॥ सा विद्या या विमुक्तये ॥

स्वामी रामानंद तीर्थ मराठवाडा विद्यापीठ, नांदेड

'ज्ञानतीर्थ', विष्णुपुरी, नांदेड – ४३१ ६०६ (महाराष्ट्र राज्य) भारत

SWAMI RAMANAND TEERTH MARATHWADA UNIVERSITY, NANDED

'Dnyanteerth', Vishnupuri, Nanded - 431 606 (Maharashtra State) INDIA

स्वामी रामानंद तीर्थ मराठवाडा विद्यापीठ, नांदेड

Established on 17th September, 1994, Recognized By the UGC U/s 2(f) and 12(B), NAAC Re-accredited with'B++' grade

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विज्ञान व तंत्रज्ञान विद्याशाखे अंतर्गत राष्ट्रीय शैक्षणिक धोरण २०२० नुसार पदव्यूत्तर द्वितीय वर्षाचे अभ्यासक्रम (Syllabus) शैक्षणिक वर्ष २०२४–२५ पासून लागू करण्याबाबत.

प रि प त्र क

या परिपत्रकान्वये सर्व संबंधितांना कळविण्यात येते की, या विद्यापीठा अंतर्गत येणा–या सर्व संलग्नित महाविद्यालयामध्ये शैक्षणिक वर्ष २०२४–२५ पासून राष्ट्रीय शैक्षणिक धोरणानुसार पदव्यूत्तर द्वितीय वर्षाचे अभ्यासक्रम लागू करण्याच्या दृष्टीकोनातून विज्ञान व तंत्रज्ञान विद्याशाखे अंतर्गत येणा–या अभ्यासमंडळांनी तयार केलेल्या पदव्यूत्तर द्वितीय वर्षाच्या अभ्यासक्रमांना मा. विद्यापरिषदेने दिनांक १५ मे २०२४ रोजी संपन्न झालेल्या बैठकीतील विषय क्रमांक १५/५९–२०२४ च्या ठरावाअन्वये मान्यता प्रदान केली आहे. त्यानुसार विज्ञान व तंत्रज्ञान विद्याशाखेतील खालील एम. एस्सी द्वितीय वर्षाचे अभ्यासक्रम (Syllabus) लागू करण्यात येत आहेत.

1) M. Sc. II year Biotechnology (Affiliated College)
2) M. Sc. II year Biotechnology (Campus)
3) M. Sc. II year Bioinformatics (Sub Campus Latur)
4) M. Sc. II year Bioinformatics (Affiliated College)
5) M. Sc. II year Clinical Research (Affiliated College)
6) M. Sc. II year Botany (Campus)
7) M. Sc. II year Herbal Medicine
8) M. Sc. II year Boany (Affiliated College)
9) M. Sc. II year Geology (Campus)
10) M. Sc. II year Dairy Science
11) M. Sc. II year Electronics
12) M. Sc. II year Environmental Science
13) M. Sc. II year Environmental Science (Campus)
14) M. Sc. II year Geography (Campus)
15) M. Sc. II year Applied Mathematics
16) M. Sc. II year Mathematics
17) M. Sc. II year Mathematics (Campus)
18) M. Sc. II year Microbiology
19) M. Sc. II year Microbiology (Campus)
20) M. Sc. II year Statistics
21) M. Sc. II year Statistics (Campus)

सदरील परिपत्रक व अभ्यासक्रम प्रस्तुत विद्यापीठाच्या **www.srtmun.ac.in** या संकेतस्थळावर उपलब्ध आहेत. तरी सदरील बाब ही सर्व संबंधितांच्या निदर्शनास आणून द्यावी, ही विनंती.

'ज्ञानतीर्थ' परिसर,
विष्णुपुरी, नांदेड – ४३१ ६०६.
जा.क्र.:शै–१/एनइपी/विवत्रंविपदवी/२०२४–२५/90e
दिनांक १२.०६.२०२४

डॉ. सरिता लोसरवार
सहा.कुलसचिव
शैक्षणिक (१–अभ्यासमंडळ) विभाग

प्रत : १) मा. आधिष्ठाता, विज्ञान व तंत्रज्ञान विद्याशाखा, प्रस्तुत विद्यापीठ.
२) मा. संचालक, परीक्षा व मुंल्यमापन मंडळ, प्रस्तुत विद्यापीठ.
३) मा. प्राचार्य, सर्व संबधित संलग्नित महाविद्यालये, प्रस्तुत विद्यापीठ.
४) मा. संचालक, सर्व संकुले परिसर व उपपरिसर, प्रस्तुत विद्यापीठ
५) सिस्टीम एक्सपर्ट, शैक्षणिक विभाग, प्रस्तुत विद्यापीठ. याना देवून कळविण्यात येते की, सदर परिपत्रक संकेतस्थळावर प्रसिध्द करण्यात यावे.

SWAMI RAMANAND TEERTH

MARATHWADA UNIVERSITY, NANDED - 431 606

स्वामी रामानंद तीर्थ
मराठवाडा विद्यापीठ, नांदेड.

(Structure and Syllabus of Two Years Multidisciplinary Master Degree Program with Multiple Entry and Exit Option)

(University Campus)

TWO YEARS MASTER DEGREE PROGRAMME IN SCIENCE

Subject: MATHEMATICS

Under the Faculty of
Science and Technology

Effective from Academic Year 2024 – 2025
(As per NEP-2020)

Forward by the Dean, Faculty of Science and Technology

From the Desk of the Dean:

To meet the challenge of ensuring excellence in Science and Technology education, the issue of quality needsto be addressed, debated and taken forward in a systematic manner. Accreditation is the principalmeans of quality assurance in higher education. The major emphasis of accreditation process is to measure the outcomes of the program that is being accredited. In line with this Faculty of Science and Technology of Swami Ramanand Marathwada University has taken a lead in incorporating philosophy of outcome based education in the process of curriculum development.

Faculty of Science and Technology, Swami Ramanand Teerth Marathwada University, in one of its meeting unanimously resolved that, each Board of Studies shall prepare some Program Educational Objectives (PEO's) and give freedom to affiliated Institutes to add few (PEO's) and course objectives and course outcomes tobe clearly defined for each course, so that all faculty members in affiliated institutes understand the depth and approach of course to be taught, which will enhance learner's learning process. It was also resolved that, maximum senior faculty from colleges and experts from industry to be involved while revising the curriculum. I am happy to state that, each Board of studies has adhered to the resolutions passed by Faculty of Science and Technology, and developed curriculum accordingly. In addition to outcome based education, semester based credit and grading systemis also introduced to ensure quality of education.

Semester based Credit and Grading system enables a much-required shift in focus from teacher-centric to learner-centric education since the workload estimated is based on the investment of time in learning and not in teaching. It also focuses on continuous evaluation which will enhancethe quality of education. Swami Ramanand Teerth Marathwada University has taken a lead in implementing the system through its affiliated Institutes and Faculty of Science and Technology has devised a transparent credit assignment policy and adopted ten points scale to grade learner's performance. Credit assignment for courses is based on 15 weeks teaching learning process, however content of courses is to be taught in 12-13 weeks and remaining 2-3 weeks to be utilized for revision, guestlectures, coverage of content beyond syllabus etc.

Credit and grading based system was implemented for First Year of from the academic year 2014-2015 and subsequently this system will be carried forward for Second Year2015-2016 respectively.

Dr. M. K. Patil, I/C Dean, Faculty of Science and Technology,
Swami Ramanand Teerth Marathwada University, Nanded

From Desk of Chairman, Board of Studies of the Subject MATHEMATICS

Preamble:

M. A. / M. Sc. Mathematics programme is of minimum 88 credits spread over four semesters. The programme emphasizes both theory and applications of Mathematics and is structured to provide knowledge and skills in depth necessary for the employability of students in industry, other organizations, as well as in academics. The program has some unique features such as independent projects, a large number of elective courses, extensive computer training including standard software packages such as LaTeX, SciLab, SageMath, R-software. The department has the academic autonomy and it has been utilized to add the new and need based elective courses. The independent project work is one of the important components of this program. The syllabus of the first year (two semesters) covers most of the core courses. In the third semester syllabus there are two core courses and eight elective courses. In the fourth semester syllabus there are two core courses and fourteen elective courses. The syllabus has been framed to have a good balance of theory, methods and applications of Mathematics.
It is possible for the students to study basic courses from other disciplines such as economics, life sciences, computer science and mathematics in place of electives.

Taking into consideration the rapid changes in science and technology and new approaches in different areas of Mathematics and related subjects, Board of studies in Mathematics after a thorough discussion with the teachers of Mathematics from Swami Ramanand Marathwada University Nanded and experts from industry as well as other Academic institutions has prepared the syllabus of M.A./M.Sc. I (w.e.f. 2023-24) Mathematics course under the NEP2020.
The Program Educational Objectives finalized for Postgraduate program in Mathematics are listed below:

Program Educational Objectives:

PEO1: To provide students Mathematical knowledge so that they are able to work as Professionals in the subject.
PEO2: To prepare them to go for higher studies and pursue research
PEO3: To train students to handle the problems faced by industry through Mathematical Knowledge and scientific computational techniques.
PEO4: To introduce the fundamentals of Mathematics to strengthen the students' logical and analytical ability.

PROGRAMME OUTCOMES (PO):

After the completion of the program, students will able to:

PO1: Pursue research in reputed institutions and solve the existing mathematical problems using the knowledge of pure and applied mathematics.

PO2: Acquire the strong foundation of basic concepts which will benefit them to become good academicians.

PO3: Apply the concept of mathematical tools to address real life problems

PO4: Gainthe knowledge of software which will be useful in Industry

PO5: Qualify various competitive exams like CSIR-UGC NET, SET, GATE, MPSC, UPSC, etc

PROGRAM SPECIFIC OUTCOMES (PSO):

PSO 1: To imbibe problem-solving and computational skills

PSO 2: To understand the motivation behind the statements and proofs

PSO 3: To enhance self learning and improve own performance.

PSO 4: To inculcate abstract mathematical thinking.

Course Outcomes (for all courses):

The course outcomes are the statement that describes the knowledge & abilities developed in the student by the end of course (subject) teaching. The focus is on development of abilities rather than mere content. There are 4 course outcomes of all courses defined here. These are to be written in the specific terms and not in general.

In addition to Program Educational Objectives, for each course of postgraduate program, objectives and expected outcomes from learner's point of view are also included in the curriculum to support the philosophy of outcome based education. I believe strongly that small step taken inright direction will definitely help in providing quality education to the stake holders.

Dr. Mahesh Sahebrao Wavare

Chairman, Board of Studies of the Mathematics

Swami Ramanand Teerth Marathwada University, Nanded

Details of the Board of Studies Members in the subject MATHEMATICS under the faculty of Science & Technology of S.R.T.M. University, Nanded

Sr No	Name of the Member	Designation	Address	Contact Number and EmailID
1	Prof. Dr. Mahesh Sahebrao Wavare	BoS Chairman (Ad hoc)under Section26(18) and BoS Member under section *40(2)(c)*	Rajarshi Shahu Mahavidyalaya (Autonomous), Latur,Tq. & Dist. Latur.	9890620620 maheshwavare@gmail.com
2	Prof. Dr. Dnyaneshwar Dadaji Pawar	*VC Nominated BoS Member Under Section 40(2)(a)*	Director School of Mathematical Sciences,SRTM University, Nanded	*9423124662 dypawar@yahoo.com*
3	Dr. B. Surendranath Reddy,	*VC Nominated BoS Member Under Section 40(2)(b)(i)*	School of Mathematical Sciences, SRTM University, Nanded	9096077789 surendra.phd@gmail.com bsreddy@srtmun.ac.in
4	Dr. Arun Babarao Jadhav,	*VC Nominated BoS Member Under Section 40(2)(b)(ii)*	DSM's College of Arts, Commerce and Science, Parbhani.	7875118707 arunbjadhav@gmail.com
5	Dr. S. S. Handibag,	*BoS Member Under Section 40(2)(b)(ii)*	Mahatma Basweshwar Mahavidylaya, Latur	9011491162 960417748 sujitmaths@gmail.com
6	Prof. Dr. Vandeo Chimnaji Borkar,	*BoS Member Under Section 40(2)(b)(iii)*	Yeshwant Mahavidyalaya, Nanded	9421769217 borkarvc@gmail.com
7	Dr. Kishor Ramrao Gaikwad,	*BoS Member Under Section 40(2)(b)(iii)*	Science College, Nanded	9923295556 drkr.gaikwad@yahoo.in
8	Dr. Hemant Kishor Undegaonkar,	*BoS Member Under Section 40(2)(b)(iii)*	Bahairji Smarak College, Basmat, Dist.Hingoli	9822546874 hkundegaonkar@gmail.com
9	Dr. S. S. Bellale	*BoS Member Under Section 40(2)(c)*	Dayanand Science College, Latur, Tq. & Dist. Latur - 413512	9405417417 sidhesh.bellale@gmail.com
10	Dr. Ram Govindrao Metkar	*BoS Member Under Section 40(2)(c)*	Indira Gandhi Sr. College, Cidco, NewNanded, Tq. & Dist.Nanded.:	9822312176 rammetkarmath@gmail.com

<u>Swami Ramanand Teerth Marathwada University, Nanded</u>

Faculty of Science & Technology

Credit Framework for Two Year PG Program (MA/M.Sc. Mathematics)

Subject: Mathematics (MAT)

Year & Level 1	Sem. 2	Major Subject (DSC) 3		Major Subject (DSE) 4	RM 5	OJT / FP 6	Research Project 7	Practicals 8	Credits 9	Total Credits 10
1	1	SMATC401	Algebra	SMATE401 (Any one of the following)	SVECR 401 *Research Methodology* (3 Cr)	--		SMATP401 (3Cr) Latex Typesetting	22	44
		SMATC402	Real Analysis	A. Elementary Number Theory						
		SMATC403	Complex Analysis	B. Introduction to Probability C. Multivariate Calculus D.Advanced Discrete Mathematics E.NPTEL/SWAYAM MOOCs						
	2	SMATC451	Linear Algebra	SMATE451 (Any one of the following)	---	SDSCOJ 451(3 Cr)	--	SMATP451 (3 Cr) Introduction to Scilab	22	
		SMATC452	Measure & Integration	A. Graph Theory B. Topology						
		SMATC453	Differential Equations	C. Numerical Analysis D. Algorithms and their Analysis E. NPTEL/SWAYAM MOOCs						
Exit option: Exit Option with PG Diploma *(after 2024-25)*										
2	3	SMATC501	Integral Equations & Transforms	*SMATE501 (Any one of the following)*	--		Research Project SDSCR551 (4Cr)	SMATP501 (2Cr) Scientific programming with Python	22	44
		SMATC502	Functional Analysis	A. Coding Theory						
		SMATC503	Riemannian Geometry	B. Difference Equations C. Analytic Number Theory D.Lattice Theory E. NPTEL/SWAYAM MOOCs						
	4	SMATC551	Galois Theory	SMATE551 *(Any one of the following)*	SVECP 551 Publication Ethics (2 Cr)		Research Project SDSCR552 (6 Cr)	SMATP551 (2Cr) R-programming	22	
		SMATC552	Fractional Calculus	A. Classical Mechanics B. Theory of Relativity C. Cryptography D. Commutative Algebra E. Operations Research						
Total Credits		44		16	05	03	10	10	88	

M.A/M. Sc. First Year Semester III *(Level 6.0)*

Teaching Scheme

	Course Code	Course Name	Credits Assigned			Teaching Scheme (Hrs/ week)	
			Theory	Practical	Total	Theory	Practical
Major	SMATC501	**Integral Equations & Transforms**	04	--	**04**	04	--
	SMATC502	**Functional Analysis**	04	--	**04**	04	--
	SMATC503	**Riemannian Geometry**	04	--	**04**	04	--
Practical	SMATP501	**Scientific programming with Python**	--	02	**02**	--	04
Elective (DSE)	*SMATE501*	(Choose any one) **A. Coding Theory** **B. Difference Equations** **C. Analytic Number Theory** **D. Lattice Theory** **E. NPTEL/SWAYAM MOOCs**	04	--	**04**	04	--
Research Project	SDSCR551	Research Project		04	**04**		08
Total Credits			**16**	**06**	**22**	**16**	**12**

M.A/M. Sc. First Year Semester III *(Level 6.0)*

Examination Scheme

[20% Continuous Assessment (CA) and 80% End Semester Assessment (ESA)]

(For illustration we have considered a paper of 02 credits, 50 marks, need to be modified depending on credits of individual paper)

Subject (1)	Course Code (2)	Course Name (3)	Theory				Practical		Total Col (6+7) / Col (8+9) (10)
			Continuous Assessment (CA) Avg of			ESA			
			Test I (4)	Test II (5)	T1+T2)/2 (6)	Total (7)	CA (8)	ESA (9)	
Major	SMATC501	Integral Equations & Transforms	20	20	20	80	--	--	100
	SMATC502	Functional Analysis	20	20	20	80	--	--	100
	SMATC503	Riemannian Geometry	20	20	20	80	--	--	100
Practical	SMATP501	Scientific programming with Python	--	-	--	--	10	40	50
Elective (DSE)	*SMATE501*	(Choose any one) A. Coding Theory B. Difference Equations C. Analytic Number Theory D. Lattice Theory E. NPTEL/SWAYAM MOOCs	20	20	20	80	--	--	100
Research Project	SDSCR551	Research Project					20	80	100

M.A/M. Sc. First Year Semester IV *(Level 6.0)*

Teaching Scheme

	Course Code	Course Name	Credits Assigned			Teaching Scheme (Hrs/ week)	
			Theory	Practical	Total	Theory	Practical
Major	**SMATC551**	**Galois Theory**	04	--	**04**	04	--
	SMATC552	**Fractional Calculus**	04	--	**04**	04	--
Practical	**SMATP551**	R-programming	--	02	**02**	--	04
Elective (DSE)	**SMATE551**	(Choose any one) **A. Classical Mechanics** **B. Theory of Relativity** **C. Cryptography** **D. Commutative Algebra** **E. Operations Research**	04	--	**04**	04	--
Research Methodology	**SVECP 551**	Publication Ethics	02		**02**	02	
Research Project	**SDSCR552**	Research Project		06			12
Total Credits			**14**	**08**	**22**	**14**	**16**

M.A/M. Sc. First Year Semester IV *(Level 6.0)*

Examination Scheme

[20% Continuous Assessment (CA) and 80% End Semester Assessment (ESA)]

(For illustration we have considered a paper of 02 credits, 50 marks, need to be modified depending on credits of individual paper)

Subject (1)	Course Code (2)	Course Name (3)	Theory				Practical		Total Col (6+7) / Col (8+9) (10)
			Continuous Assessment (CA) Avg of			ESA			
			Test I (4)	Test II (5)	(T1+T2)/ 2 (6)	Total (7)	CA (8)	ESA (9)	
Major	SMATC551	Galois Theory	20	20	20	80	--	--	100
	SMATC552	Fractional Calculus	20	20	20	80	--	--	100
Practical	SMATP551	R-programming	--	--	--	--	10	40	50
Elective (DSE)	SMATE551	(Choose any one) A. Classical Mechanics B. Theory of Relativity C. Cryptography D. Commutative Algebra E. Operations Research	20	20	20	80	--	--	100
Research Methodology	SVECP 551	Publication Ethics	5	5	10	40	--	--	50
Research Project	SDSCR552	Research Project	--	--	--	--	30	120	*150*

M. Sc. Second Year, Semester-III *(Level 6.5)*

SMATC 501: Integral Equations & Transforms

Course objectives: The aim of this course is to provide adequate knowledge of fundamentals of Fredholm, Volterra and singular integral equations and develop techniques for finding its solutions. To motivate students, how to solve problems on differential and integral equations using Laplace and Fourier transforms.

Course outcomes: After completing this course, the student will be able to:

CO1: Know the relation between differential and integral equations, and how to change from one to another.

CO2: Understand different kinds of kernels and use techniques for solving problems of each kind.

CO3: Explain Neumann series and solve linear Volterra and singular integral equations using appropriate methods.

CO4: Use of Laplace transforms, Fourier transforms for solving a wide range of differential and integral equations.

Curriculum Details:

Module No.	Unit No.	Topic	Hours Required to cover the contents
1.0	1.1	Types of integral equation, Types of Kernels, Eigenvalues and eigen functions	15
	1.2	Convolution integral, relation between differential equation and integral equation	
	1.3	Relation between integral equation and boundary value problems	
	1.4	Initial value problems and Integral equations	
	2.1	Solution of Homogeneous Fredholm integral equation of the second kind with separable kernel	15

	2.2	Orthonormal system of functions, Fredholm theorem, iterated kernel	
	2.3	Method of successive approximations, an approximate method, complex Hilbert spaces, Riesz-Fischer theorem	
	2.4	Hilbert –Schmidt theorem and its application for the solution of Fredholm integral equation with symmetric kernel.	
	3.1	Iterated kernels, Neumann series for Volterra integral equations	15
	3.2	Singular integral equations, solution of Abel's integral equation	
	3.3	weakly singular kernel, Cauchy principal for integrals, Cauchy type integrals	
	3.4	Solution of Cauchy type singular integral equations	
	4.1	Fourier Transforms and its properties, evaluation of Fourier and inverse Fourier transforms of functions	15
	4.2	Convolution theorem for Fourier Transforms, Sine and Cosine Fourier transforms, solving integral equations using Fourier Transforms	
	4.3	Laplace Transforms and its properties, evaluation of Laplace and Inverse Laplace transforms of functions, Convolution theorem for Laplace Transforms	
	4.4	Solving initial value problem using Laplace Transforms, solving integral equations using Laplace Transforms.	

Text Book:

1. Linear Integral Equations (Theory and Technique) – Ram P.Kanwal, Birkhauser

2. Advanced Differential Equations (12th Revised Ed) –M. D. Raisinghania ,S. Chand pub.

Scope:

Unit 1- Kanwal's book (Chapter 1 and Chapter 5(5.1 to 5.3, 5.5 to 5.7))

Unit 2- Kanwal's book (Chapter 2 , Chapter 3(3.1, 3.2) and Chapter 7(7.1, 7.4, 7.5, 7.6))

Unit 3- Kanwal's book (Chapter 3(3.3, 3.4) and Chapter 8(8.1 to 8.5))

Unit 4- From Raisinghania's Book

Reference Books:

1] A First course in integral equations - A.M. Wazwaz (world Scientific)

2] Introduction to Integral Equation with Applications (2nd edition) - A.J. Jerri (Wiley Interscience)

SMATC 502 : Functional Analysis

Course objectives: The motto of course is to show interconnection between linear algebra and analysis, to examine the structure of infinite dimensional vector spaces, Hilbert spaces and the spectra.

Course outcomes: After completing this course, the student will be able to:

CO1: Understand Banach Spaces, The Hahn-Banach Theorem.

CO2: Study the open Mapping Theorem, Hilbert Spaces.

CO3: Analyze different operators and their properties.

CO4: Understand Finite Dimensional Spectral Theory.

Curriculum Details:

Module No.	Unit No.	Topic	Hours Required to cover the contents
1	1.1	Definition and some Examples of Banach Spaces.	15
	1.2	Continuous Linear Transformations.	
	1.3	The Hahn-Banach Theorem.	
	1.4	The Natural embedding of N in N**.	
2	2.1	The Open Mapping Theorem.	15
	2.2	The Closed Graph Theorem.	
	2.3	The conjugate of an operator.	
	2.4	The definition and some simple properties of Hilbert Space.	
3	3.1	Orthogonal complements, Orthonormal sets.	
	3.2	The conjugate space H*.	

	3.3	The adjoint of an operator.	15
	3.4	Self Adjoint operators.	
	4.1	Normal and Unitary Operators	
	4.2	Projections.	
	4.3	Spectrum of an operator.	
4	4.4	The Spectral Theorem.	15

Text Book: Introduction to Topology and Modern Analysis :- G.F. Simmons

McGraw-Hill Book Company, International student Edition, New York.

Scope: Articles 46 to 62 excluding Topology part (Strong , Weak , Weak*)

Reference Books:

1. B.V. Limaye, Functional Analysis, Wiley Eastern Ltd.
2. G. Bachman and L. Narici, Functional Analysis.
3. Kreyszig , Introductory Functional Analysis with Applications, John Wiley & Sons, New York, 1978Academic Press 1966.
4. J. B. Conway, A course in functional analysis, Springer-Verlag, New York 1990.
5. S.Ponnusamy, Foundations Of Functional Analysis, Narosa Publishing House.

SMATC503 : Riemannian Geometry

Course objectives: The students will learn the Basic ideas of Riemannian geometry such as Riemannian metric, covariant differentiation; geodesics, curvature etc belong to the core of mathematical knowledge and are widely used in applications that range from general relativity in physics to mechanics and engineering.

Course outcomes: After completing this course, the student will be able to:

CO1: Explain the various geometrical and algebraic concepts of tensor algebra, Riemannian metric and familiar with Christoffel symbols, transformations and covariant derivatives.

CO2: Interpret the phenomenon of parallel vector fields and geodesic.

CO3: Understand the geometrical and mathematical formulation of Curvature tensor, its properties and its applications.

CO4: Use the theory, methods and techniques of the course to analyze and solve problems of static and non static line element.

Curriculum Details:

Module No.	Unit No.	Topic	Hours Required to cover the contents
1	1.1	Riemannian metric , metric tensor, Christoffel Symbol.	15
	1.2	Christoffel Symbol of first kind, second kind, Properties of Christoffel Symbol.	
	1.3	Computations of Christoffel's Symbol for static and non static spherically symmetric and R-W space time, transformation of Christoffel Symbol.	
	1.4	Derivatives of tensor, absolute derivative, covariant derivatives , divergence, gradient, Laplacian.	
	2.1	Parallel vector Fields: Parallel vector field of constant magnitude, parallel displacement of covariant vector field.	
	2.2	Parallelism of vector field of variable magnitude.	

2	**2.3**	Geodesic: Differential equations of Geodesic.	**15**
	2.4	Special Co-ordinate systems: Local Cartesians, Riemannian Co-ordinates, Normal Co-Ordinates, Geodesic normal co-ordinate.	
3	**3.1**	Curvature tensor: Covariant curvature tensor of Riemann tensor.	**15**
	3.2	Curvature tensor in Riemannian co-ordinates.	
	3.3	Properties of curvature tensors, on a cyclic property.	
	3.4	Number of independent components of R.	
4	**4.1**	Ricci tensor, curvature invariant, Einstein tensor.	**15**
	4.2	Computation of Einstein's tensor for static and non static spherically symmetric and R-W space time, the Bianchi identity.	
	4.3	Geodesic deviation: Equations of Geodesic deviation.	
	4.4	Riemannian curvature, space of constant curvature, flat space, Cartesian tensor.	

Reference Books:

1.T. M. Karade, G. S. Khadekar, and Maaya S. Bendre, Lecture on General Relativity , Sonu Nilu Publication

2.T. J. Willmore, An Introduction in Differential Geometry .

3. J. L. Synge, Tensor Calculus, Schild

4. C. E. Weatherburn , An Introduction to Reimannian Geometry and Tensor Calculus, Cambridge University Press -1963

5. L. P. Eisenhard , Reimannian Geometry, University Press Princeton 1926

6. J . A. Schouten, Ricci Calculus, Springer Verlag Berlin

7. T. Y. Thomas, Concept from Tensor Analysis and Differential Geometry, Academic Press, New York.

8. W. Boothby, Introduction to Differentiable Manifold and Reimannian Geometry, Academic Press , 1975

9. S. Kobayashi and K. Nomizu, Foundations of Differential Geometry, Vol. I and Vol. II, Wiley Interscience Publisher, 1961(Vol.I) , 1969 (Vol.II)

SMATE501(A): CODING THEORY

Course Objective: This course is aimed to provide an introduction to the theories, concepts of linear codes and their parameters. It also focuses on encoding and decoding tehniques of linear codes.

Course Outcomes:

Upon successful completion of this course, students will able to

CO1: Understand the concept of encoding and decoding.

CO2: Explain various bounds on linear codes.

CO3: Understand various tools to obtain new linear codes out of old ones.

CO4: Study BCH codes and their parameters.

Curriculum Details:

Module No.	Unit No.	Topic	Hours Required to cover the contents
1	1.1	Communication channels, Maximum likelihood decoding, Hamming distance, nearest neighbour / minimum distance decoding, Distance of a code.	15
	1.2	Vector spaces over finite fields, Linear codes, Hamming weight, Bases of linear codes, Generator matrix and parity check matrix	
	1.3	Equivalence of linear codes, Encoding with a linear code, Decoding of linear codes	
	1.4	Cosets, Nearest neighbour decoding for linear codes, Syndrome decoding	
2	2.1	The main coding theory problem, Lower bounds(in connection with linear codes only), Sphere-covering bound,	15
	2.2	Gilbert–Varshamov bound, Hamming bound and perfect codes,	

	2.3	Binary Hamming codes, Singleton bound	
	2.4	MDS codes, Griesmer bound	
3	**3.1**	Propagation rules, Reed–Muller codes	**15**
	3.2	Subfield codes, Definitions, Generator polynomials	
	3.3	Generator and parity check matrices	
	3.4	Decoding of cyclic codes.	
4	**4.1**	BCH codes	**15**
	4.2	Parameters of BCH codes.	

Textbook: San Ling and Chaoping Xing, Coding Theory- A First Course, Cambridge University Press, 1st Edition.

Scope: Chapters 1, 2, 4, chapter 5(Art: 5.1, 5.2, 5.2.1, 5.2.2, 5.3, 5.3.1, 5.4, 5.7, 5.8), chapter 6, 7, chapter 8(Art: 8.1 to 8.1.3)

Reference Books:

1. Lid and Pilz , Applied Abstract Algebra - 2nd Edition.

2. R. Lidl, H.Neiderreiter, Introduction to finite fields and their applications, Cambridge University Press.

SMATE501(B) : Difference Equations

Course objectives: To learn different methods to solve linear and nonlinear difference equations , use them to model real life problems. Also learn to check the stability of various models.

Course outcomes: After completing this course, the student will be able to:

CO1: Acquire the knowledge of Difference Calculus

CO2: Attain mastery to solve Linear Difference equations

CO3: Learn and apply Z-transform and stability Theory

CO4: Study in detail Phase plane analysis, and floquet theory

Curriculum Details:

Module No.	Unit No.	Topic	Hours Required to cover the contents
1.0	**1.1**	The difference operator, summation	**15**
	1.2	Generating function and approximate summation	
	1.3	Linear Difference equations: First order equations	
	1.4	General results for linear for linear equations	
2.0	**2.1**	Solving linear equations,	**15**
	2.2	Applications	
	2.3	Equations with variable coefficients	
	2.4	Non linear equations that can be linearized	
3.0	3.1	The Z-transform: Properties	15

	3.2	Initial and final value theorem, partial sum theorem, convolution theorem, Inverse Z-transforms,	
	3.3	Solution of difference equation with constant coefficients by Z-transforms,	
	3.4	Stability Theory: Initial Value Problems for linear systems. Stability of linear systems	
4.0	4.1	Phase plane analysis	15
	4.2	Fundamental matrices	
	4.3	Floquet theory	
	4.4	Stability of non- linear system	

Text Book:

1) Difference equations: An introduction with applications by Walter G. Kelley and Allan C. Peterson,Elsevier, 2nd edition, 2012 (Indian reprint).

Reference Books:

1) Discrete Hamiltonian systems, Difference equations, continued Fractions and Riccati Equations by Calvin Ahlbrandt and Allan C-peterson; Kluwer,Bostan, 1996.

2) An introduction to difference equations by Saber Elaydi, Springer.

3) Difference Equations by Pundir S. K. and Pundir R., Pragati Prakashan, Meerut.

SMATE-501(C): Analytic Number Theory

Course objectives: Study of distribution of prime numbers is of vital importance in mathematics. The syllabus aims to develop basic techniques to understand problems in analytic number theory viz; distribution of prime numbers, equivalent forms of Prime Number Theorem and its relation with Riemann zeta function.

Course outcomes: After completing this course, the student will be able to:

CO1: Understand different arithmetic functions and their convolutions

CO2: Distribute prime numbers and construct the proof of prime number theorem

CO3: Master Dirichlet series and its analytic properties

CO4: Explore Riemann Zeta function and explain Riemann Hypothesis

Curriculum Details:

Module No	Unit No	Topics	Hours Required to cover the contents
1	1.1	Arithmetical functions: $\mu(n)$, $\varphi(n)$, $\Lambda(n)$, $\lambda(n)$, u(n) etc., Multiplicative functions, Dirichlet Product and its properties	15
	1.2	Dirichlet inverses, Inverse of a completely multiplicative function, derivative of arithmetical functions	
	1.3	Euler Summation formula and its applications, averages of arithmetical functions	
	1.4	Partial sums of arithmetical functions	
2	2.1	Prime numbers, distribution of prime numbers, the prime counting function $\pi(x)$ and its properties	15
	2.2	Chebyshev's functions $\theta(x)$, $\psi(x)$and their properties	
	2.3	Abel's Identity, Shapiro's Tauberian theorem and its applications	
	2.4	Equivalent forms of Prime number theorem	
3	3.1	Dirichlet Series, half plane of Convergence and absolute convergence of Dirichlet series, multiplication of Dirichlet series	15

	3.2	Analytical properties of Dirichlet Series, Euler Product	
	3.3	Dirichlet series with non negative coefficient, Mean value formulas for Dirichlet Series	
	3.4	An integral formula for the coefficients of a Dirichlet Series, Perron's formula	
4	**4.1**	Riemann Zeta function ζ(s), analytical properties of ζ(s)	**15**
	4.2	Analytic continuation, zero free region	
	4.3	study of the zeros of ζ(s)	
	4.4	Riemann Hypothesis (RH) and some consequences of RH	

Textbooks:

1) Tom M. Apostol, Introduction to Analytic Number Theory, Springer International Student Edition.

2) E.C.Titchmarsh, The Theory of Riemann Zeta Function"(second edition), revised by D. R. Heath-Brown, Clarendon Press. Oxford

3) A.E.Ingham, The Distribution of Prime Numbers, Cambridge University Press

Scope:

Unit I: Apostol chapter 2 (2.1 to 2.14, 2.18), Chapter 3 (3.1 to 3.7)

Unit II: Apostol Chapter 4 and Ingham's book

Unit III: Apostol chapter 11

Unit IV: Titchmarsh and Ingham's book

Reference Books:

1) H.M.Edward, Riemann Zeta Function, Academic Press

2) G.H.Hardy and E.M.Wright, D.R.Heath-Brown, J.H. Silverman, An Introduction to the Theory of Numbers.

3) A.J.Hildebrand, Introduction to Analytic Number Theory

4) Paul T.Bateman, Harold G. Diamond, Analytic Number Theory:An Introductory Course, World Scientific.

SMATE501(D): Lattice Theory

Course objectives: To learn different lattices, their properties, types of lattices. Explore about Distributive lattices, modular lattices and semi modular lattices and interplay between them.

Course outcomes: After completing this course, the student will be able to:

CO1: Understand two versions of lattice definition and construct some examples

CO2: Outline the proofs of Birkhoff's and Stone theorems

CO3: Analyse characteristics of Modular lattices

CO4: Construct proofs of Jordan Holder Chain condition and M-symmetric lattices

Curriculum Details:

Module No.	Unit No.	Topic	Hours Required to cover the contents
1.0	1.1	Two definitions of lattices, Hasse diagrams, homomorphism, isotone maps, ideals	15
	1.2	Congruence relations, congruence lattices, the homorphism theorem, product of lattices	
	1.3	Complete lattice, ideal lattice, distributive –modular inequalities and identifies, complements, pseudocomplements	
	1.4	Boolean lattice of pseudo complements, join and meetirreducible elements	
2.0	2.1	Characterization theorems and representation theorems-Dedekind`s modularity criterion	15
	2.2	Birkhoff`s distributivity criterion	

	2.3	Hereditary subsets, rings of sets, Stone theorems	
	2.4	Nachbin theorem, statements of Hashimoto's theorem	
3.0	**3.1**	Modular lattices	**15**
	3.2	Isomorphism theorem	
	3.3	Upper and lower covering conditions.	
	3.4	Kuros-Ore theorem, independent sets	
4.0	**4.1**	Semi modular lattices	**15**
	4.2	Jordan-Holder chain condition	
	4.3	Modular pair	
	4.4	M-sysmmetric lattices	

Text Book:

G. Gratzer- Birkhauser, General Lattice Theory, IInd Edition 199.

Scope: Chapter- 1 (Section 1,2, 3,4,6), Chapter – 2(Section -1), Chapter-3(Section –1, 2)

Reference Books:

Vijay K. Garg, Introduction to lattice theory with computer science applications, John Wiley and Sons.

SMATE501(E): NPTEL/ SWAYAM MOOCs

Students can opt any 4 credit SWAYAM/NPTEL MOOCs as per their choice.

SDSCR551: Research Project

Students will select an advanced topic as a research project, which is a base for the research and works under a teacher to complete the project. Project report should be typed in Latex typesetting.

SMATP501: Scientific programming with Python

Course objectives:

Students will acquire a solid foundation in Python programming, enabling them to write code efficiently, will learn to perform numerical computations, work with arrays, and solve mathematical problems involving linear algebra, and students will learn to visualize mathematical data effectively, creating plots and charts.

Course outcomes: After completing this course, the student will be able to:

CO1: Demonstrate proficiency in writing Python code, utilizing fundamental programming concepts to implement mathematical algorithms and solutions.

CO2: Able to use the NumPy library to perform efficient numerical computations, manipulate arrays, and solve linear algebraic equations.

CO3: The course will equip students with the ability to create clear and informative visualizations of mathematical data using the Matplotlib library.

CO4: Gain an understanding of scientific computing techniques, including integration, differentiation, solving differential equations, and optimization, using the SciPy library.

Curriculum Details:

Module No.	Unit No.	Topic	Hours Required to cover the contents
1.0	1.1	Overview of Python language, Installation and setup of Python environment (Anaconda, Jupyter Notebooks, Google Colab), Basic syntax and data types (variables, strings, numbers), Variables and Input Statement	15
	1.2	Operator and Expressions, Introduction to set, list, tuple and dictionary, Control flow: if statements, loops (for, while)	
	1.3	Nested loop statement. Loop control statements (break, continue, pass),	

		Defining functions, Introduction to import libraries.	
	1.4	Introduction to the NumPy library, Mathematical functions: trigonometry, exponentials, logarithms, NumPy arrays: creation, attributes, Array indexing and slicing,	
2.0	**2.1**	Matrix operations: multiplication, inversion, determinant, Finding eigenvalues and vectors and inverse of matrix, Solving linear algebraic equations using NumPy	**15**
	2.2	Introduction to the Matplotlib and seaborn library Creating basic plots: line plots, scatter plots, histograms, Customizing plots and adding labels, Visualizing mathematical functions using Matplotlib. Creating 3D plots.	
	2.3	Introduction to the SymPy library, Creating and manipulating symbolic expressions, Solving algebraic equations symbolically, Calculus operations with SymPy (derivatives, integrals)	
	2.4	Overview of the SciPy library, Integration and differentiation using SciPy, Solving differential equations with SciPy, Optimization techniques with SciPy	

Text Book: **Python for Scientists - by John M. Stewart**

Reference Books:

1) Doing Math with Python: Use Programming- Amit Saha
2) Applying Math With Python-Sam Morley
3) Mathematics And Python Programming-J. C. Bautista

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SMATC 551: Galois Theory

Course objectives: To introduce the concepts and to develop working knowledge of field extensions, Galois groups and interrelation between group theory and field theory.

Course outcomes: After completing this course, the student will be able to:

CO1: Understand the main algebraic properties of fields.

CO2: Analyze properties of algebraic, normal and separable extension

CO3: Compute Galois groups in simple cases and to apply the group-theoretic information to comprehend results about fields.

CO4: Develop knowledge of some classical Greek problems.

Curriculum Details:

Module No.	Unit No.	Topic	Hours Required to cover the contents
1.0	1.1	Irreducible polynomials	15
	1.2	Adjunction of roots	
	1.3	Algebraic extensions	
	1.4	Algebraically closed fields	
2.0	2.1	Splitting fields	15
	2.2	Normal extensions, Multiple roots	
	2.3	Finite fields	

	2.4	Separable Extensions	
3.0	**3.1**	Automorphism groups	**15**
	3.2	Fixed fields	
	3.3	Fundamental Theorem of Galois Theory	
	3.4	Fundamental theorem of algebra	
4.0	**4.1**	Roots of unity and cyclotomic polynomials	**15**
	4.2	Cyclic extensions	
	4.3	Polynomials solvable by radicals	
	4.4	Symmetric functions, Ruler and compass constructions	

Text Book:

P.B. Bhattacharya, S.K. Jain, S.R. Nagpaul, Basic Abstract Algebra, 2nd Ed., Cambridge University Press.

Scope: Chapter 15 to 18.

Reference Books:

1. D.S. Dummit and R. M. Foote, Abstract Algebra,2nd Ed., John Wiley, 2002.
2. Joseph Rotman, Galois Theory, 2nd Ed., Springer International Edition
3. N. Jacobson, Basic Algebra I, 2nd Ed., Hindustan Publishing Co., 1984
4. S. Lang, Algebra I, III Edition, Addison Wesley, 2005

SMATC 552 : Fractional Calculus

Course objectives: The main objective of this course is to introduce the basic concepts of fractional order derivatives and integrations and study the different fractional transforms, existence and uniqueness theorem to solve fractional order differential equations.

Course outcomes: After completing this course, the student will be able to:

CO1: Understand properties of gamma and beta functions and interplay between them.

CO2: Understand different kinds of fractional derivatives.

CO3: Find Laplace, Fourier , Mellin transforms of different fractional derivatives.

CO4: Solve fractional differential equations using different transform techniques.

Curriculum Details:

Module No.	Unit No.	Topic	Hours Required to cover the contents
1	1.1	Gamma and Beta Functions, Some properties of Gamma and Beta Functions, Relation between Gamma and Beta Functions.	15
	1.2	Mittag-Leffler Functions of one and two parameters	
	1.3	Relations of Mittag-Leffler Function to some other functions	
	1.4	The Laplace transform of Mittag-Leffler Function in two parameters. Wright Function	
2	2.1	Grunwald-Letnikov fractional derivatives	15
	2.2	Riemann-Liouville fractional derivative	
	2.3	Caputo's fractional derivative	
	2.4	Fractional integral	

3	**3.1**	Left and right fractional derivatives	**15**
	3.2	Laplace transform of fractional derivatives	
	3.3	Fourier transform of fractional derivatives	
	3.4	Mellin transform of fractional derivatives	
4	**4.1**	Homogeneous fractional differential equations and non-homogeneous fractional differential equations	**15**
	4.2	Existence and uniqueness theorem as a method of solution	
	4.3	Laplace transform method to solve fractional differential equations	
	4.4	Fourier transform method to solve fractional differential equations.	

Text Book: Igor Podlubny - Fractional Differential Equations, Academic press, San Diego, California.

Reference Books:

1. Miller K. S. and Ross B. – An Introduction to Fractional Calculus and Fractional Differential Equations, New York, John Wiley, 1993.
2. Oldham K. B. and Spanier J. – The Fractional Calculus, New York, Academic press, 1974.
3. Anatoly A. Kilbas, Hari M. Shrivastav, Juan J. Trujillo- Theory and Applications of Fractional Differential Equations, Elesevier, New York 2006.
4.. Shananu Das – Functional Fractional Calculus, 2011 Springer-Verlag, Berlin Heidelberg.

SMATE551(A): Classical Mechanics

Course objectives:

To demonstrate knowledge and understanding of the fundamental concepts in the dynamics of system of particles and motion of rigid body. Also learn to represent the equations of motion for complicated mechanical systems using the Lagrangian and Hamiltonian formulation of classical mechanics.

Course outcomes: After completing this course, the student will be able to:

CO1: Understand Calculus of variation and solve different problems

CO2: Learn D-Alemberts principle and formulate Laganges equation of motion

CO3: Formulate Hamiltonian equation and understand its physical significance

CO4: Gain knowledge of Eulerian angles and Cayley Klein parameters

Curriculum Details:

Module No.	Unit No.	Topic	Hours Required to cover the contents
1.0	1.1	Calculus of variation, Euler Lagrange's equation,	15
	1.2	First integrals of Euler Lagrange's equation, the case of several dependent variables,	
	1.3	Geodesics in a plane, the minimum surface of revolution, Brachistochrome problem	
	1.4	Isoperimetric problems, problems of maximum enclosed area.	
2.0	2.1	Mechanics of system of particles	15
	2.2	Constraints, Generalized co-ordinates	
	2.3	D. Alembert's principle, Lagrange's equations of motion.	

	2.4	Kinetic energy as a homogeneous function of generalized velocities	
3.0	3.1	Cyclic co-ordinates and generalized momentum conservation Theorems	15
	3.2	Hamilton's Principle for conservative systems	
	3.3	Lagrange's equation from Hamilton principle for conservative system,Hamiltonian function.	
	3.4	Hamiltonian canonical equations of motion, Derivation of Hamiltonian equation from variational principle, Physical significance of Hamiltonian,	
4.0	4.1	The principle of least action, Cyclic co-ordinates and Routh's procedure.	15
	4.2	The independent co-ordinates of a rigid body, Orthogonal transformations,Properties of transformation matrix, Infinitesimal rotations,	
	4.3	The Eulerian angles, The Calyley-Klein parameters, Eulers theorem on motion of rigid body	
	4.4	Angular momentum and kinetic energy of motion of a rigid body about a point.	

Text Book:

Goldstein H, Classical Mechanics, Narosa Publishing House,(Second edition)

Reference Books:

1) Goldstein Pooler & Saflco, Classical Mechanics, Pearson Educations.

2) N.C. Rana & P. S. Jog, Classsical Mechanics, Tata Mc.Graw Hill (1992).

3) J.C. Upadhyay, Classical Mechanics, Himalaya Pub.

SMATE551(B): Theory of Relativity

Course objectives: The students shall be familiar with the fundamental principles of the special and general theory of relativity. They shall know the meaning of basic concepts like inertial frames and how gravity is understood as a manifestation of a curved space-time. They shall also be familiar with some of the main contents of the theory: Einstein's field equations, three crucial tests for general relativity and Schwarzschild solutions.

Course outcomes: After completing this course, the student will be able to:

CO1: Describe physical phenomena in different coordinate systems, Galilean and Laurentz transformations. Analyze the conflict between Newtonian theory of gravitation and special theory of relativity.
CO2: Define energy momentum tensor of various fluids and understand gravity due to curved space-time.
CO3: Obtain Einstein's field equations by different approach and prove Newtonian theory as a first approximation.
CO4: Solve Einstein's field equations for static spherically symmetric Schwarzschild space-time and calculating the advances of perihelion, relativistic frequency shifts for sources moving in a gravitational field, as well as the bending of light passing a spherical mass distribution.

Curriculum Details:

Module No.	Unit No.	Topic	Hours Required to cover the contents
1.0	1.1	Review of the special theory of relativity and the Newtonian theory of gravitation. Galilean and Laurentz transformations.	15
	1.2	Distinction between Newtonian space and relativistic space.	
	1.3	The conflict between Newtonian theory of Gravitation and Special Relativity.	
	1.4	The action principle, the energy momentum tensor.	
2.0	2.1	The stress energy momentum tensor for Incoherent matter,	15
	2.2	perfect fluid, electromagnetic field. Einstein's Relativity: SR to GR, Non-Euclidean space-time,	
	2.3	General relativity and gravitation, desirable features of gravitational theory	
	2.4	Principle of equivalence, Principle of covariance and Mach's	

		Principles.	
3.0	3.1	Einstein's field equations, Derivation of Einstein's field equations from action principle, Flat space and empty space.	15
	3.2	Local conservation laws associated with perfect fluid distribution	
	3.3	Newtonian approximation: Relation between g44 and V,	
	3.4	Einstein equations compared with Poisson equation.	
4.0	4.1	Spherical symmetry, Einstein's field equations under spherical symmetry,	15
	4.2	Schwarzschild exterior solution and its isotropic form,	
	4.3	Planetary orbits, General relativistic Kepler problem,	
	4.4	Three crucial tests for general Theory of relativity: 1. Perihelion of the planet Mercury, 2. Bending of light, 3. Gravitational red shift, Schwarzschild interior solutions.	

References:

(1) Introduction to General Relativity – Ronald Ader, Maurice Bazin, Menahem Schiffer, 2 Edition, McGraw Hill Company.

(2) Lectures of Relativity – T. M. Karade, et. al, Einstein Foundation International Nagpur.

(3) General Relativity and Cosmology – J. V. Narlikar, Macmillan Company of India, 1978.

(4) Gravitation and Cosmology: Principles and Applications of General theory of Relativity – Steven Weinberg, John Wiley Pblication.

(5) Relativity,Thermodynamics and Cosmology – R. C. Tolman (Oxford Press).

(6) Mathgematical Teory of Relativity – A. S. Eddington, Cambridge University Press, 1965.

(7) Dr. S. R .Roy, Dr. Raj Bali, Theory of Relativity, Jaipur publishing house.

(8) H. Stepheni: General Relativity: An Introduction to the theory of gravitational field, Cambridge University press, 1982.

(9) R. Resnicik,Introduction to special relativity, Wiley Eastern Ltd.

SMATE 551(C) Cryptography

Course objectives: To introduce the concepts and to develop working knowledge of encryption, decryption and cryptanalysis.

Course outcomes: After completing this course, the student will be able to:

CO1: Understand the main essence of how cryptography helps to achieve common security goals.
CO2: Analyze the notions of public-key cryptography, Study different primality tests and their gradual development.
CO3: Study discrete logarithm problem and various methods to solve this problem.
CO4: Develop knowledge of elliptic curves, Elliptic curve cryptosystems, Elliptic curve primality test etc.

Curriculum Details:

Module	Unit No	Topic	**Hours Required to cover the contents**
1	1.1	Time estimates for doing arithmetic, divisibility and Euclidean algorithm	15
	1.2	congruences, quadratic residues and reciprocity, Fermat's little theorem	
	1.3	applications to factoring, Finite fields	
	1.4	Study of various number systems	
2	2.1	Classical cryptosystems- Shift Cipher, Substitution Cipher, Affine Cipher, Vigenere Cipher, Hill Cipher and their cryptanalysis	15
	2.2	Introduction to Public key cryptosystem, Chinese Remainder Theorem, RSA cryptosystem	
	2.3	Cryptanalysis of RSA, Primality Tests - Solovay - Strassen algorithm, Miller Rabin Algorithm	
	2.4	Factoring Algorithms - Pollard's P-1 method, Pollard Rho method	

3	3.1	discrete logarithm Problem, The ElGamal cryptosystem, Diffee-Hellman key exchange system	15
	3.2	Algorithms for discrete logarithm problem -Shank's algorithm, Pollard rho discrete log algorithm,	
	3.3	Pohlig-Hellman Algorithm,Index calculus method	
	3.4	Security of ElGamal system	
4	4.1	Introduction to Elliptic curves, Elliptic curves over finite fields	15
	4.2	Properties of Elliptic curves, elliptic curve addition algorithm	
	4.3	Elliptic curve discrete log problem, The double-and-add algorithm	
	4.4	Elliptic ElGamal Public key cryptosystem, Lenstra's elliptic curve factorization algorithm	

Textbooks:

1) Neal Koblitz, A Course in Number Theory and Cryptography (second edition), Springer-Verlag.

2) Douglas R. Stinson, Cryptography: Theory and practice (Third Edition), CRC Press.

Reference Books:

1. William Stallings, Cryptography and Network Security, Prentice Hall.
2. Henk C A, Van Tilborg, Fundamentals of Cryptography, Kluwer Academic Publishers
3. Jeffery Hoffstein, Jill Pipher, Joseph H. Silverman, An Introduction to Mathematical Cryptography, Springer

SMATE 551(D) : Commutative Algebra

Course objectives: Commutative Algebra is the study of commutative rings, and their modules and ideals. This course will give the student a solid grounding in commutative algebra which is used in both algebraic geometry and number theory.

Course outcomes: After completing this course, the student will be able to:

CO1: Understand the proof of snake lemma and construction of tensor product

CO2: Explain localization of rings and master the concepts like extended and contracted ideals in ring of fractions

CO3: Construct the proof of the primary decomposition of ideals, going up and going down theorems.

CO4: Identify the relation between Artin and Noetherian rings; relate with dedekind domains.

Curriculum Details:

Module No.	Unit No.	Topic	Hours Required to cover the contents
1	1.1	Nilradical and Jacobson radical, Operations on ideals.	15
	1.2	Extension and Contraction	
	1.3	Modules and module homomorphisms, Sub modules and quotient modules.	
	1.4	Operations on sub modules, Direct sum and product.	
2	2.1	Finitely generated modules, Exact sequences.	15
	2.2	Tensor product of modules.	
	2.3	Restriction and extension of scalars.	
	2.4	Exactness properties of the tensor product, Algebras.	

3	3.1	Tensor product of algebras.	15
	3.2	Local properties. Extended and contracted ideals in ring of fractions.	
	3.3	Integral dependence, the going-up theorem.	
	3.4	Integrally closed integral domains, the going- down theorem.	
4	4.1	Chain conditions.	15
	4.2	Noetherian rings. Primary decomposition in Noetherian rings.	
	4.3	Artin rings.	
	4.4	Discrete valuation rings. Dedekind domains.	

Text Book: Introduction to Commutative Algebra :- M. F. ATIYAH & I. G. MACDONALD, University of Oxford Press.

Scope: Chapter 1 to Chapter 9.

Reference Books:

1. H.Matsumura, Commutative Ring Theory, Cambridge University Press.
2. N. S. Gopalakrishnan, Commutative Algebra.
3. D.S. Dummite and R.M. Foote, Abstract Algebra, Second ed., John Wiley & Sons.
4. D.P. Patil, Patil, Storch, Introduction to Algebraic Geometry and Commutative Algebra, Anshan Publishers.
5. S. Lang, ”Algebra”, Springer(GTM).

SMATE551(E):OPERATIONS RESEARCH

Course objectives: To learn advanced methods in operations research courses that are used in the systems approach to Engineering and Management, so as to provide them with the requisite tools for the mathematical representation of decision-making problems, in particular emphasizing the roles of uncertainty and risk.

Course Outcomes: After completion of the practical students will able to:

CO1: Understand and solve real life problems using linear programming, duality and sensitivity problems.

CO2: Understand Transportation and assignment problems, theory of games and PERT/CPM.

CO3: Understand and use Integer programming problems. Dynamic programming in multistage solution problems.

CO4: Understand and deal with inventory problems with and without shortages.

Module No	Unit No.	Topic	Hrs.Required to cover the contents
1. 0			**15**
	1.1	Introductions to Linear programming problems (LPP), General LPP and its Mathematical Formulation, Graphical method for solution, solution of linear programming problem, some important theorems.	
	1.2	Theory of Simplex methods: Introduction, slack and surplus variables, Fundamental theorems of linear programming, optimality of solutions.	
	1.3	Artificial variable technique. Duality, Dual simplex method.	
	1.4	Revised simplex method and sensitivity analysis.	
2.0			**15**
	2.1	Transportation problem, finding an initial basic feasible solution, test of optimality, degeneracy, MODI method, stepping stone method	

	2.2	Assignment problem, mathematical formulation, assignment method (Hungarian), special cases in assignment problem, traveling salesman problem	
	2.3	Competitive game, two person zero sum game, rectangular game, solution of game, saddle point, solution of a rectangular game with saddle point.	
	2.4	PERT-CPM, product planning control with PERT-CPM.	
3.0			**15**
	3.1	Integer Linear Programming Problem (ILPP): The concept of cutting plane, Gomory's method of cutting plane for all ILPP	
	3.2	Mixed ILPP, Branch and Bound method.	
	3.3	Dynamic programming: The Recursive equation approach,	
	3.4	Characteristics and algorithm	
4.0			**15**
	4.1	Inventory models: Inventory problems and their analytical structure.EOQ, deterministic models of inventory control.	
	4.2	Inventory (S,s) policy periodic review models with stochastic demand.	
	4.3	Probabilistic reorder point,	
	4.4	Lot size inventory system.	
		Total	**60**

Text books:

1. Kanti Swaroop, P.K.Gupta and Manmohan, Operations Research, Sultan Chand & Sons, New Delhi.
2. G.Hadley, Linear Programming, Narosa publishing House, 1995.
3. G.Hadley, Nonlinear and Dynamic Programming, Addison-Wesley, Reading Mass.
4. H.A.Taha, Operations Research - An Introduction, Macmillan Publishing Company, Inc, New York.
5. P. K. Gupta and D. S. Hira, Operations Research – An Introduction. S. Chand & company Ltd, New Delhi.

Reference Books:

1. R. K. Gupta "Linear Programming",Krishna Prakashan Mandir.
2. S.S.Rao, Optimization Theory and Applications, Wiley Eastern Ltd., New Delhi.
3. F.S.Hillier and G.J.Liebermann,(1995) Introduction to Operations Research (6th Ed.) Mc Graw Hill.
4. N. S. Kambo, Mathematical Programming Techniques. Affiliated East-West Press Pvt. Ltd, New Delhi.

SMATP551 R-Programming (2Cr)

Course objectives:

- To familiar and to develop learning mindsets to analyze statistical data through R software.
- To learn basic syntax, coding and vocabulary to aid in data analysis.

Course outcomes: After completion of the course students will able to:

- **CO1:** Get familiar with R software and learn basics of R with descriptive statistics. Compute probabilities and fitting of probability distribution with R environment.
- **CO2:** Explore small and large data-sets to create testable hypotheses and identify appropriate statistical tests. Perform correlation, regression analysis and appropriate statistical tests for real life situations using R.

Module No.	UnitNo.	Topic	Hrs. Required to cover the contents
1. 0			**15**
	1.1	Introduction: History of R programming, starting and ending R, Data types, Getting help in R, R use as calculator. Descriptive Statistics: Diagrammatic representation of data. Measures of central tendency	
	1.2	Measures of dispersion, measures of skewness and kurtosis	
	1.3	Probability problems on finding basic probabilities.	
	1.4	Probability distributions: some special discrete and continuous probability distributions. Probabilities and inverse for various distributions, sketching graphs for various distributions	
2.0			**15**
	2.1	Statistical inference: Sampling distribution of sample means, Estimation of parameters, Hypothesis testing, Goodness of fit tests.	
	2.2	Correlation, inference procedure for correlation coefficient, Bivariate correlation, Multiple correlations	
	2.3	Linear regression and its inference procedure, Simple optimization method	
		Total	**30**

Text books:

1. Purohit S. G., Gore S. D. and Deshmukh S. K. (2010) Statistics using R, Narosa.
2. Peter Dalgaard (2008) Introductory Statistics with R, Springer.
3. M. D. Ugarte, A. F. Militino, A. T. Arnholt (2008) Probability and Statistics with R, CRC Press.

Reference Books:

1. Normal Maltoff (2009) The art of R programming.
2. W. John Braun, John Braun, Duncan James Murdoch (2007) First Course in Statistical Programming with R, Cambridge University Press.
3. Michael J. Crawley (2007) The R Book, John Wiley and Sons.

SVECP 551 Publication Ethics

Common paper, syllabus will be provided by the University

SDSCR552: Research Project

Students will select an advanced topic as a research project, which is a base for the research and works under a teacher to complete the project. Project report should be typed in Latex typesetting.

Guidelines for Course Assessment:

A. Continuous Assessment (CA) (20% of the Maximum Marks):

This will form 20% of the Maximum Marks and will be carried out throughout the semester. It may be done by conducting **Two Tests** (Test I on 40% curriculum) and **Test II** (remaining 40% syllabus). Average of the marks scored by a student in these two tests of the theory paper will make his **CA** score (col. 6).

B. End Semester Assessment (80% of the Maximum Marks):

(For illustration we have considered a paper of 04 credits, 100 marks and need to be modified depending upon credits of an individual paper)

1. **ESA Question paper will consists of 6 questions, each of 20 marks.**
2. **Students are required to solve a total of 4 Questions.**
3. **Question No.1 will be compulsory and shall be based on entire syllabus.**
4. Students need to solve **ANY THREE** of the remaining Five Questions (Q.2 to Q.6) and shall be based on entire syllabus.

Note: **Number of lectures required to cover syllabus of a course depends on the number of credits assigned to a particular course. One credit of theory corresponds to 15 Hours lecturing and for practical course one credit corresponds to 30 Hours. For example, for a course of two credits 30 lectures of one hour duration are assigned, while that for a three credit course 45 lectures.**