**No change in the syllabus.**

		function and use relative frequencies to estimate probabilities and conditional probabilities. • Calculate posterior probabilities using Bayes' theorem • Describe the role of the posterior distribution, the likelihood function and the posterior distribution in Bayesian inference about a parameter. • Explain in detail the Bayesian framework for data analysis and its flexibility and be able to demonstrate when the Bayesian approach can be beneficial. • Develop, analytically describe, and implement both single and multi parameter probability models in the Bayesian framework. • Demonstrate the role of the prior distribution in Bayesian inference and be able to articulate the usage of non-informative priors and conjugate priors. • Show high level Interpretation of Bayesian Analysis Results and be able to readily perform Bayesian model		https://www.statistics.com/bayesian-statistics/	

		evaluation and assessment. • Demonstrate the necessary skills to: fit hierarchical models, provide thorough technical specifications for these models. • Demonstrate how Bayesian Methods can be used to solve real world problems. • Communicate complex statistical ideas to a diverse audience.			
13.	STAT 609 Population Sciences	On completion of the course, students will be able to: • Identify principle sources of population data and assess their strengths and weaknesses. • Able to evaluate of human development index. • Construct and interpret life tables. • Aware various population policies and programs. • Calculation and interpretation of the principal demographic measures, and standardize these measures for comparison. • Understand the significance of age- sex structures and their implications on population		**Suggested E-learning material** 1. Demographic data; Platform: National Family Health Survey, India http://rchiips.org 2. Population Studies; Platform; e-PG Pathshala https://epgp.inflibnet.ac.in/loaddata.php?action=loadpaperlist1&maincat=453 3. Demography ; Platform: University Library - The University of Adelaide https://www.adelaide.edu.au/library/ 4. Demography; Platform: MIT OPENCOURSEWARE https://ocw.mit.edu/index.htm	**No change in the syllabus.**

		change, including the effects of changing birth, death and migration rates, and demonstrate their influences on age structure. • Understand the concept of urbanization on the economic growth of the contrary. • Estimate and project the population by different methods.			
14.	STAT 613 Time Series Modeling	On completion of this course, the students will be able to, • Estimate and eliminate trend and seasonality in a time series • Fit stationary and non-stationary time series model to a series • Understand the concept of testing for parameter stability of a time series model • Demonstrate fitting of multivariate ARMA model to series • Understand the concept of cointegration analysis and procedure for two variable models. • Understand the concept of Vector autoregression and		**Suggested E-learning material** 1. Econometric Modeling. Platform: https://nptel.ac.in/courses/110105053/29 2. Video lectures on Econometric Modeling: https://nptel.ac.in/courses/110105030/37 3. Video lectures on e-PG- Pathshala, Subject: Statistics, Paper Name: P-14. Econometrics and Financial Time Series https://epgp.inflibnet.ac.in/ahl.php?csrno=34	**No change in the syllabus.**

		causality. • Understand the concept of volatility in a series and related models.			
15.	MATH (to be generated) Fuzzy Logic and Belief Theory	On completion of the course, students will be able to, • Learn crips and fuzzy set theory. • Decide the difference between crips set and fuzzy set theory. • Make calculation on fuzy set theory. • Recognize fuzzy logic membership function. • Recognize fuzzy logic fuzzy inference systems • Make applications on Fuzzy logic membership function and fuzzy inference systems. • Utilize fuzzy logic approach to problems arising in the field of Operations Research, Computer Science and Engineering. • Formulate logical expressions, fuzzy logic to solve a variety of problems related to real scenarios • Apply defuzzification methods.	-	**Section A** Basic concept of Fuzzy Logic: Introduction to fuzzy set, membership function, Various forms of membership functions, type of fuzzy sets, LR- representations of fuzzy sets, properties of fuzzy sets (support, cardinality, alpha-cut set, convexity).Operations on Fuzzy sets: Union, Intersection, complement, combinations of operations. Fuzzy extension principle, Fuzzy Relations: fuzzy cartesian product and composition, Crisp versus fuzzy relations, binary fuzzy relation, fuzzy equivalence relations, fuzzy compatibility relations, fuzzy ordering relations. Fuzzy graphs, Fuzzy morphism (homomorphism), Fuzzy relation equations.Fuzzy Numbers: Definitions and types of fuzzy numbers, interval analysis in arithmetic, triangular and trapezoidal types, Arithmetic operations on fuzzy numbers. Fuzzy Function: Introduction to fuzzy function, type of fuzzy function, fuzzy extrema of function, differentiation and integration of fuzzy function. **Section B** Fuzzy Logic: Classical logic, logic variable, logic function, truth tables, tautology and inference rule, Linguistic variables. Predicate logic, Quantifier, fuzzy expression, operators in fuzzy expression, fuzzy predicate, fuzzy modifier, fuzzy truth qualifier.Fuzzy if-then rules: Basics of fuzzy rules, fuzzy mapping rules, fuzzy implication rules.Fuzzy Decision Making:	New elective

				Introduction, multistage decision making, fuzzy ranking method, fuzzy linear programming, fuzzy transportation problemsFuzzy System: Introduction to fuzzy system.Defuzzification methods: centre of area (or centre of gravity or centroid), centre of maxima, mean of maxima.Fuzzy controllers: an overview of fuzzy controller.Fuzzy Systems and Neural Network: Introduction to neural network, fuzzy neural networks. **Section C** Probability, Uncertainty and Fuzzy Measures: Probability verses Possibility, Fuzzy event, Crisp probability of fuzzy event and fuzzy probability of fuzzy event, Level of uncertainty, Measure of fuzziness: (i) using Shannon's entropy formula and (ii) using metric distance. Belief Theory: Evidence Theory- Mathematical Theory of evidence, Introduction to Shafer's Belief Theory, Belief representation: mass of belief, belief measure, plausibility measure, properties of belief function-relation between belief and plausibility measure, Dempster's Rule of Combination, Applications of Fuzzy logic and fuzzy set theory in Operations Research, Computer Science and Engineering fields. **Suggested Text Books:** 1. Lee, K. H. (2005). First course on fuzzy theory and applications. Berlin: Springer-Verlag 2. Klir, G. J., & Yuan, B. (2003). Fuzzy sets and fuzzy logic: Theory and applications. New Delhi: Prentice Hall of India. **Suggested Reference Books:** 1. Klir, G. J., & Folger, T. A. (2010). Fuzzy sets,	

				uncertainity and information. New Delhi: PHI Learning Private Ltd. 2. Yen, J., &Langari, R. (2005). Fuzzy logic: Intelligence, control and information. Pearson Education. 3. Shafer, G. (1976). A mathematical theory of evidence. Princeton: Princeton University Press. 4. Mukaidono, M. (2010). Fuzzy logic for beginners. Singapore: World Scientific. 5. Nguyen, H. T., & Walker, E. A. (2006). A first course in fuzzy logic. Boca Raton, Fla: Chapman & Hall/CRC. **Suggested E-learning material:** 1. Introduction to Fuzzy Logic(Videos) https://nptel.ac.in/courses/106105173/2/ 2. Fuzzy Logic: Introduction (PDF) http://cse.iitkgp.ac.in/~dsamanta/courses/sca/resources/slides/FL-01%20Introduction.pdf	
16.	MATH (to be generated) Inventory Theory	On completion of this course, students will be able to: • Comprehend the dynamics of inventory management's principles, concepts, and techniques as they relate to the entire supply chain (customer demand, distribution, and product transformation processes), • Understand the methods used by organizations to obtain the	**Section A** *Analytical structure of production and Inventory problems, Inventory related costs, properties of inventory systems, Factors influencing inventories.* *Deterministic inventory models and extensions without and with lead time, Inventory models with partial backlogging and sales, Models with continuous production and non-constant demand with known production capacity, Inventory models with constraints, Quantity discounts; All units and incremental, Sensitivity of the lot size system,* ~~N products and M Machines model.~~ **Section B**	**Section A** Concepts of Inventory, Classification of inventory models, EOQ model, EPQ model, EOQ model with shortages, EPQ model with shortages, EOQ model with constraints: Quantity discounts, Floor Constraints, Investment Constraint. Sensitivity analysis in inventory models. **Section B** Stochastic Inventory Models and Extensions without and with lead time. Power demand pattern inventory model, Introduction to Just In Time (JIT) and Vendor Managed	

		right quantities of stock or inventory, • Familiarize themselves with inventory management practices. • Optimize different case studies requires efficient methods and practices to address inventory management problems. • Understand the behavior of the inventory parameters after some time using simulation techniques.	Stochastic Inventory Models and Extensions without and with lead time, ~~Use of transformation from time-dependent for continuous and discrete demand,~~ Power demand pattern Inventory Model~~, Safety stock and Buffer stock.~~ **Section C** Simulation in Inventory system, Production scheduling, Classification of items viz: ABC, VED, (FNSD, HML, SDE, XYZ), Case studies. **Books Recommended:** **Text Books:** 1. Kanti Swarup, **Operation Research**, Sultan Chand & Sons, 2010. 2. Sharma S.D., **Operations Research**, Kedarnath Ramnath, Meerut, 1972. **Reference Books:** 1. G. Hadley, T. Whitin, **Analysis of Inventory Systems**, Prentice Hall, 1963. 2. E.Naddor, **Inventory System**, John Wiley, New York, 1966.	Inventory (VMI). **Section C** Simulation in Inventory system, Classification of items viz: ABC, VED, FNSD, HML, SDE, XYZ, Case studies in inventory control. **Suggested Books:** 1. Hadley, G., Whitin, T. M.. (1963). *Analysis of inventory systems.* Englewood Cliffs, N.J.: Prentice-Hall. 2. Naddor, E. (1984). *Inventory systems*. Malabar, Fla: R.E. Krieger. 3. Waters, D. (2008). *Inventory Control And Management, 2Nd Ed*. Wiley India Pvt. Limited. **Suggested E-learning material:** 1. Inventory Models costs, EOQ model(Lecture PDF) https://nptel.ac.in/courses/110106045/9 2. Inventory management(PDF) https://ocw.mit.edu/courses/engineering-systems-division/esd-260j-logistics-systems-fall-2006/lecture-notes/	
17.	MATH (to be generated) Queuing Theory	On completion of the course, the student will be able to • Understand the principles and objectives of model building based on Markov chains. • Analyze the queueing situations. • Understand the mathematical tools that are needed to solve queueing problems.	**Section A** *Concept of stochastic processes*. Markov Chains *discrete and continuous time parameter.* Objectives and different characteristics of a Queueing system. Performance measures. Steady state solution of Markovian Models (M/M/1, M/M/c, [redacted]. **Section B** *Analytical method and use of randomization technique to find the transient solution of M/M/1,* ~~M/M/c and~~	**Section A** Introduction of stochastic processes, Markov process, Markov Chain, Poisson process with its properties and related distributions (without proof) and birth-death process. Objectives and different characteristics of a Queueing system. Performance measures. Steady state solution of Markovian queueing models: M/M/1 and M/M/c. and their performance measures. **Section B**	**Change in Credit.**

		• Identify and develop queueing models from the verbal description of the real system.	~~M/M/μ~~ queuing models including busy period distribution. **Section C** Imbedded markov chain technique and its use to the queueing models: M/G/1, GI/M/1 ~~and M/D/c~~, *Bulk queuing models*. Different design and control policies ((O, N) and vacation policies) for Markovian Queuing models. ~~Introduction to discrete time queuing system.~~ Simulation procedures: Data generation and Book-keeping aspects. **Suggested Text Books:** 1. D. Gross and C.M. Harris, **Fundamentals of Queueing Theory**, 2nd Ed., John Wiley, 1985. 2. Michel E. Woodward, **Communication and Computer Networks Modeling with Discrete Time Queues**, IEEE Computer Society Press, 1994. (Chapter 4) **Suggested Reference Books:** 1. R.B. Cooper, **Introduction to Queuing Theory**, 2nd Ed., North Holland, 1981 2. D.R. Cox and W.L. Smith, **Queues**, Mathuen, 1961. 3. L. Kleinrock, **Queuing Systems, Vol. I**, John Wiley, 1975. 4. J. Medhi, **Stochastic Model in Queuing theory**, Academic Press, 1991. 5. T.L. Satty, **Elements of Queuing Theory with Applications**, Mc-Graw Hill, 1961.	Steady State solution of M/E_k/1 and E_k/M/1 queueing models with their performance of measures. The transient solution of M/M/1 and M/M/∞ Queueing models including busy period distribution. **Section C** Imbedded Markov chain technique and its use to solve the Queueing models: M/G/1 and GI/M/1. Bulk queuing models: $M^{[X]}$/M/1 and M/$M^{[Y]}$/1. Different design and control policies for Markovian Queueing models. Simulation procedures: Data generation and Book- keeping aspects. **Suggested Text Books:** **1.** Gross, D., & Harris, C. M. (1985). *Fundamental of Queueing Theory*. (2nd ed.). John Wiley. **2.** Michel, E. W. (1994). *Communication and Computer Networks Modeling with discrete Time queues*. IEEE Computer Society Press. (Chapter 4) **Suggested Reference Books:** 1. Cooper, R. B. (1981). *Introduction to Queuing Theory*. (2nd ed.). North Holland, Elsevier. 2. Cox, D. R. & Smith, W. l. (1961). *Queues*. Mathuen& Co. Ltd. 3. Kleinrock, L. (1975). *Queuing System*. (Vol. 1). John Wiley. 4. Medhi, J. (1991). *Stochastic Models in queuing Theory*. Academic Press. 5. Satty, T. L. (1961). *Elements of Queuing Theory with Applications*. Tata McGraw Hill. **Suggested E-learning Material:** 1. Queuing Systems, NPTEL	

				https://nptel.ac.in/courses/117103017/1 2. Introduction to stochastic process and applications, NPTEL https://nptel.ac.in/courses/110104024/1 3. Stochastic Process and Time series, ePATHSHALAhttps://epgp.inflibnet.ac.in/ahl.php?csrno=34	
18.	STAT (to be generated) Reliability and Renewal Theory	On successful completion of the course, the students will be able to: • Understand the importance of validity and reliability assessment and the link between the two. • Estimate the reliability function and mean time to failure for different types of systems • Analyze statistical experiments leading to reliability modeling. • Estimate life length distributions, using complete or censored data. • Identify reliability testing components. • Apply reliability theory to assessment of reliability in engineering design. • Analyze non-repairable systems of independent components, with and without redundancy • First look at what a random process is and then explain what renewal processes are.	-	**Section A** Concept of Reliability. Classes of Life time distributions. Evaluation of Reliability function, Shape of Reliability function. System, Reliability Evaluation : Series & Parallel system, partially redundant system, standby system with perfect switching/imperfect switching, (k,n) system, Bridge Structure. Availability theory and its molding for various configurations. Introduction to Software Reliability. **Section B** Reliability models of maintained systems. Reliability Allocation Problems, Discrete Replacement Policies : Age, Block, Policies, Preventive Maintenance Policies, Corrective Maintenance Policies, Concept of minimal repair, Notions of aging. **Section C** Renewal Theory, Distribution of number of renewals & moments, Recurrence time & its limiting distribution. Application of Renewal Theory, Solutions of Renewal type equations, Optimization problem with respect to system reliability. **Text Books** 1. Sinha, S. K. (1986). *Reliability and life testing*. New York: Wiley.	New Course

		• Describe, derive, and prove important theorems and formulas for renewal theory • Use renewal theory to solve problems where Poisson is not a realistic process		2. Gert s bakh, I. B. (2009). *Reliability theory: With applications to preventive maintenance*. New Delhi: Springer. 3. Cox, D. R. (1982). *Renewal theory*. London: Chapman and Hall. 4. Lewis, E. E. (1996). *Introduction to reliability engineering*. New York, NY: Wiley. **Reference Books** 1. Barlow, R. E., &Proschan, F. (1975). *Statistical theory of reliability and life testing*. New York: Holt, Rinehart and Winston. 2. Jardine, A.K.S. (1973). *Maintenance, Replacement andReliability*. UK: Pitman Publication. 3. Medhi, J. (2009). *Stochastic Process* (3rd Ed.). New Age International, 2009. **Suggested E-learning material:** 1. 2011 Lecture 17: Modules, Systems, and Reliability: https://ocw.mit.edu/courses/mechanical-engineering/2-627-fundamentals-of-photovoltaics-fall-2013/lecture-videos-slides/2011-lecture-17-modules-systems-and-reliability/ 2. Probability Theory and Applications: Lecture 40-Reliability of Systems: https://nptel.ac.in/courses/111104079/40	
19.	MATH (to be generated) Fields and Galois Theory	On completion of this course, students will be able to • Understand the concepts of field extension and appreciate its importance.	-	**Section A** Fields, prime subfields, Extension fields, algebraic extensions, simple extensions, transcendental extension, minimal polynomial, Kronecker's Theorem, splitting fields, uniqueness of splitting fields and algebraic	New Course

		• Understand different types of extensions. • Find the Galois group for some extension fields. • Know the link between field theory and group theory. • Demonstrate the solvability of quadratic, cubic and quartic equations by radicals.		closures. **Section B** Finite fields, existence and uniqueness of finite fields, Normal and separable extensions, perfect fields, Automorphisms of field, fixed fields, Galois group, F–conjugate, Frobenius map, character, linear independence of characters. **Section C** Fundamental theorem of Galois theory, cyclotomic extensions and abelian extensions, cyclotomic polynomials, cyclic extension, radical extension, solution of quadratic, cubic and quartic equations by radicals. **Suggested Books:** 1. Howie, J. M. (2006). *Fields and Galois theory*. London: Springer. 2. Escofier, J.-P. (2001). *Galois theory*. New York: Springer. 3. Gallian, J. A. (2013). *Contemporary abstract algebra*. (8th Ed.). Boston, MA: Brooks/Cole Cengage Learning. 4. Dummit, D. S. & Foote, R. M. (2004) *Abstract algebra* (3rd Ed.). New Jersey: Wiley. 5. Sen, M. K., Ghosh, S., Mukhopadhyay, P. &Maity, S. K. (2019) *Topics in abstract algebra* (3rd Ed.). University Press. 6. Morandi, P. J. (2003). *Field and Galois theory*. Beijing: Beijing World Pub. **Suggested E-learning Material:** 1. Notes on Galois Theory: www.math.iitb.ac.in/~srg/Lecnotes/*galois*.pdf	

				2. Lecture Notes: https://nptel.ac.in/courses/111101001/	
20.	MATH (to be generated) Coding Theory	On successful completion of this course students will be able to, • Understand the need of coding theory. • Appreciate the applications of abstract and linear algebra in coding theory. • Find the generator and parity check matrix of linear codes. • Understand the main coding theory problem. • Derive classical bounds of codes and the distance of the code. • Understand cyclic codes and their decoding.		**Section A** Communication channels, maximum likelihood decoding, Hamming distance, minimum distance decoding, distance of a code, finite fields, structure of finite fields, minimal polynomial, linear codes, Hamming weight, bases of linear codes, generator matrix and parity check matrix, encoding and decoding of linear codes, syndrome decoding. **Section B** The coding theory problem, lower bounds, Hamming bounds and perfect codes, singleton bound and MDS codes, nonlinear codes, Reed-Muller codes, subfields codes. **Section C** Cyclic codes: definitions, generator polynomials, generator and parity check matrices, decoding of cyclic codes, Burst-error-correcting codes, BCH codes: definitions, parameters of BCH codes, Decoding of BCH codes. Reed–Solomon codes, generalized Reed–Solomon codes, Goppa codes. **Suggested Text Book:** 1. Ling, S., & Xing, C. (2004). *Coding Theory: A first Course*. Cambridge: Cambridge University Press. **Suggested Reference Books:** 1. MacWilliams, F. J., & Sloane, N. J. A. (2007). *The theory of error-correcting codes*. Amsterdam: North-Holland.	New elective

				2. Peterson, W. W., & Weldon, E. J. (2008). *Error-correcting codes*. (2nd Ed.). Cambridge, Mass: MIT Press. 3. Berlekamp, E. R. (2015). *Algebraic coding theory*. (Algebraic Coding Theory.) Singapore: World Scientific. 4. Huffman, W. C., &Pless, V. (2010). *Fundamentals of error-correcting codes*. Cambridge: Cambridge Univ. Press. 5. Hill, R. (2001). *A first course in coding theory*. Oxford: Clarendon Press. 6. Rhee, M. Y. (1989). *Error-correcting coding theory*. Singapore: McGraw-Hill. **Suggested E-learning Material:** 1. Online Course on Coding Theory:https://onlinecourses.nptel.ac.in/noc17_ee07 2. Lecture Notes: https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-895-essential-coding-theory-fall-2004/	
21.	MATH (to be generated) Fixed Point Theory	On successful completion of this course students will be able to: • Understand various concepts in metric spaces such as completeness. • Demonstrate standard examples of metric spaces and prove simple results related to them. • Understand the proof of open mapping theorem and Closed graph theorem.		**Section A** Metrics space, Complete metric space, Convergence, Cauchy sequence and Completeness, Various concept in metric space, Normed linear space, Banach space, normed space and Hilbert space, open mapping theorem and Closed graph theorem, linear operator. **Section B** Lipschitz mapings,expansive and Nonexpansive Mappings, contractive and contraction mappings, Upper and lower semi continuity of maps, contractive and	New elective

		• Check the conditions for expansive and Nonexpansive Mappings, contractive and contraction mappings. • Understand standard fixed-point theorems. • To present the basic ideas of the theory, and illustrate them with a wealth of examples and applications in differential and integral equations.		nonexpansive multivalued maps, Banach's contraction principle, Fixed point theorem of Schauder's and Kirk, Tarsiki's Fixed point theorem. **Section C** Banach Fixed point theorem for multivalued maps, Generalized Schauder Fixed point theorem. Existence of solutions of ordinary equations and systems of linear equations in several unknowns, applications in the theory of differential and integral equations. **Suggested Books:** 1. Zeidler, E. (2000). *Nonlinear functional analysis and its applications: Vol 1*. New York: Springer. 2. Khamsi, M. A., & Kirk, W. A. (2001). *An introduction to metric spaces and fixed point theory*. New York: John Wiley & Sons. 3. Smart, D. R. (1980). *Fixed point theorems*. Cambridge: Cambridge University Press. 4. Istra tescu, V. I. (1981). *Fixed point theory: An introduction*. Dordrecht, Holland: D. Reidel Pub. 5. Agarwal, R. P., Meehan, M., &O'Regan, D. (2009). *Fixed point theory and applications*. Cambridge, UK: Cambridge University Press. **E-Resources** 1. National Programme for Technology Enhanced Learning (NPTEL) https://nptel.ac.in/courses/111105037/	
22.	MATH (to be generated) Introduction to Dynamical	On successful completion of this course students will be able to, • Describe the main features of dynamical systems and their	-	**Section A** Introduction to Dynamical Systems: Background and examples, dynamical systems, attractors and invariant sets.	New Elective

	System	realisation as systems of ordinary differential equations. • Identify fixed points of simple dynamical systems, and study the local dynamics around these fixed points, in particular to discuss their stability. • Use a range of specialised analytical techniques which are required in the study of dynamical systems. • Describe dynamical systems geometrically and represent them graphically via phase plane analysis. • Find fixed points and period orbits of discrete dynamical systems, and find their stability. • Do graphical analysis of 1D discrete dynamical systems. • Understand the basic properties of a chaotic dynamical system.		Non-linear Systems-local analysis: the fundamental existence-uniqueness theorem, The flow defined by a differential equation, Linearization, The stable manifold theorem, The Hartman-Grobman theorem, Stability and Liapunov functions, Saddles, Nodes, Foci, and Centers. **Section B** Non-linear Systems-global analysis: Dynamical systems and global existence theorem, Limit sets and Attractors, Periodic orbits, Limit Cycles, and Seperatrix cycles, the Poincare map, the stable manifold theorem for periodic orbits, the Poincare-Bendixon theory in R2, Lineard Systems, Bendixon's Criteria. **Section C** Discrete dynamical systems: finite dimensional maps, limit sets, Stability, Invariant manifolds, Runge-Kutta methods: the framework, linear decay, Lipschitz conditions, Dissipative systems, Generalized dissipative systems, Gradient system. **Suggested Books:** 1. Perko, L. (2009). *Differential equations and dynamical systems*. (3rd Ed.). New York, NY: Springer. 2. Stuart, A. M., & Humphries, A. R. (1998). *Dynamical systems and numerical analysis*. Cambridge: Cambridge University Press. 3. Lynch, S. (2014). *Dynamical systems with applications using MATLAB*. (2nd Ed.). Cham: Birkhäuser.	
23.	MATH (to be generated)	On completion of the course, the student will be able to,		**Section A** Continuous population Models for single species: Basic	New elective

	Bio Mathematics	• model the single species and two species systems. • study the stability of these systems. • Apply harvesting of the species. • to model epidemics and analyse the dynamics		concepts. Exponential growth model, formulation, solution, interpretation, and limitations. Compensation and depensation. Logistic growth model, Continuous Growth Models, Insect out break Model: Spruce Budworm, Delay models, Linear Analysis of Delay Population Models: Periodic solutions. Harvesting a single Natural Population. **Section B** Continuous Models for interacting Population:Interaction between species: two species models, definition of stability, community matrix approach, Qualitative behavior of the community matrix, Competition: Lotka-Volterra models, Extension to Lotka-Volterra models, Competition in field experiments, Competition for space, Models for Mutualism. Predator-Prey interaction: Lotka-Volterra Models, dynamic of the simple Lotka-Volterra models, Role of density dependent in the Prey, Classic laboratory experiment on predator, predation in natural system. Some predator-prey models. **Section C** Mathematical modeling of epidemics: Basic concepts. Simple epidemic model, formulation, solution, interpretation, and limitations. General epidemic model, formulation, solution, interpretation, and limitations **Suggested Text Books:** 1. Murray, J. D. (2013). *Mathematical Biology*. Berlin: Springer Berlin. 2. Freedman, H. I. (1987). *Deterministic mathematical models in population ecology*. (2nd Ed.). Edmonton,	

				Alta., Canada: HIFR Consulting. **Suggested Reference Books:** 1. Hastings, A. (2010). *Population biology*. New York: Springer. 2. Meerschaert, M. M. (2013). *Mathematical modeling*. (4th Ed.). Amsterdam: Elsevier Academic Press. 3. Meyer, W. J. (1984). *Concepts of mathematical modeling*. New York, N.Y. 4. May, R. (1976). *Theoretical ecology. Principles and applications*. United States. 5. Bailey, N. T. J., & Bailey, N. T. J. (1975). *The mathematical theory of infectious diseases and its applications*. New York: Oxford University Press. **Suggested E-learning material** 1. NPTEL: https://nptel.ac.in/courses/102101003/ and https://nptel.ac.in/courses/102101003/# 2. Biomathematics Lectures - UBC Zoology**:** www.zoology.ubc.ca/~bio301/Bio301/Lectures.html	
24.	MATH (to be generated) Combinatorial Optimization	On completion of the course, the student will be able to, • define the concept of combinatorial (optimisation or satisfaction) problem • recognize many types of combinatorial optimization problems; • formulate linear and integer programs, and identify when a problem can be viewed in terms of various "standard"	-	**Section A** Combinatorial algorithms for classic discrete optimization problems: Quick Overview of flow problems- Maximum flow, Minimum Cut, Minimum cost flow, Multi-commodity flow, Matching theory - Matchings and alternating paths-Tutte-Berge formula- Maximum cardinality matchings: Bipartite matching via flow, Edmond's blossom algorithm. Introduction to computational complexity. Single Source Shortest path algorithms–Bellman Ford algorithm, all pair shortest path algorithms – Floyd	New elective

		combinatorial optimization problems; understand the mathematical concepts underlying these problems and their solutions; • solve combinatorial optimization problems using suitable algorithms • analyze the performance of simple algorithms, understand and interpret computational complexity, and reduce one problem to another.		Warshall algorithm. **Section B** Algorithmic Perspective to Simplex Method: Introduction to Linear Optimization, Equivalence of optimization and separation, LP Formulation, Geometry of Linear Programs, Theory of Simplex Algorithm, Geometric interpretation of Degeneracy, Avoiding cycles, Methods for obtaining initial Basic Feasible Solutions, Linear Programming formulations of shortest path problem. **Section C** Integer Programing: Integrality gap, Branch and Bound algorithm, Cutting-plane algorithm, Applications of these algorithms on Travelling Salesman Problem Primal-Dual Algorithms: Interpretation of Dual, Optimality conditions for primal and dual, primal-dual algorithms based on complementary slackness, Primal-dual algorithms for shortest path problem, vertex cover and set cover. **Suggested Text Books:** 1. Papadimitriou, C. H., &Steiglitz, K. (2006). *Combinatorial optimization: Algorithms and complexity*. New Delhi: Prentice-Hall of India. 2. Hillier, F. S., & Lieberman, G. J. (1995). *Introduction to mathematical programming; 2nd ed*. New York: McGraw-Hill. 3. Cook, W. J. (2011). *Combinatorial optimization*. New York: Wiley.	

				Suggested References Books: 1. Lange, K. (2004). *Optimization*. New York: Springer. 2. Bazaraa, M. S., Jarvis, J. J., &Sherali, H. D. (2013). *Linear Programming and Network Flows*. Hoboken: Wiley. 3. Taha, H. A., & Pearson Education. (2017). *Operations research: An introduction*. Harlow: Pearson. 4. Korte, B., &Vygen, J. (2012). *Combinatorial Optimization: Theory and Algorithms*. Berlin, Heidelberg: Springer Berlin Heidelberg. 5. Ahuja, R. K., Magnanti, T. L., & Orlin, J. B. (1993). *Network flows: Theory, algorithms, and applications*. Upper Saddle River, N.J: Prentice-Hall. **Suggested E-learning material** 1. Topics in Combinatorial Optimization: Lecture Notes(PDF): https://bit.ly/2MY9MB3 2. Optimization –Introduction(Video Lecture) https://nptel.ac.in/courses/111105039/	
25.	MATH (to be generated) Transportation System Analysis	On completion of the course, the student will be able to, • Use optimal transportation decision-making schemes based on transportation data analysis by establishing, testing and solving transportation models. • Perform simple statistical analysis on transportation field data, sample estimation and hypothesis testing in		**Section A** Introduction of transportation system analysis; characteristics, goal and role of transportation system analysis; applications and methodologies of transportation system analysis; Scope of transportation system analysis; TAF system; Impact of TAF system **Section B** Random variables, applications of probability	New elective

		transportation system. • Design suitable sampling and experimental methods for transportation system analysis and realize error sources.		distributions in transportation system analysis, sample distributions and means in transportation system analysis, Central Limit Theorem, Bayesian Theorem, significance and hypothesis testing in transportation systems. Use of transportation field data and data gathering techniques, sources of errors, considerations of transportation system sample size; experiment design for transportation system demand forecasting and transportation operations analysis. **Section C** Intelligent Transportation System (ITS), components of ITS; Causal Loop Diagramming (CLD) system dynamics approach, conceptualization and development in transportation system policy and scenario analysis; Transportation system scenario generation models and techniques: Delphi technique; Seth Harva model; Multi criteria decision making model. **Suggested Books:** 1. Papacostas,C.S. (1987)*Fundamentals of transportation system analysis*, PHI. 2. Cascetta, Ennio. (2012). *Transportation Systems Analysis: Models and Applications*. Springer Verlag. 3. Edwards, J. D., & Institute of Transportation Engineers. (1999). *Transportation planning handbook*. (2nd Ed.). Washington: Institute of Transportation Engineers. 4. Levin, R. I., & Rubin, D. S. (2008). *Statistics for management*. New Delhi: Prentice Hall of India. 5. Walpole, R. E. (2014). *Essentials of probability and*	

				statistics for engineers and scientists. Pearson. 6. Mohapatra, P. K. J., Mandal, P., & Bora, M. C. (1994). *Introduction to system dynamics modelling*. London: Sangam. 7. Roberts, N. (1998). *Introduction to computer simulation: A system dynamics modeling approach*. Portland, Or: Productivity Press.	
26.	STAT (to be generated) Stochastic Models	On completion of this course, the students will be able to: • Acquire skills in handling situations involving more than one random variables. • Understand to analyze the performance of reliability models. • Learn how to analyze a network of queues with Poisson arrivals and exponential service requirements. • Learn how to analyze a network of queues with Poisson arrivals and general service requirements. • Understand the concept of switching in reliability modeling.	-	**Section A** Review of Stochastic processes, Markov process, Markov chain, Poisson Process. Birth and Death process. Expression for mean and variance of a birth and death process. Introduction of queues, Queueing system. Components of a queueing system, Measures of effectiveness and Notations. Steady state solution of M/M/1 and M/M/1/N Queueing Models and their measures of effectiveness. **Section B** Steady state solution of M/M/C Queueing Models and their measures of effectiveness. The transient solution of M/M/1 and M/M/∞ Queueing models including busy period distribution. Imbedded Markov chain technique and its use to solve the M/G/1 queueing models. Measures of Effectiveness of M/G/1 queueing model. **Section C** Reliability Models: Concept of reliability, early age failures, wearout failures and chance failures. Derivation of general reliability function failure rate, failure density functions and mean time between failures (MTBF). System reliability evaluation: series system, parallel system, partially redundant system, standby system	**New elective introduced.**

				with perfect switching / imperfect switching. Effect of spare components (identical / non- identical) on the system reliability. **Text/References books:** 1. Cox, D. R., & Miller, H. D. (1972). *The theory of stochastic processes*. London: Chapman and Hall. 2. Billinton, R., & Allan, R. N. (2013). *Reliability evaluation of engineering systems: Concepts and techniques*. New Delhi: Springer (India). 3. J. Medhi, J. (1994). *Stochastic processes*. New Age International Publications. 4. Bazovsky, I. (2013). *Reliability Theory and Practice*. Dover Publications. 5. Gross, D., &Harris C.M (2002). *Fundamentals of Queueing Theory*. John Wiley & Sons. 6. Allen, A. O. (2014). *Probability, Statistics, and Queueing Theory with Computer Science Applications*. Academic Press. **Suggested E-learning Resources** 1. Introduction to Stochastic Processes and its Applications https://nptel.ac.in/courses/110104024/ 2. Statistics e-PG-pathshala: https://epgp.inflibnet.ac.in/ahl.php?csrno=34 3. Reliability Engineering, NPTEL: **https://nptel.ac.in/courses/105108128/**	
27.	STAT (to be generated) Demography	On completion of the course, students will be able to, • Identify principle sources of demographic data and assess their strengths and weaknesses.		**Section A** Meaning and scope of demography; Sources of demographic data; Census; Population composition and its basic demographic measures: Ratios, Proportions and Percentages; Population pyramids; Quality of	**New elective introduced**

		• Discuss the demographic significance of age and sex structures and the implications of variations in age & sex structure. • Construct and interpret life tables. • Calculation and interpretation of the principal demographic measures, and standardize these measures for comparison. • Understand the components of population change, including the effects of changing birth, death and migration rates, and demonstrate their influences on age structure. • Understand the concept of urbanization on the economic growth of the contrary. • Estimate and project the population by different methods. • Understand the concept of stable and stationary population.		demographic data: Population growth rate; Rates of natural increase; Doubling time; Stochastic models for population growth; Intrinsic growth rate models for population growth and their fitting to population data; Coverage and content errors in demographic data; Balancing equations;Chandrasekharan - Deming formula to check completenessof registration data; Adjustment of age data- use of Whipple, Myer and UN indices; Population transitiontheory. **Section B** Mortality: Rates and Ratios; Crude and age-specific death rates;Infant mortality rate (IMR); Child death rate (CDR); Under five, neo-natal and post neo-natal mortality rate; Maternal mortality rate and Maternal mortality ratio (MMR); Direct and Indirect Standardization; Factors for decline in mortality in recent past; Life tables and their applications; Increment-decrement life tables; Construction of complete and abridged life tables; Model life table. Natality:Fecundity and fertility; Measure of fertility: Cohort fertility; Children ever born (CEB); Current family size (CFS); Age specific martial fertility rate;Birth order and parity; Parity progression ratio; Length of generation, Measures of reproduction: Total fertility rate; Gross reproduction rate; Net reproduction rate; Replacement index; General fertility models; Fertility schedules; Differential fertility; Levels and trends of fertility. **Section C** Migration - Concepts and types; Its effect on population growth and pattern; Differentials of migration; Measures of migration: Migration rates; Volume of migration and	

				its estimation; Migration component; Migration streams; Hamilton's rate; Migration models; Concept of international migration; Concept of morbidity and its measures. Urbanization - Growth and distribution of rural - urban population in developed and developing countries. Nuptiality - Concept and analysis of marital status; Singulate mean age at marriage. Stationary and Stable population theory; Uses of Lotka's stable population theory in estimation of demographic parameters; Population estimates; Population projections and forecasting; Methods of Inter-censal and Post-censal estimation; Methods of population projection. **Suggested Text Books:** 1. Ramkumar, R.(2006). *Technical Demography*. New Age International. 2. Pathak, K.B.& Ram, F. (2019). *Techniques of Demographic Analysis* (2nd. ed.). Himalaya Publishing House. 3. Srinivasan, K., Saxena, P. C., &Kanitkar, T. (1979). *Demographic and Socio-economic Aspects of the Child in India*. Himalaya Publishing House. **Suggested Reference Books:** 1. Cox, P. R. (2009). *Demography* (6th. ed.). GBR Cambridge University Press. 2. Sinha, V. C., & Zacharia, E. (1984). *Elements of demography*. Allied Publishers. 3. Bhinde, A. A. &Kanitker, T. (2018). *Principles of Population Studies* (19th. ed.). Himalaya	

				Publishing House. **Suggested E-learning Resources** 1. Demographic data; Platform: National Family Health Survey, India http://rchiips.org 2. Population Studies; Platform; e-PG Pathshalahttps://epgp.inflibnet.ac.in/loaddata.php?action=loadpaperlist1&maincat=453 3. Demography ; Platform: University Library - The University of Adelaide https://www.adelaide.edu.au/library/ 4. Demography; Platform: MITOPENCOURSEWARE https://ocw.mit.edu/index.htm	

Reading Electives

S.N.	Course List	Learning Outcomes	Existing Syllabus	Suggested Syllabus	Remark

1.	MATH 603R Advanced Cryptography	On completion of this course, students should be able to, • Understand digital signatures in detail. • Understand the concept of signcryption and its security requirements. • Understand the identity based cryptography.	-		**No change in syllabus.**
2.	MATH 604R Advanced Queueing Models	On completion of this course, students should be able to, • Understand the principles and objectives of model building based on Markov chains. • Analyze the queueing situations. • Understand the mathematical tools that are needed to solve queueing problems. • Identify and develop queueing models from the verbal description of the real system. • Understand the various Non-Markovian queueing models.	-	**Suggested E-learning Resources** 1. Queuing Systems, NPTEL https://nptel.ac.in/courses/117103017/1 2. Transient solution of an M/M/1 queue with catastrophes. https://core.ac.uk/download/pdf/81115439.pdf 3. On the M/M/1 queue with catastrophes and its continuous approximation. Source: Queueing Systems journal. https://link.springer.com/article/10.1023/A:1023261830362 4. Some new results for the M/M/1 queue, Source: Management Science journal. https://pubsonline.informs.org/doi/10.1287/mnsc.28.7.821	
3.	MATH 605R Algebraic Aspects of Cryptography	On completion of this course, students should be able to, • Understand the finite field arithmetic and what are the efficient algorithms for theme ? • Know the group law of elliptic curves and able to perform computation on the elliptic			

		curves. • Grasp the concepts of lattices and their applications in cryptography.			
4.	MATH 606R Algebraic Geometry	On completion of this course, students should be able to, õ have knowledge of the basic affine and projective geometries. õ Be familiar with explicit examples including plane curves, quadrics, cubic surfaces, Segre and Veronese embedding. õ increased their knowledge of finitely generated commutative rings and their fields of fractions. õ learn how to formulate and prove basic statements about algebraic varieties. precise abstract algebraic language.		**Suggested E-learning Resources** 1. Basic Algebraic Geometry : Varieties, Morphisms, Local Rings, Function Fields and Nonsingularity, NPTEL course: https://nptel.ac.in/downloads/111106097.	
5.	MATH 607R Decision and Game Theory	On completion of this course, students should be able to, • Understand and explain the framework of Decision Theory, its intrinsic limitations and broad goals, and how it leads to Game Theory. • Demonstrate an understanding of games in pure and mixed		**Suggested E-learning Resources** 1. Economic Applications of Game Theory (Lecture notes PDF): https://ocw.mit.edu/courses/economics/14-12-economic-applications-of-game-theory-fall-2012/index.htm	

		strategies. • Explain the game theoretic concepts of uncertainty, information and strategic moves. • Explain the characteristics and application of repeated games and associated trigger strategies. • Apply decision making models in interaction situations. • Gain a proper understanding of game theoretic concepts and modeling: covering equilibrium in static and dynamic games, with varying information structures.			
6.	MATH 612R Finite Element Methods	On completion of the course, the student will be able to, • Understand global, local, and natural coordinates. • Understand the significance of shape functions (linear, quadratic, cubic) in finite element formulations and can formulate one and two-dimensional elements like triangular and rectangular elements. • Understand the concepts behind variational methods and weighted residual methods in FEM and • implement the Galerkin residual		**Suggested E-learning Resources** 1. PDF of Lectures on Finite Element Method by C. Mercier; Platform: The Tata Institute of Fundamental Research, Bombay http://www.math.tifr.res.in/~publ/ln/tifr49.pdf	

		weak formulation into the Finite Element Method for the solution of Ordinary and Partial Differential Equations.			
7.	MATH 613R Finite Field Theory	On completion of this course, students should be able to • Understand finite fields and their extension in detail. • Find primitive polynomial, factorization of polynomials. • Understand Gauss, Jacobi, and Kloosterman sums, character sums and their applications.			
8.	MATH 616R Intelligent Transport System	On completion of this course, students should be able to • understand the sensor and communication technologies. • differentiate different ITS user services • define the significance of ITS under Indian conditions • select appropriate ITS technology depending upon site specific conditions. • design and implement ITS components		**Suggested E-learning Resources** 1. Benefits of Intelligent Transportation System; Platform: *https://www.its.dot.gov/factsheets/benefits_factsheet.htm* 2. Intelligent Transportation System; Platform NPTEL: https://nptel.ac.in/courses/105101008/48 3. Intelligent Transportation System; https://www.wsp.com/en-US/services/intelligent-transportation-systems-its	
9.	MATH 617R	On completion of this course, the		**Suggested E-learning Resources**	

	Inventory and Production Management	students will be able to, • Demonstrate what inventory is and where we find it within the supply chain. • Demonstrate the types of demand patterns common in real inventory problems. • Prepare appropriate inventory planning models for differing demand patterns. • Recognize the importance of inventory management. • Understand Production management basics and its history. • Formulation of aggregate planning problems; their objectives, constraints and applicable solution techniques. • Understand the terms Trade credit, Inflation, VMI etc. and learn how to use these policies in inventory modeling.		1. Basic Inventory Principles (PDF): https://nptel.ac.in/courses/112102106/38 2. Supply Chain Management &Vendor-managed Inventory (PDF): https://ocw.mit.edu/courses/sloan-school-of-management/15-760a-operations management-spring-2002/lecture-notes/	
10.	MATH 618R Marketing Management				
11.	MATH 621R Numerical Solutions of Partial Differential	On completion of the course, students will be able to, • Solve mathematical models represented by initial or boundary value problems		**Suggested E-learning Resources** 1. Lecture notes on Numerical Methods for Partial Differential Equations; Platform: MIT open course ware; https://ocw.mit.edu/courses/aeronautics-and-	

	Equations	involving partial differential equations that cannot be solved directly using standard mathematical techniques but are amenable to a computational approach. • Select appropriate numerical methods based on the characteristics of a PDE problem. • Introduce the discretization methodologies, with particular emphasis on the finite difference method that allows the construction of accurate and stable numerical schemes. • Discuss about the stability and convergence of the numerical methods.		astronautics/16-920j-numerical-methods-for-partial-differential-equations-sma-5212-spring-2003/lecture-notes/ 2. Lecture notes on Numerical Solution of Partial Differential Equations; Platform: nptel; https://nptel.ac.in/courses/111107063/2 1	
12.	MATH 622R Operator Theory	On completion of this course, the students will be able to, • Tell what is operators • Define several standard examples of linear operators, self-adjoint operators and prove simple results related to them. • Spectral representation of compact self-adjoint operators in Hilbert spaces. • Applications of spectral Theorem for compact operators. • Some recent results and open problems in operator theory			

13.	MATH 624R Special Functions	On completion of the course, the student will be able to, • understand various types of special functions, and their conditions of existence. • carry out relations between different special functions, including some of the most useful special functions. • demonstrate understanding of the concepts of recurrence relations, generating functions, series representations pertaining to different special functions and polynomials. • determine some significant properties of special functions and their integral forms. • discuss the nature of various special functions in different domains.		**Suggested E-learning Resources** 1. Special Functions and Their Symmetries:www.maths.leeds.ac.uk/~kisilv/courses/special.html	
14.	STAT 602R Advanced Reliability Theory	On completing the course, the student will be able to, • Estimate the reliability function and mean time to failure for different types of systems. • Understand major concepts of reliability prediction. • Analyze statistical experiments leading to reliability modeling.		**Suggested E-learning Resources** 1. Reliability Theory, Platform: NPTEL https://nptel.ac.in/courses/114106041/15 2. MLE and Bayesian Estimation-1, Platform: NPTEL https://nptel.ac.in/courses/pdf_link/103106123/lec109.pdf 3. Module, Sysytems and Reliability; Platform: MIT Open Course ware https://ocw.mit.edu/courses/mechanical-engineering/2-627-fundamentals-of-	

		• Estimate life length distributions, using complete or censored data. • Identify reliability testing components. • Apply reliability theory to assessment of reliability in engineering design. • Know Bayesian reliability concept. • Determine Life table and Kaplan-Meier approach. • Understand MCMC technique for simulation.		photovoltaics-fall-2013/lecture-videos-slides/2011-lecture-17-modules-systems-and-reliability/	
15.	STAT 604R Bio-statistics				
16.	STAT 608R Generalized Linear Models	On completion of the course, the student will be able to, • Understand the concept of logistic regression, its estimation and testing. • Understand the procedure to regression analysis for dependent count variable using Poisson regression. • Broaden their understanding of regression model to generalized linear models and their application.			
17.	STAT 610R	After successful completion of this		**Suggested E-learning Resources**	

	Statistical Computing	course, student will be able to: • Simulate and generate statistical data by different techniques. • Estimate the unknown parameter of population via different methods. • Understand the basic concepts of statistical theories besides developing their ability to • handle real world problems with large scale data.		1. Statistical computing Platform: MITOPENCOURSEWARE https://ocw.mit.edu/index.htm 2. Statistics: Platform: e-PG Pathshala https://epgp.inflibnet.ac.in	
18.	STAT 611R Supply Chain Management	On completion of the course, the student will be able to: • Understand the structure of supply chains and the different ways through which supply chains can become competitive in the realistic problems. • Understand fundamental supply chain management concepts. • Apply knowledge to evaluate and manage an effective supply chain. • How to align the management of a supply chain with corporate goals and strategies. • Analyze and improve supply chain processes. • Identify the principles of		**Suggested E-learning Resources** 1. Introduction to Supply chain management (PDF): https://nptel.ac.in/courses/110106045/35	

		customer and supplier relationship management in supply chains.			
19.	STAT 612R Survival Analysis	On completion of the course, students will be able to: • Identify characteristics of survival data and problems in their correct analysis • Define and understand the relationship between the survival function, distribution function, Hazard function, relative hazard, and cumulative hazard • Perform and interpret univariate analyses of survival data using the Kaplan-Meier estimator • Perform and interpret two-sample analyses of survival data using common statistical procedures such as the log rank test • Formulate research questions involving survival data as regression problems • Fit the proportional hazards regression model to survival data and assess the scientific significance, precision, and interpretation of regression coefficients • Use graphical and other methods to assess the adequacy of fitted models and propose alternate solutions when common assumptions are violated.	Verified Offg. Secretary Banasthali Vidyapith P.O. Banasthali Vidyapith Distt. Tonk (Raj.)-304022	**Suggested E-learning Material:** 1. http://www.stat.columbia.edu/~madigan/W2025/notes/survival.pdf	