CBCS SYLLABUS

FOR

THREE YEARS UNDER-GRADUATE COURSE

in

B. Sc. Mathematics (HONOURS)

(*w.e.f. A.Y. 2022-2023*)

BANKURA UNIVERSITY

BANKURA

WEST BENGAL

PIN 722155

STRUCTURE IN MATHEMATICS (HONOURS)

SEMESTER –I

Course Code	Course Title	Credit	Marks			No. of Hours		
			I.A.	ESE	Total	Lec.	Tu.	Pr.
SH/MTH/ 101/C-1	Calculus, Geometry & Vector Analysis	06	10	40	50	05	01	00
SH/MTH/ 102/C-2	Algebra	06	10	40	50	05	01	00
SH/MTH/ 103/GE-1	Calculus, Geometry & Vector Analysis	06	10	40	50	05	01	00
ACSHP/104/ AECC-1	Environmental Studies	04	10	40	50	03	01	00
Total in Semester - I		**22**	**40**	**160**	**200**	**18**	**04**	**00**

SEMESTER –II

Course Code	Course Title	Credit	Marks			No. of Hours		
			I.A.	ESE	Total	Lec.	Tu.	Pr.
SH/MTH/ 201/C-3	Real Analysis	06	10	40	50	05	01	00
SH/MTH/ 202/C-4	Group Theory-I	06	10	40	50	05	01	00
SH/MTH/ 203/GE-2	Algebra	06	10	40	50	05	01	00
ACSHP/204/ AECC-2	English/Hindi/MIL	02	10	40	50	01	01	00
Total in Semester - II		**20**	**40**	**160**	**200**	**16**	**04**	**00**

SEMESTER –III

Course Code	Course Title	Credit	Marks			No. of Hours		
			I.A.	ESE	Total	Lec.	Tu.	Pr.
SH/MTH/ 301/C-5	Theory of Real Functions	06	10	40	50	05	01	00
SH/MTH/ 302/C-6	Ring Theory & Linear Algebra-I	06	10	40	50	05	01	00
SH/MTH/ 303/C-7	ODE & Multivariate Calculus-I	06	10	40	50	05	01	00
SH/MTH/ 304/GE-3	Real Analysis	06	10	40	50	05	01	00
SH/MTH/ 305/ SEC-1	**Any one of the following** • Mathematical Logic • Programming Using C	04	10	40	50	03	01	00
Total in Semester - III		**28**	**50**	**200**	**250**	**23**	**05**	**00**

SEMESTER –IV

Course Code	Course Title	Credit	Marks			No. of Hours		
			I.A.	ESE	Total	Lec.	Tu.	Pr.
SH/MTH/ 401/C-8	Riemann Integration and Series of Functions	06	10	40	50	05	01	00
SH/MTH/ 402/C-9	PDE & Multivariate Calculus-II	06	10	40	50	05	01	00
SH/MTH/ 403/C-10	Mechanics	06	10	40	50	05	01	00
SH/MTH/ 04/GE-4	ODE & Multivariate Calculus-I	06	10	40	50	05	01	00
SH/MTH/ 405/ SEC-2	**Any one of the following** • Graph Theory • Operating System: Linux	04	10	40	50	03	01	00
	• Programming Using C-Practical	04	10	40	50	01	01	04
Total in Semester - IV		**28**	**50**	**200**	**250**	**23**	**05**	**04**

SEMESTER –V

Course Code	Course Title	Credit	Marks			No. of Hours		
			I.A.	ESE	Total	Lec.	Tu.	Pr.
SH/MTH/ 501/C-11	Numerical Analysis	06	10	40	50	03	01	04
SH/MTH/ 502/C-12	Group Theory-II & Linear Algebra-II	06	10	40	50	05	01	00
SH/MTH/ 503/DSE-1	**Any one of the following** • Linear Programming • Mathematical Modeling • Integral Transforms and Fourier Analysis	06	10	40	50	05	01	00
SH/MTH/ 504/DSE-2	**Any one of the following** • Tensors and Differential Geometry • Advanced Mechanics	06	10	40	50	05	01	00
Total in Semester - V		**24**	**40**	**160**	**200**	**18**	**04**	**04**

SEMESTER –VI

Course Code	Course Title	Credit	Marks			No. of Hours		
			I.A.	ESE	Total	Lec.	Tu.	Pr.
SH/MTH/ 601/C-13	Metric Space and Complex Analysis	06	10	40	50	05	01	00
SH/MTH/ 602/C-14	Probability and Statistics	06	10	40	50	05	01	00
SH/MTH/ 603/DSE-3	**Any one of the following** • Advanced Algebra • Discrete Mathematics • Point Set Topology	06	10	40	50	05	01	00
SH/MTH/ 604/DSE-4	**Any one of the following** • Special Theory of Relativity • Number Theory • Dissertation on any topic of Mathematics	06	10	40	50	05	01	00
Total in Semester - VI		**24**	**40**	**160**	**200**	**20**	**04**	**00**

SH = Science Honours , MTH=Mathematics, ACSHP = Arts Commerce Science Honours Pass,C = Core Course, AECC = Ability Enhancement Compulsory Course, SEC= Skill Enhancement Course, GE = Generic Elective, DSE = Discipline Specific Elective, IA = Internal Assessment, ESE = End-Semester Examination, Lec. = Lecture, Tu.= Tutorial, and Prc.= Practical.

Undergraduate Syllabus of Mathematics (Honours)

w.e.f. A.Y. 2022-2023

Bankura University

Bankura
West Bengal
PIN 722155

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1. Introduction

The syllabus for Mathematics at undergraduate level using the Choice Based Credit system has been framed in compliance with model syllabus given by UGC.

The main objective of framing this new syllabus is to give the students a holistic understanding of the subject giving substantial weightage to both the core content and techniques used in Mathematics. Keeping in mind and in tune with the changing nature of the subject, adequate emphasis has been given on new techniques of mapping and understanding of the subject.

Mathematics is the study of quantity, structure, space and change. It has very broad scope in science, engineering and social sciences.

The syllabus has also been framed in such a way that the basic skills of subject are taught to the students, and everyone might not need to go for higher studies and the scope of securing a job after graduation will increase.

It is essential that students in Mathematics (Honours) select the general electives courses from Physics, Chemistry and/or any branch of Life Sciences disciplines.

While the syllabus is incompliance with UGC model curriculum, some changes have been made students to ensure all topics are covered and any of the subjects don't become difficult to be completed in one semester. For example, Core course 1 titled "Calculus, Geometry & Vector Analysis" now also has introductory concepts on Geometry and Differential equations and has been renamed accordingly.

Similarly, Discipline Specific Electives have been grouped where in student can choose 1 elective from a pool of courses. This has been done to help students learn a cross the semesters in their inter semesters.

Dissertation on any topic of Mathematics have been introduced instead of the 4th Elective with a credit of 6 splits into 2 + 4, where 2 credits will be for continuous evaluation and 4 credits reserved for the merit of the dissertation.

The syllabus of Generic Elective (GE), GE-1, GE-2, GE-3, GE-4 courses are same as of the syllabus of the core courses, C-1, C-2, C-3, C-7, respectively.

Evaluation process of each course is carried out through Internal Assessment (IA) and End Semester Examination (ESE). Out of full marks 50 of a course, 10 marks is allotted for Internal Assessment and 40 marks is allotted for End Semester Examination. Question paper of each course for End Semester Examination contains three units: Unit I - 05 questions to be answered out of 08 questions carrying 02 marks of each; Unit II - 04 questions to be answered out of 06 questions carrying 05 marks of each and Unit III- 01 question to be answered out of 02 questions carrying 10 marks. Otherwise, the marks distribution of the particular course should be clearly mentioned.

The Bachelor's Degree in B.A./B.Sc. Mathematics (Hons) is awarded to the students on the basis of knowledge, understanding, skills, attitudes, values and academic achievements sought to be acquired by learners at the end of these programmes. Hence, the course objectives and course specific outcomes of mathematics for these courses are aimed at facilitating the learners to acquire these attributes, keeping in view of their preferences and aspirations for knowledge of mathematics.

The course objectives and course specific outcomes of each course are designed so that these may help learners to understand the main objectives of studying the course. This will enable learners to select elective papers depending on the individual inclinations and contemporary requirements. These syllabi in Mathematics under CBCS are recommended keeping in view of the wide applications of Mathematics in science, engineering, social science, business and a host of other areas. The study of the syllabi will enable the students to be equipped with the state of the art of the subject and will empower them to get jobs in technological and engineering fields as well as in business, education and healthcare sectors.
The textbooks mentioned in references are denotative/demonstrative. The divisions of each paper in units are specified to the context mentioned in courses. These units will help the learners to complete the study of concerned course in certain periods and prepare them for examinations.

Hence, the programme has been chalked out in such manner that there is scope of flexibility and innovation in modifications of prescribed syllabi, teaching-learning methodology, assessment technique of students and knowledge levels, learning outcomes of courses, inclusion of new elective courses subject to availability of experts across the country.

Programme Objectives (POs):

PO1: Mathematical Reasoning: Applications of the mathematical knowledge to the solutions of more complex problems in academic and in real life.

PO2: Analyzing Ability: Identification, formulation and solution of a problem which leads to conclusion using basic principles.

PO3: Developing Confidence: Analyzing more complicated problems and getting solutions helps to build up confidence.

PO4: Design/development of more accuracy: Design and development of methods/ procedures for solutions of problems which meet the specific queries in industry as well as real life.

PO5: Ability of investigations for more complex problems: Use of research-based knowledge and research methods to handle more complex problems.

PO6: Applications of theory-based knowledge: Ability to apply the theoretical knowledge including theory, experiment and computational data; analysis and interpretation of data, to get the definite conclusions.

PO7: Ability of Modern tool usage: Application of appropriate techniques, resources, updated software and modern mathematical tools to solve mathematical activities with a good understanding of their limitations.

PO8: Team work practice: Collective efforts for functioning effectively as a member or leader in diverse teams, and/or in multidisciplinary settings.

PO9: Communication skill: Effective Communication skill for scientific activities helps to establish a good researcher with popular face in the scientific community.

PO10: Ability of presentation: Writing the effective reports and design document to give and receive clear instructions/limitations/restrictions for good presentations.

PO11: Life-long learning process: Recognize the needs, proper learning and ability to engage in life-long learning in the broadest context of scientific & technological changes.

PO12: Students undergoing this programme learn to logically question assertions, to recognise patterns and to distinguish between essential and irrelevant aspects of problems. They also share ideas and insights while seeking and benefitting from knowledge and insight of others. This helps them to behave responsibly in a rapidly changing interdependent society.

Programme Specific Outcomes (PSOs):

The Department of Mathematics offers exciting opportunities to talented students holding a Bachelor's degree for acquiring a rigorous and modern education in mathematics and for pursuing master's degree in both pure and applied mathematics as well as higher studies based on Mathematics. As a part of this Programme, the student has to complete 148 credits of courses including a "Dissertation ", whose major part is kind of academic research (and does not involve classroom teaching), in a chosen area of mathematics. This Program will introduce the classical topics of mathematics, which helps in acquiring thinking skills to undertake cutting-edge research in a higher education programme.

Career Opportunities:

This program will enable the students to take part and qualify for the state and national level examinations such as JAM, NBHM, etc. After completion of this programme, the students are well prepared for higher studies such as M. Sc. and Integrated Ph.D. program in Mathematics. This programme will also help students to enhance their employability for government jobs, jobs in banking, insurance and investment sectors, data analyst jobs and jobs in various other public and private enterprises. Completion of this programme will also enable the learners to join teaching profession in primary and secondary schools. The skills and knowledge gained has intrinsic beauty, which also leads to proficiency in analytical reasoning which also helps them to become more professional.

2. Scheme for CBCS Curriculum for B.A./B.Sc. (Hons.) Mathematics

2.1 Credit Distribution

Course Type	Total Papers	Credits	
		Theory + Practical	Theory*
Core Courses	14	14*4=56 14*2=28	14*5=70 14*1=14
Discipline Specific Electives	4	4*4=16 4*2=8	4*5=20 4*1=4
Generic Electives/Interdisciplinary	4	4*4=16 4*2=8	4*5=20 4*1=4
Ability Enhancement Papers	2	2*4=8	2*4=8
Skill Enhancement Papers	2	2*4=8	2*4=8
Totals	26	148	148

*Tutorials of 1Credit will be conducted in case there is no practical component

2.2 Scheme for CBCS Curriculum for Mathematics (Hons)

Semester	Course Name	Course Detail	Credits
I	Ability Enhancement Compulsory Course–I	Environmental Science	4
	Core course-I	Calculus, Geometry and Vector Analysis	6
	Core course–I Practical	-	-
	Core course–II	Algebra	6
	Core course–II Practical	-	-
	Generic Elective–1	TBD (Course from other discipline)	6
	Generic Elective–1 Practical	-	-
II	Ability Enhancement Compulsory Course–II	English Communication	2
	Core course–III	Real Analysis	6
	Core course– III Practical	-	-
	Core course– IV	Group Theory-I	6
	Core course–IV Practical	-	-
	Generic Elective–2	TBD (Course from other discipline)	6
	Generic Elective–2Practical	-	-
III	Core course–V	Theory of Real Functions	6
	Core course–V Practical	-	-
	Core course–VI	Ring Theory & Linear Algebra-I	6
	Core course–VI Practical	-	-
	Core course–VII	ODE & Multivariate Calculus -I	6
	Core course–VII Practical	-	-
	Skill Enhancement Course–1	As per Section 2.4	4

	Generic Elective–3	TBD (Course from other discipline)	6
	Generic Elective–3 Practical	-	-
IV	Core course–VIII	Riemann Integration and Series of Functions	6
	Core course–VIII Practical	-	-
	Core course–IX	PDE & Multivariate Calculus-II	6
	Core course–IX Practical	-	-
	Core course –X	Mechanics	6
	Core course–X Practical	-	-
	Skill Enhancement Course-2	As per Section 2.4	4
	Generic Elective–4	TBD (Course from other discipline)	6
	Generic Elective–4 Practical	-	-
V	Core course– XI	Numerical Analysis	4
	Core course–XI Practical	Numerical Analysis Lab	2
	Core course–XII	Group Theory-II & Linear Algebra-II	6
	Core course–XII Practical	-	-
	Discipline Specific Elective–1	As per Section 2.3	6
	¤ Discipline Specific Elective– 1 Practical	-	-
	Discipline Specific Elective–2	As per Section 2.3	6
	Discipline Specific Elective– 2 Practical	-	-
VI	Core course–XIII	Metric Spaces and Complex Analysis	6
	Core course–XIII Practical	-	-
	Core course–XIV	Probability and Statistics	6
	Core course–XIV Practical	-	-
	Discipline Specific Elective–3	As per Section 2.3	6

	Discipline Specific Elective– 3 Practical	-	-
	Discipline Specific Elective–4	As per Section 2.3	6
	DisciplineSpe cific Elective– 4 Practical	-	-

TBD= To be decided (by the concerned department)

2.3 Choices for Discipline Specific Electives

(One course to be chosen from each of Discipline Specific Elective-1, 2, 3, 4)

Discipline SpecificElective–1	DisciplineSpecificElective–2	DisciplineSpecificElective–3	DisciplineSpecificElective–4
Linear Programming	Tensors and Differential Geometry	Advanced Algebra	Special Theory of Relativity
Mathematical Modelling	Advanced Mechanics	Discrete Mathematics	Number Theory
Integral Transforms and Fourier Analysis		Point Set Topology	Dissertation on Any Topic of Mathematics

- Optional Dissertation or project working place of one Discipline Specific Elective Paper (6 credits) in 6^{th} Semester

2.4 Choices for Skill Enhancement Courses

(One course to be chosen from each of Skill Enhancement Courses -1, 2)

Skill Enhancement Course-1	Skill Enhancement Course-2
Mathematical Logic	Graph Theory
Programming Using C	Operating System: Linux
	Programming Using C -Practical

2. Syllabus: B.A./B.Sc. in Mathematics (Hons)

Core Subjects Syllabus: B.A./B.Sc. in Mathematics (Hons)

2.1 Core T1–Calculus, Geometry & Vector Analysis

Calculus, Geometry & Vector Analysis	
	6 Credits
Course Objectives: The main objective of this course is to give a deep insight of the differentiations and its applications, and techniques of sketching for curves in cartesian and polar coordinate systems. This course also gives the outstanding knowledge of two and three dimensional coordinate-geometry and also the concept vector calculus.	
Course Specific Outcomes: After completion of this course a student would have • a vast knowledge of Calculus, which they can use for their further study. • a clear idea of characterizations of two dimensional as well as three dimensional coordinate geometry. • a clear concept of vector analysis and its applications.	
Unit 1	
Higher order derivatives, Leibnitz rule and its applications to problems of type $e^{ax}+b\sin x$, $e^{ax}+b\cos x$, $(ax+b)^n\sin x$, $(ax+b)^n\cos x$, Arc length, Derivative of arc length (Cartesian and Polar), Pedal equation, Curvature, Radius of curvature, Centre of curvature, concavity, convexity and inflection points, envelopes, asymptotes (Cartesian), Singular points, Classification of double points, curve tracing in Cartesian and polar coordinate systems, Indeterminate forms: L'Hospital's rule.	
Unit 2	
Reduction formulae, derivations and illustrations of reduction formulae of the type $\int sinnx\,dx$, $\int cosnx\,dx$, $\int tannx\,dx$, $\int secnx\,dx$, $\int (logx)^n\,dx$, $\int \sin nx \sin mx\,dx$, Area under Cartesian and Polar curves, parametric equations, parameterizing of a curve, arc length, arc length of parametric curves, area and volume of surface of revolutions.	
Unit 3	

Reflection properties of conics, Transformation of axes and second degree equations, Invariants, classification of conics using the discriminant, Pair of straight lines, polar equations of straight lines, circles and conics.

Spheres, Cone, Cylindrical surfaces. Central conicoids, paraboloids, plane sections of conicoids, Tangent, Normal, Enveloping Cone and Cylinder, Generating lines, classification of quadrics, Transformation of axes in space and general equation of second degree.

Unit 4

Product of three or more vectors, Applications in Geometry, introduction to vector functions of one independent variable, operations with vector-valued functions of one independent variable, limits and continuity of vector functions, differentiation and integration of vector functions of one independent variable.

Graphical Demonstration (Teaching Aid)

1. Plotting of graphs of function $e^{ax} + b$, $log(ax + b)$, $1/(ax + b)$, $sin(ax + b)$, $cos(ax + b)$, $|ax + b|$ and to illustrate the effect of a and b on the graph.
2. Plotting the graphs of polynomial of degree 4 and 5, the derivative graph, the second derivative graph and comparing them.
3. Sketching of parametric curves (e.g., Trochoid, cycloid, epicycloids, hypocycloid).
4. Obtaining surface of revolution of curves.
5. Tracing of conics in Cartesian coordinates/polar coordinates system.
6. Sketching of ellipsoid, hyperboloid of one and two sheets, elliptic cone, elliptic, paraboloid, and hyperbolic paraboloid using Cartesian coordinates.

Reference Books

- G.B. Thomas and R. L. Finney, Calculus, 9th Ed., Pearson Education, Delhi, 2005.
- M.J. Strauss, G.L. Bradley and K.J. Smith, Calculus, 3rd Ed., Dorling Kindersley (India) P. Ltd. (Pearson Education), Delhi, 2007.
- H. Anton, I. Bivens and S. Davis, Calculus, 7th Ed., John Wiley and Sons (Asia) P. Ltd., Singapore, 2002.
- R. Courant and F. John, Introduction to Calculus and Analysis (Volumes I & II), Springer-Verlag, New York, Inc., 1989.
- T.G. Vyvyan, Elementary Analytic Geometry, Deighton, Bell and Company, 1867.
- E.H. Askwith, The Analytical Geometry of the Conic Sections, Adam and Charles Black, London, 1908.
- B.K. Kar, Advanced Analytic Geometry and Vector Analysis, Books & Allied Pvt. Ltd., Kolkata, 2000.
- S. Karmakar, S. Karmakar, Analytical Geometry: Two Dimensions, CRC Press (Taylor and Francis Group)/ Levant Books (India), London, 2022.
- R.M. Khan, Analytical Geometry of Two and Three Dimensions and Vector Analysis, New Central Book Agency, 2010.

- T. Apostol, Calculus, Volumes I and II. 2nd Ed., John Wiley & Sons, Inc, 1991.
- R.R. Goldberg, Methods of Real Analysis, Oxford & Ibh Publishing, 2020.
- K.C. Ghosh and R.K. Maity, An Introduction to Analysis: Differential Calculus (Part I), New Central Book Agency (P) Ltd., 2011.
- K.C. Ghosh and R.K. Maity, An Introduction to Analysis: Integral Calculus, New Central Book Agency (P) Ltd., 2013.
- S. Narayan and M.D. Raisinghania, Elements of Real Analysis, S. Chand and Co. Ltd., 2003
- J.E. Marsden, and A. Tromba, Vector Calculus, 6th Ed., McGraw Hill, 2011.
- K.C. Maity and R.K. Ghosh, Vector Analysis, New Central Book Agency (P) Ltd. Kolkata (India), 2011.
- M.R. Speigel, Schaum's Outline of Vector Analysis, 2nd Ed. McGraw Hill, 2011.

2.2 Core T2-Algebra

Algebra	
	6 Credits

Course Objectives:
The main objective of this course is to give a deep insight of the roots of real and complex polynomials and learn various methods of obtaining roots. Employ De Moivre's theorem in a number of applications and able to knowledge to solve the system of linear equations.

Course Specific Outcomes:
After completion of this course a student would recognize the idea of consistent and inconsistent systems of linear equations by the row echelon form of the augmented matrix, using rank. Also, they would be able to find out the eigenvalues and corresponding eigenvectors for a square matrix.

Unit 1

Polar representation of complex numbers, nth roots of unity, De Moivre's theorem for rational indices and its applications.

Theory of equations: Relation between roots and coefficients, Transformation of equation, Location of roots: Descartes rule of signs, Sturm's theorem, Cubic and biquadratic equation, Cardon's, Ferrai's and Euler's method.

Inequality: The inequality involving AM≥GM≥HM, Cauchy-Schwartz inequality.

Unit 2

Equivalence relations, partial order relation, poset, linear order relation. Well-ordering property of positive integers, Division algorithm, Divisibility and Euclidean algorithm. Prime numbers and their properties, Euclid's theorem. Congruence relation between integers. Principles of Mathematical Induction, statement of Fundamental Theorem of Arithmetic.

Unit 3

Systems of linear equations, row reduction and echelon forms, vector equations, the matrix equation Ax=b, solution sets of linear systems, applications of linear systems, linear independence.

Unit 4

Introduction to linear transformations, matrix of a linear transformation, inverse of a matrix, characterizations of invertible matrices. Subspace of $\mathbb{R}^n$, dimension of subspaces of $\mathbb{R}^n$, Geometric significance of subspaces. Rank of a matrix, Eigen values, Eigen Vectors and Characteristic Equation of a matrix. Cayley-Hamilton theorem and its use in finding the inverse of a matrix.

Reference Books

- T. Andreescu and D. Andrica, Complex Numbers from A to Z, Birkhauser, 2006.
- E.G. Goodaire and M.M. Parmenter, Discrete Mathematics with Graph Theory, 3rd Ed., Pearson Education (Singapore) P. Ltd., Indian Reprint, 2005.
- D.C. Lay, Linear Algebra and its Applications, 3rd Ed., Pearson Education Asia, Indian Reprint, 2007.
- K.B. Dutta, Matrix and Linear Algebra. Prentice Hall India Pvt., Ltd., 2004.
- K. Hoffman and R. Kunze, Linear Algebra. 2nd Ed., Prentice Hall India Pvt., Ltd., 2015
- W.S. Burnstine and A.W. Panton, Theory of Equations. 7th Ed. Hodges, Figgis and Company, 1924

2.3 Core T3–Real Analysis

Real Analysis

	6 Credits

Course Objectives: This course will enable the students to
i) understand many properties of the real line ℝ and learn to define sequences in terms of functions from ℕ to a subset of ℝ.
ii) recognize bounded, convergent, divergent, Cauchy and monotonic sequences and to calculate their limit superior, limit inferior, and the limit of a bounded sequence.
iii) recognize the series, properties of series and different test for convergence of series.

Course Specific Outcomes: The student acquires deep **l**earning of real analysis starting with ε-δ concepts and acquires the knowledge of series and sequences which are very much important for basic starting of this course.

Unit 1

Review of Algebraic and Order Properties of ℝ, Intervals, ε-neighbourhood of a point in ℝ, Idea of countable sets, uncountable sets and uncountability of ℝ. Bounded above sets, Bounded below sets, Bounded Sets, Unbounded sets, Suprema and Infima, Completeness Property of ℝ and its equivalent properties, The Archimedean Property, Density of Rational (and Irrational) numbers in ℝ.

Limit points of a set, Isolated points, Interior points, Open set, closed set, the union and intersection of open and closed sets, derived set, Dense sets with examples, Illustrations of Bolzano-Weierstrass theorem for sets, compact sets in ℝ, Heine-Borel Theorem.

Unit 2

Sequences, Bounded sequence, Convergent sequence, Limit of a sequence, uniqueness of limit, Limit Theorems. Sandwich rule. Nested interval theorem, Monotone Sequences, Monotone Convergence Theorem. Subsequences, lim inf, lim sup, A bounded sequence $\{x_n\}$ is convergent if and only if lim sup x_n= lim inf x_n. Divergence Criteria. Monotone Subsequence Theorem (statement only), Bolzano Weierstrass Theorem for Sequences. Cauchy sequence, Cauchy's Convergence Criterion. Cauchy's first and second limit theorems with applications.

Unit 3

Infinite series, convergence and divergence of infinite series, Cauchy's Criterion, Series of positive terms, Tests for convergence: Comparison test, Limit Comparison test, Ratio Test, Cauchy's nth root test, Raabe's test, Logarithmic Test, Gauss test (statements only), Alternating series, Leibniz test. Absolute and Conditional convergence, Riemann's rearrangement theorem (Statement only).

Graphical Demonstration (Teaching Aid)

1. Plotting of recursive sequences.
2. Study the convergence of sequences through plotting.
3. Verify Bolzano-Weierstrass theorem through plotting of sequences and hence identify convergent subsequences from the plot.
4. Study the convergence/divergence of infinite series by plotting their sequences of partial sum.
5. Cauchy's root test by plotting nth roots.
6. Ratio test by plotting the ratio of nth and (n+1)th term.

Reference Books

- R.G. Bartle and D.R. Sherbert, Introduction to Real Analysis, 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.
- G.G. Bilodeau, P.R. Thie and G.E. Keough, An Introduction to Analysis, 2nd Ed., Jones & Bartlett, 2010.
- B.S. Thomson, A.M. Bruckner and J.B. Bruckner, Elementary Real Analysis, Prentice Hall, 2001.
- S. K. Berberian, A First Course in Real Analysis, Springer Verlag, NewYork,1994.
- T.M. Apostol, Mathematical Analysis, 2nd Ed. Narosa Publishing House, 2002.
- R. Courant and F. John, Introduction to Calculus and Analysis, Vol I, Springer Berlin, Heidelberg, 1965.
- W. Rudin, Principles of Mathematical Analysis, Tata McGraw-Hill, 1976.
- T. Tao, Analysis I, Hindustan Book Agency, 2006.
- R.R. Goldberg, Methods of Real Analysis, Oxford & Ibh Publishing, 2020.
- K.C. Ghosh and R.K. Maity, An Introduction to Analysis: Differential Calculus (Part I), New Central Book Agency (P) Ltd., 2011.
- S. Narayan and M.D. Raisinghania, Elements of Real Analysis, S. Chand & Co. Ltd., 2003.

2.4 Core T4–Group Theory-I

Group Theory-I	
	6 Credits

Course Objectives: The main objective of this course is to develop the concept of group with its various properties along with its geometrical significance.

Course Specific Outcomes: The student acquires the knowledge of basics of group theory. This course not only put light on Lagrange's theorem but also gives the clear concept about structure preserving maps between groups and their consequences.

Unit 1

Symmetries of a square, definition of group, examples of groups including permutation groups, Dihedral groups and Quaternion groups (through matrices), elementary properties of groups, examples of commutative and non-commutative groups. order of an element, order of a group. Subgroups and examples of subgroups, necessary and sufficient condition for a nonempty subset of a group to be a subgroup. Normalizer, centralizer, center of a group, product of two subgroups.

Unit 2

Properties of cyclic groups, classification of subgroups of cyclic groups. Cycle notation for permutations, properties of permutations, even and odd permutations, alternating group, properties of cosets, Lagrange's theorem and consequences including Fermat's Little theorem.

Unit 3

External direct product of a finite number of groups, normal subgroups, factor groups, Cauchy's theorem for finite abelian groups.

Unit 4

Group homomorphisms, properties of homomorphisms, correspondence theorem and one-one correspondence between the set of all normal subgroups of a group and the set of all congruences on that group, Cayley's theorem, properties of isomorphisms. First, Second and Third isomorphism theorems.

Reference Books

- J.B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.
- M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.
- D.S. Dummit and R.M. Foote, Abstract Algebra, 3rd Ed., Wiley, 2003.
- J.A. Gallian, Contemporary Abstract Algebra, 4th Ed., 1999.
- J.J. Rotman, An Introduction to the Theory of Groups, 4th Ed., 1995.
- I.N. Herstein, Topics in Algebra, Wiley Eastern Limited, India,1975.
- D.S. Malik, J.M. Mordeson and M.K. Sen, Fundamentals of Abstract Algebra, McGraw-Hill College, 1996.

2.5 Core T5–Theory of Real Functions

Theory of Real Functions

	6 Credits

Course Objectives: The course will enable the students to
i) recognize the fundamental concept of limit and continuity of a function in ε - δ approach.
ii) acquire the knowledge of expansion of function, different types of mean value theorem.
iii) to employ the techniques of finding the extremum value of a function.

Course Specific Outcomes: The student acquires the knowledge of analyzing consequences of function's criterion. This course also gives the idea about 0/0 form and corresponding calculations of limits.

Unit 1

Limits of functions (ε - δ approach), algebra of limits of functions, sequential criterion for limits, divergence criteria. Limit theorems, one sided limits. Infinite limits and limits at infinity. Continuous functions, sequential criterion for continuity and discontinuity. Algebra of continuous functions. Continuous functions on an interval, intermediate value theorem, location of roots theorem, preservation of intervals theorem. Uniform continuity, non-uniform continuity criteria, uniform continuity theorem.

Discontinuity of functions, different types of discontinuity, step functions, piecewise discontinuity, monotone functions, Theorems: a monotone function have only jump discontinuity and at most countably many points of discontinuity.

Neighbourhood properties of continuous functions on boundedness and maintenance of sign, continuous function on a bounded closed interval attains its bound.

Unit 2

Differentiability of a function at a point and in an interval, Caratheodory's theorem, algebra of differentiable functions. Meaning of sign of derivatives, Chain rule, Lipschitz condition and associate result on derivative, Relative extrema, interior extremum theorem. Rolle's theorem. Mean value theorems: Lagrange's, Cauchy's, intermediate value property of derivatives, Darboux's theorem, Applications of mean value theorems to inequalities and approximation of polynomials.

Unit 3

Taylor's theorem with Lagrange's form of remainder, Taylor's theorem with Cauchy's form of remainder, concept of convex functions with examples, application of Taylor's theorem to convex functions, relative extrema. Taylor's series and Maclaurin's series expansions of exponential and trigonometric functions, ln(1 + x), 1/ax+b and $(1+x)^n$ with their range of validity, Applications of Taylor's theorem to inequalities.

Statement of L'Hospital's rule, and its associated results, point of local extremum of a function on an interval (ensure to include the concepts of interval in calculus part of T-1: Calculus, geometry and Vector calculus), Sufficient condition for the existence of a local extremum of a function (statement only), determination of local extremum using first order derivative, applications of the principle of maximum/minimum.

Reference Books

- R. Bartle and D. R. Sherbert, Introduction to Real Analysis, John Wiley and Sons,2003.
- K.A. Ross, Elementary Analysis: The Theory of Calculus, Springer, 2004.
- A. Mattuck, Introduction to Analysis, Prentice Hall,1999.
- S.R. Ghorpade and B.V. Limaye, A Course in Calculus and Real Analysis, Springer, 2006.
- T.M. Apostol, Mathematical Analysis, Narosa Publishing House, 2002.
- R. Courant and F. John, Introduction to Calculus and Analysis, Vol II, Springer, 2004.
- W. Rudin, Principles of Mathematical Analysis, Tata McGraw-Hill, 1976.
- T. Tao, Analysis II, Hindustan Book Agency, 2006.
- K.C. Ghosh and R.K. Maity, An Introduction to Analysis: Differential Calculus (Part I), New Central Book Agency (P) Ltd., 2011.

2.6 Core T6–Ring Theory and Linear Algebra-I

Ring Theory and Linear Algebra-I	
	6 Credits
Course Objectives: The course will enable the students to i) have the fundamental concept of Ring, ideals and their various properties. Field and its consequences. ii) employ the concept of basis of a vector space. (iii) acquire the knowledge of IPS and properties of operators on an IPS.	
Course Specific Outcomes: The student acquires the knowledge of i) basics of ring theory, notions of its ideals and homomorphisms. ii) properties of vector spaces and linear transformations. iii) inner product spaces and orthonormal sets, and how one can transform a set to an orthonormal set.	
Unit 1	
Definition and examples of rings, properties of rings, subrings, polynomial rings, integral domains and fields, subfield, necessary and sufficient condition for a nonempty subset of a field to be a subfield, characteristic of a ring. Ideal, ideal generated by a subset of a ring, factor rings, operations on ideals, prime and maximal ideals.	
Unit2	
Ring homomorphisms, properties of ring homomorphisms. Isomorphism theorems I, II and III, Correspondence theorem, congruence on rings, one-one correspondence between the set of ideals and the set of all congruences on a ring.	
Unit 3	
Vector spaces, subspaces, algebra of subspaces, quotient spaces, linear combination of vectors, linear span, linear independence, basis and dimension, dimension of subspaces.	
Unit 4	
Linear transformations, null space, range, rank and nullity of a linear transformation, matrix representation of a linear transformation, change of coordinate matrix. Algebra of linear transformations. Isomorphisms. Isomorphism theorems, invertibility and isomorphisms. Inner product spaces, matrix of an inner product, Cauchy-Schwarz inequality. orthogonal/orthonormal set, Orthonormal basis, Gram-Schmidt orthogonalisation process. Matrix of a linear operator on finite dimensional inner product spaces with respect to orthogonal (orthonormal) basis, Inner product space isomorphism and related theorems.	

Reference Books

- J.B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.
- M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.
- S.H. Friedberg, A.J. Insel, L.E. Spence, Linear Algebra, 4th Ed., Prentice-Hall of India Pvt. Ltd., New Delhi, 2004.
- J.A. Gallian, Contemporary Abstract Algebra, 4th Ed., Narosa Publishing House, New Delhi, 1999.
- S. Lang, Introduction to Linear Algebra, 2nd Ed., Springer, 2005.
- G. Strang, Linear Algebra and its Applications, Thomson, 2007.
- S. Kumaresan, Linear Algebra- A Geometric Approach, Prentice Hall of India, 1999.

2.7 Core T7–ODE & Multivariate Calculus-I

ODE & Multivariate Calculus-I	
	6 Credits
Course Objectives: The course will enable the students to i) understand the genesis of ordinary differential equations. ii) learn various techniques of getting exact solutions of solvable first order differential equations and linear differential equations of higher order.	
Course Specific Outcomes: This course specifically enables students to i) grasp the concepts of general solutions of a linear differential equation of an arbitrary order and also learn a few methods to obtain the general solution of such equations. ii) formulate mathematical models in the form of ordinary differential equations to suggest possible solutions of the day-to-day problems arising in physical, chemical and biological disciplines.	
Unit 1	
First order differential equations: Exact differential equations and integrating factors, special integrating factors and transformations, linear equations, Bernoulli equations and reducible to linear forms, the existence and uniqueness theorem of Picard (Statement only).	
Unit 2	
First order higher degree equations solvable for *x*, *y* and *p*. Clairaut's equations and singular solution.	
Unit 3	
Linear differential equations of second order, Wronskian: its properties and applications, C.F., P.I. and General solutions, D operator method, Euler equation, method of undetermined coefficients, method of variation of parameters. Special forms.	
Unit 4	
System of linear differential equations, types of linear systems, differential operators, an operator method for linear systems with constant coefficients, Simultaneous equations of form 2, Total differential equations.	
Unit 5	
System of linear differential equations, types of linear systems, differential operators, an operator method for linear systems with constant coefficients.	
Unit 6	
Basic Theory of linear systems in normal form, homogeneous linear systems with constant coefficients: Two Equations in two unknown functions.	

Unit 7

Power series solution of a differential equation about an ordinary point, solution about a regular singular point (up to second order).

Unit 8

Concept of neighbourhood of a point in $\mathbb{R}^n (n > 1)$, interior point, limit point, open set and closed set in $\mathbb{R}^n (n > 1)$.

Unit 9

Functions from $\mathbb{R}^n (n > 1)$ to $\mathbb{R}^m (m \geq 1)$, limit and continuity of real-valued functions of two or more variables. Partial derivatives, total derivative and differentiability, sufficient condition for differentiability. Chain rule for one and two independent parameters, theorems on equality of mixed partial derivatives of two variables, directional derivatives, Homogeneous functions and Euler's theorems. Extrema of functions of two and three variables, method of Lagrange multipliers, constrained optimization problems.

Reference Books

- D.A. Murray, Introductory course in Differential Equations, Andesite Press, 2017.
- H.T. H. Piaggio, Elementary Treaties on Differential Equations and their applications, C.B.S Publisher & Distributors, Delhi, 1985.
- G. F. Simmons, Differential Equations, Tata McGraw Hill, 2017.
- S. L. Ross, Differential Equations, 3rd Ed., John Wiley and Sons, India, 2004.
- K.C. Ghosh and R.K. Maity, An Introduction to Analysis: Differential Calculus (Part II), New Central Book Agency (P) Ltd., 2008.
- K.C. Ghosh and R.K. Maity, An Introduction to Differential Equations, New Central Book Agency (P) Ltd., 2011.
- H.R. Beyer, Calculus and Analysis, Wiley, 2010.

2.8 Core T8– Riemann Integration and Series of Functions

Riemann Integration and Series of Functions	
	6 Credits
Course Objectives: The course will enable the students to i) understand the genesis of Riemann integration and its related topic. ii) learning about the improper integral and its properties. iii) understand the idea of Fourier series expansion of a function.	
Course Specific Outcomes: This course specifically enables the students to i) grasp the concept of integration. ii) knowledge of the radius of convergence for power series.	
Unit 1	
Riemann integration: Partition and refinement of a partition, results related to them, inequalities of upper and lower sums, Darboux integration, Darboux theorem, Riemann conditions of integrability, Riemann sum and definition of Riemann integral through Riemann sums, equivalence of two Definitions. Necessary and sufficient condition for Riemann integrability Integrability of sum, scalar multiple, product, quotient, modulus of Riemann integrable functions. Riemann integrability of monotone and continuous functions, Properties of the Riemann integral; definition and integrability of piecewise continuous and monotone functions. Zero set, Examples of zero sets, Theorem: a bounded function on a closed and bounded interval in Riemann integrable if and only if the set of points of discontinuity is a zero set. Functions defined by $\int_a^x f(t)dt$, its properties, primitive, logarithmic and exponential functions, their properties Intermediate Value theorem for Integrals. Fundamental theorem of Integral Calculus.	
Unit 2	
Improper integrals. Range of integration: finite or infinite, types of improper integration, Necessary and sufficient condition for convergence of improper integral for both cases, Test of convergence: comparison test, M-test, absolute and non-absolute convergence and inter-relations, Statement of Abel's and Dirichlet's test on the integral of product. Convergence of Beta and Gamma functions. Their properties and inter-relation $[\Gamma(n)\Gamma(1-n) = \frac{\pi}{sin n\pi}$, Evalution: $\int_0^{\frac{\pi}{2}} sin^n x dx$, $\int_0^{\frac{\pi}{2}} cos^n x dx$, $\int_0^{\frac{\pi}{2}} tan^n x dx$ by Beta and Gamma functions.	
Unit 3	

Pointwise and uniform convergence of sequence of functions. Theorems on continuity, derivability and integrability of the limit function of a sequence of functions. Series of functions.

Theorems on the continuity and derivability of the sum function of a series of functions; Cauchy criterion for uniform convergence and Weierstrass M-Test.

Unit 4

Fourier series: Definition of Fourier coefficients and series, Reimann Lebesgue lemma, Bessel's inequality, Parseval's identity, Dirichlet's condition.

Examples of Fourier expansions and summation results for series.

Unit 5

Power series, radius of convergence, Cauchy Hadamard Theorem.

Differentiation and integration of power series; Abel’s Theorem; Weierstrass Approximation Theorem.

Reference Books

- K.A. Ross, Elementary Analysis, The Theory of Calculus, Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.
- R.G. Bartle D.R. Sherbert, Introduction to Real Analysis, 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.
- C.G. Denlinger, Elements of Real Analysis, Jones & Bartlett (Student Edition), 2011.
- S. Narayan, Integral Calculus, S. Chand, 2005.
- T.M. Apostol, Calculus I, II., Wiley, 1975.
- K.C. Ghosh and R.K. Maity, An Introduction to Analysis: Integral Calculus, New Central Book Agency (P) Ltd., 2013.

2.9 Core T9–PDE & Multivariate Calculus-II

PDE & Multivariate Calculus-II	
	6 Credits

Course Objectives: The course will enable the students to:
i) apply a range of techniques to solve first & second order partial differential equations.
ii) model physical phenomena using partial differential equations such as the heat and wave equations.

Course Specific Outcomes: This course specifically enables the students to

i) learn conceptual variations while advancing from one variable to several variables in calculus.

ii) inter-relationship amongst the line integral, double and triple integral formulations.

iii) realize importance of Green, Gauss and Stokes' theorems in other branches of mathematics.

Unit 1

Partial differential equations of the first order, Lagrange's solution, nonlinear first order partial differential equations, Charpit's general method of solution, some special types of equations which can be solved easily by methods other than the general method.

Unit 2

Derivation of heat equation, wave equation and Laplace equation. Classification of second order linear equations as hyperbolic, parabolic or elliptic, Reduction of second order linear equations to canonical forms.

Unit3

The Cauchy problem, Cauchy problem of finite and infinite string. Initial boundary value problems, De Alembert's solutions. Method of separation of variables, solving the vibrating string problem, Solving the heat conduction problem.

Unit4

Multiple integral: Concept of upper sum, lower sum, upper integral, lower-integral and double integral (no rigorous treatment is needed). Statement of existence theorem for continuous functions. Iterated or repeated integral, change of order of integration, Triple integral, Cylindrical and spherical coordinates, Change of variables in double integrals and triple integrals, Transformation of double and triple integrals (problems only), Determination of volume and surface area by multiple integrals (problems only), Differentiation under the integral sign, Leibniz's rule (problems only).

Unit5

Definition of vector field, the gradient, maximal and normal property of the gradient, tangent planes, divergence and curl, Line integrals, applications of line integrals: mass and work, Fundamental theorem for line integrals, conservative vector fields, independence of path.

Unit 6

Green's theorem, surface integrals, integrals over parametrically defined surfaces, Stoke's theorem, The Divergence theorem.

Reference Books

- G.B. Thomas and R.L. Finney, Calculus, 9th Ed., Pearson Education, Delhi, 2005.
- M.J. Strauss, G.L. Bradley and K. J. Smith, Calculus, 3rd Ed., Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2007.
- E. Marsden, A.J. Tromba and A. Weinstein, Basic Multivariable Calculus, Springer (SIE), 2005.
- J. Stewart, Multivariable Calculus, Concepts and Contexts, 2nd Ed., Brooks /Cole, Thomson Learning, USA, 2001
- T.M. Apostol, Mathematical Analysis, 2nd Ed., Narosa Publishing House, 2002
- R. Courant and F. John, Introduction to Calculus and Analysis, Vol II, Springer, 2004.
- W. Rudin, Principles of Mathematical Analysis, 3rd Ed., Tata McGraw-Hill, 2017.
- H.R. Beyer, Calculus and Analysis, Wiley, 2010.
- I. Sneddon, Elements of Partial Differential Equations, McGraw-Hill International Edition, 1957.
- K.C. Ghosh and R.K. Maity, An Introduction to Analysis: Integral Calculus, New Central Book Agency (P) Ltd., 2013.
- M.D. Raisinghania, Ordinary and Partial Differential Equations, S. Chand Higher Academic, 19th Edition, 2017.
- K.S. Rao, Introduction to Partial Differential Equations, PHI, Third Edition, 2015.

2.10 Core T10–Mechanics

Mechanics	
	6 Credits

Course Objectives: The course will enable the students to:
i) familiarize with subject matter, which has been the single centre, to which were drawn mathematicians, physicists, astronomers, and engineers together.
ii) understand necessary conditions for the equilibrium of particles acted upon by various forces and learn the principle of virtual work for a system of coplanar forces acting on a rigid body.
iii) determine the centre of gravity of some materialistic systems and discuss the equilibrium of a uniform cable hanging freely under its own weight.

Course Specific Outcomes: This course specifically enables the students to

i) deal with the kinematics and kinetics of the rectilinear and planar motions of a particle including the constrained oscillatory motions of particles.

ii) learn that a particle moving under a central force describes a plane curve and know the Kepler's laws of the planetary motions, which were deduced by him long before the mathematical theory given by Newton.

Unit 1

Equilibrium of a particle, Equilibrium of a system of particles, Necessary conditions of equilibrium, Moment of a force about a point, Moment of a force about a line, Couples, Moment of a couple, Equipollent system of forces, Work and potential energy, Principle of virtual work for a system of coplanar forces acting on a particle or at different points of a rigid body, Forces which can be omitted in forming the equations of virtual work.

Unit 2

Centres of gravity of plane area including a uniform thin straight rod, triangle, circular arc, semicircular area and quadrant of a circle, Centre of gravity of a plane area bounded by a curve, Centre of gravity of a volume of revolution; Flexible strings, Common catenary,

Intrinsic and Cartesian equations of the common catenary, Approximations of the catenary.

Unit 3

Kinematics and kinetics of the motion, Rectilinear motion under variable accelerations, Simple harmonic motion (SHM) and its geometrical representation, SHM under elastic forces, Motion under inverse square law, Motion in resisting media, Concept of terminal velocity.

Unit 4

Two dimensional motions: expressions for velocity and acceleration in Cartesian, polar and intrinsic coordinates; Motion in a vertical circle, projectiles in a vertical plane and cycloidal motion (Constrained motion).

Unit 5

Equation of motion under a central force, Differential equation of the orbit, (p, r) equation of the orbit, Apses and apsidal distances, Areal velocity, Characteristics of central orbits, Planetary motion, Kepler's laws of planetary motion.

- I.H. Shames and G. Krishna Mohan Rao, Engineering Mechanics: Statics and Dynamics, (4thEd.), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2009.
- R.C. Hibbeler and Ashok Gupta, Engineering Mechanics: Statics and Dynamics,11thEd., Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2009.
- C. F., Textbook of Dynamics, 2nd Ed. CBS, 2002.
- S.L. Loney, An Elementary Treatise on the Dynamics of particle and of Rigid Bodies, 1st Ed. Math Valley, 2018.
- S.L. Loney, Elements of Statics and Dynamics I and II., Aitbs, 2004.
- M.C. Ghosh, Analytical Statics. 11 Ed., SHREEDHAR PRAKASHANI, 2010.
- R.S. Verma, A Text book on Statics, Pothishala,1962.
- M.M. Rahman, Statics, New Central Book Agency, 2014.
- A.S. Ramsey, Dynamics (PartI), Cambridge University Press, 1932.
- P. L. Srivatava, Elementary Dynamics. Ram Narin Lal, Beni Prasad Publishers Allahabad, 1964.
- J. L. Synge & B. A. Griffith, Principles of Mechanics. McGraw-Hill, 1949.
- S. Ramsey, Statics. Cambridge University Press, 2009.
- A. S. Ramsey, Dynamics. Cambridge University Press, 2009.

2.11 Core T11–Numerical Analysis

Numerical Analysis	
	4 Credits

Course Objectives: The course will enable the students to:
i) obtain numerical solutions of algebraic and transcendental equations.
ii) find numerical solutions of system of linear equations and check the accuracy of the solutions.
iii) learn about various interpolating and extrapolating methods.

Course Specific Outcomes: This course specifically enables the students to

i) solve initial and boundary value problems in differential equations using numerical methods.
ii) apply various numerical methods in real life problems.

Unit 1

Error: Significant figures, Round-off error and computer arithmetic, Local and global truncation errors, Algorithms and convergence.
Algebraic and Transcendental equations: Bisection method, False position method, Fixed point iteration method, Newton's method and secant method for solving equations.

Unit 2

System of Linear equations: Partial and scaled partial pivoting, Lower and upper triangular (LU) decomposition of a matrix and its applications, Thomas method for tridiagonal systems; Gauss-Jacobi, Gauss-Seidel and successive over-relaxation (SOR) methods.

Unit 3

Lagrange and Newton interpolations, Piecewise linear interpolation, Cubic spline interpolation, Finite difference operators, Gregory-Newton forward and backward difference interpolations.

Unit 4

First order and higher order approximation for first derivative, Approximation for second derivative; Numerical integration: Trapezoidal rule, Simpson's rules and error analysis, Bulirsch-Stoer extrapolation methods, Richardson extrapolation.

Unit 5

Euler's method, Runge-Kutta methods, Higher order one step method, Multi-step methods;
Finite difference method, Shooting method, Real life examples: Google search engine, one dimension and two dimension simulations, Weather forecasting.

Evaluation: Unit I - 05 questions to be answered out of 08 questions carrying 01 marks of each; Unit II - 02 questions to be answered out of 03 questions carrying 05 marks of each and Unit III- 01 question to be answered out of 02 questions carrying 10 marks.

Reference Books

- B. Bradie, A Friendly Introduction to Numerical Analysis, Pearson Education, India, 2007.
- M.K. Jain, S.R.K. Iyengar and R.K. Jain, Numerical Methods for Scientific and Engineering Computation, 6^{th} Ed., New age International Publisher, India, 2007.
- C.F. Gerald and P.O. Wheatley, Applied Numerical Analysis, Pearson Education, India, 2008.
- U.M. Ascher and C. Greif, A First Course in Numerical Methods, 7^{th} Ed., PHI Learning Private Limited, 2013.
- J.H. Mathews and K.D. Fink, Numerical Methods Using Matlab, 4^{th} Ed., PHI Learning Private Limited, 2012.
- J.B. Scarborough, Numerical Mathematical Analysis, 6^{th} Ed. Oxford and IBH publishing co., 2005.

- K.E. Atkinson, An Introduction to Numerical Analysis, Wiley India Private Limited, 2008.
- F. B. Hildebrand, Introduction to Numerical Analysis, 2nd Ed. Dover Publications, 2013.
- R.J. Schilling & S.L. Harris, Applied Numerical Methods for Engineers Using, MATLAB and C. Thomson-Brooks/Cole, 1999.

2.12 Core T11- Numerical Analysis Lab

Numerical Analysis	
	2 Credits

List of practical (using C programming)

1. Calculate the sum 1/1+1/2+1/3+1/4+ ------------------ +1/N.
2. Enter 100 integers into an array and sort the min an ascending order.
3. Solution of transcendental and algebraic equations by
   a. Bisection method
   b. Newton Raphson method.
   c. Fixed point Iteration method
4. Solution of system of linear equations
   a. Gauss-Seidel method
5. Interpolation
   a. Lagrange Interpolation
6. Numerical Integration
   a. Trapezoidal Rule
   b. Simpson's one third rule
7. Method of finding Eigenvalue by Power method
8. Solution of ordinary differential equations
   a. Euler method
   b. Modified Euler method
   c. Runge-Kutta method

Note: For any of the CAS (Computer aided software) Data types-simple data types, floating data types, character data types, arithmetic operators and operator precedence, variables and constant declarations, expressions, input/output, relational operators, logical operators and logical expressions, control statements and loop statements, Arrays should be introduced to the students.

Evaluation: 01 questions to be answered out of 06 questions carrying 10 marks of each and viva-voce should be held for 05 marks.

2.13 Core T12–Group Theory-II & Linear Algebra II

Group Theory-II & Linear Algebra II	
	6 Credits

Course Objectives: The course will enable the students to
i) recognize the fundamental properties of automorphism on a group.
ii) acquire the knowledge regarding fundamental theory of finitely generated abelian groups.
iii) to employ the canonical form of a linear problem.

Course Specific Outcomes: The student acquires the knowledge of

i) various types of automorphism groups, direct product of groups, properties of group action.

ii) eigenspace towards achieving diagonalization of a operator along with various types of canonical forms.

Unit1

Automorphism, inner automorphism, automorphism groups, automorphism groups of finite and infinite cyclic groups, applications of factor groups to automorphism groups, Characteristic subgroups, Commutator subgroup and its properties.

Unit 2

Properties of external direct products, the group of units modulo n as an external direct product, internal direct products, Fundamental Theorem of finitely generated abelian groups, invariant factors, elementary divisors.

Unit 3

Group action (definition, examples), orbit formulas, Class equation and consequences, conjugacy in S_n, p-groups, Cauchy's theorem.

Unit 4

Dual spaces, dual basis, double dual, transpose of a linear transformation and its matrix in the dual basis, annihilators. Eigen spaces of a linear operator, diagonalizability, invariant subspaces and Cayley-Hamilton theorem, Project on operator and its relation with the eigenvalues of a linear operator, the minimal polynomial for a linear operator, primary decomposition theorem, invariant factors, elementary divisors, working procedure to find possible Rational and Jordan canonical forms of a linear operator.

Unit 5

The adjoint of a linear operator. Normal and self-adjoint operators. Bessel's inequality, Orthogonal complement, Orthogonal projections, Best approximation and its application to Least Squares approximation, minimal solutions to systems of linear equations.

Bilinear and quadratic forms, Diagonalisation of symmetric matrices, Second derivative test for critical point of a function of several variables, Hessian matrix, Sylvester's law of inertia. Index, signature.

Reference Books

- J.B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.
- M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.
- J.A. Gallian, Contemporary Abstract Algebra, 4th Ed., 1999.
- D.S. Dummit and Richard M. Foote, Abstract Algebra, 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2004.
- J. R. Durbin, Modern Algebra, John Wiley & Sons, New York Inc., 2000.
- D.A.R. Wallace, Groups, Rings and Fields, Springer Verlag London Ltd., 1998
- D.S. Malik, John M. Mordeson and M. K. Sen, Fundamentals of Abstract Algebra.
- I.N. Herstein, Topics in Algebra, Wiley Eastern Limited, India, 1975.
- S.H. Friedberg, A.J. Insel, L.E. Spence, Linear Algebra, 4th Ed., Prentice-Hall of India Pvt. Ltd., New Delhi, 2004.
- S. Lang, Introduction to Linear Algebra, 2nd Ed., Springer, 2005.
- G. Strang, Linear Algebra and its Applications, Thomson, 2007.
- S. Kumaresan, Linear Algebra- A Geometric Approach, Prentice Hall of India, 1999.
- K. Hoffman, R.A. Kunze, Linear Algebra, 2nd Ed., Prentice-Hall of India Pvt. Ltd., 1971.

2.14 Core T13–Metric Spaces and Complex Analysis

Metric Spaces and Complex Analysis	
	6 Credits

Course Objectives: The course will enable the students to

i) understand several standard concepts of metric spaces and their properties like openness, closedness, Heine Borel property and compactness.

ii) identify the continuity of a function defined on metric spaces and homeomorphisms.
iii) acquire the complete knowledge of Complex Analysis.

Course Specific Outcomes: The student acquires the knowledge of

i) complete Metric Space and Cantor's intersection theorem.
ii) singularities and contour integration.

Unit1

Metrics paces: Definition and examples. Open and closed balls, neighbourhood, open set, interior of a set. Limit point of a set, closed set, closed set as a complement of an open set, diameter of a set, distance of a set from a point, distance between two sets, subspaces, dense sets, separable spaces.

Sequences in metric spaces, Cauchy sequences. Complete Metric Spaces with examples, Examples of incomplete metric spaces, every convergent sequence is Cauchy and bounded but converse need not be true, Cantor's intersection theorem.

Unit 2

Continuous mappings, sequential criterion and other characterizations of continuity. Uniform continuity. Connectedness, connected subsets of $\mathbb{R}$.

Compactness: Concept of compactness, Sequential compactness, Heine Borel property, Totally bounded spaces, finite intersection property, and continuous functions on compact spaces.

Homeomorphism. Contraction mappings. Banach Fixed point Theorem and its application to ordinary differential equation.

Unit 3

Properties of complex numbers, regions in the complex plane, functions of complex variable, mappings, Stereographic Projection, Limits, Limits involving the point at infinity, continuity.

Derivatives, Cauchy-Riemann equations, sufficient conditions for differentiability.

Unit 4

Analytic functions, examples of analytic functions, exponential function, Logarithmic function, trigonometric function, derivatives of functions, and definite integrals of functions. Contours, Contour integrals and its examples, upper bounds for moduli of contour integrals. Cauchy- Goursat theorem, Cauchy integral formula.

Unit 5

Liouville's theorem and the fundamental theorem of algebra. Convergence of sequences and series, Taylor's series and its applications.

Unit 6

Laurent's series and its applications, absolute and uniform convergence of power series.

Reference Books

- S. Shirali and H.L. Vasudeva, Metric Spaces, Springer Verlag, London, 2006.
- S. Kumaresan, Topology of Metric Spaces, 2^{nd} Ed., Narosa Publishing House, 2011.
- G.F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, 2004.
- J.W. Brown and R.V. Churchill, Complex Variables and Applications, 8thEd., McGraw–Hill International Edition, 2009.
- J. Bak and D.J. Newman, Complex Analysis, 2^{nd} Ed., Undergraduate Texts in Mathematics, Springer-Verlag New York, Inc., NewYork,1997.
- S. Ponnusamy, Foundations of complex analysis, Narosa, 2011.
- E.M. Stein and R. Shakrachi, Complex Analysis, Princeton University Press, 2003.

2.15 Core T14– Probability and Statistics

Probability and Statistics

	6 Credits

Course Objectives: The course will enable the students to
i) understand the concept of random experiment and probability.
ii) understand distributions in the study of the joint behaviour of two random variables.

Course Specific Outcomes: The student acquires the knowledge of

i) axiomatic idea of probability and its related topics.

ii) different types of distribution functions.

Unit 1

Probability axioms, real random variables (discrete and continuous), cumulative distribution function, probability mass/density functions, mathematical expectation, Properties, Mean and Variance, moments, moment generating function, characteristic function, discrete distributions: uniform, binomial, Poisson, geometric, continuous distributions: uniform, normal, exponential, gamma, beta first and second kind, Cauchy distributions. Transformation of random variables.

Unit 2
Joint cumulative distribution function and its properties, joint probability density functions, marginal and conditional distributions, expectation of function of two random variables, conditional expectations, independent random variables, bivariate normal distribution, correlation coefficient, joint moment generating function (jmgf) and calculation of covariance (from jmgf), linear regression for two variables.
Unit 3
Markov and Chebyshev's inequality, statement and interpretation of (weak) law of large numbers and strong law of large numbers, Central Limit theorem for independent and identically distributed random variables with finite variance, Markov Chains, Chapman-Kolmogorov equations, classification of states.
Unit 4
Random Samples, Sampling Distributions, Estimation of parameters: Point and interval estimations, Testing of hypothesis, Sampling from the normal distributions, Chi-square, *t* and *F*-distributions.
Reference Books

- R.V. Hogg, Joseph W. Mc Kean and Allen T. Craig, Introduction to Mathematical Statistics, Pearson Education, Asia, 2007.
- I. Miller and Marylees Miller, John E. Freund, Mathematical Statistics with Applications, 7th Ed., Pearson Education, Asia, 2006.
- S. Ross, Introduction to Probability Models, 9th Ed., Academic Press, Indian Reprint, 2007.
- A.M. Mood, Franklin A. Graybill and Duane C. Boes, Introduction to the Theory of Statistics,3rd Ed., Tata McGraw-Hill, Reprint 2007.
- A. Gupta, Ground work of Mathematical Probability and Statistics, Academic publishers, 2015

3. Discipline Specific Electives Subjects Syllabus

3.1 DSE T1–Linear Programming

Linear Programming	
	6 Credits

Course Objectives: The course will enable the students to
i) analyze and solve linear programming models of real-life situations.
ii) provide graphical solutions of linear programming problems with two variables and illustrate the concept of convex set and extreme points.
iii) understand the theory of the simplex method.

Course Specific Outcomes: The student acquires the knowledge of

i) relationships between the primal and dual problems, and to understand sensitivity analysis.
ii) learn about the applications to transportation, assignment and two-person zero-sum game problems.

Unit 1

Introduction to linear programming problem, graphical solution. Theory of simplex method, convex sets, optimality and unboundedness, the simplex algorithm, simplex method in tableau format, introduction of artificial variables, two-phase method. Big-M method and their comparison.

Unit 2

Duality, formulation of the dual problem, primal-dual relationships, related theorems, Fundamental theorem of Duality, Duality and simplex method, economic interpretation of the dual, Dual simplex method.

Transportation problem and its mathematical formulation, related theorems, northwest-corner method, least cost method and Vogel's approximation method for determination of starting basic solution, algorithm for solving transportation problem, assignment problems and its mathematical formulation, Hungarian method for solving assignment problems.

Unit 3

Game theory: formulation of two person zero sum games, solving two person zero sum games, games with mixed strategies, Dominance property, graphical solution procedure, linear programming solution of games.

Reference Books

- M.S. Bazaraa, J.J. Jarvis and H.D. Sherali, Linear Programming and Network Flows, 2nd Ed., John Wiley and Sons, India, 2004.
- F.S. Hillier and G.J. Lieberman, Introduction to Operations Research, 9th Ed., Tata McGraw Hill, Singapore,2009.

► H.A. Taha, Operations Research, An Introduction, 8th Ed., Prentice-Hall India, 2006.
► G. Hadley, Linear Programming, Narosa Publishing House, New Delhi, 2002.

3.2 DSE T2–Mathematical Modeling

Mathematical Modeling	
	6 Credits

Course Objectives: The course will enable the students to
i) generate the basic idea of mathematical modelling.
ii) build a model, how to study it and how to test a model.

Course Specific Outcomes: The student acquires the knowledge of

i) formulation of mathematical model from real life problem.
ii) electric circuits (L-R, R-C, L-R-C).

Unit 1

Introduction, Emergence of Mathematical Modelling on simple situations; Basic steps of Mathematical Modelling - its needs; Process / technique of Mathematical Modeling; Some characteristics of Mathematical Models; Importance of the usage of mathematical models over physical models; Classification of mathematical models; Deterministic and Stochastic models and their distinctive features with illustrations; Limitations of Mathematical Modelling.

Unit 2

Autonomous dynamical system and its classification, Jacobian matrix, System reducible to autonomous system, Time-dependent system, Fixed points and their characterization – node, saddle point, focus, centre and concept of limit cycle with simple illustrations, Stability of fixed points.

Unit 3

Modelling of Physical Systems: Formulation of some mathematical models and their analyses for (i) harmonic oscillator, (ii) damped and forced oscillator. Simple pendulum; Compound pendulum; Electric circuits (L-R, R-C, L-R-C).

Unit 4

Biological System: Population Models: (i) Single-species models – Exponential, Logistic and Gompertz growth models; Stochastic birth and death processes; Discrete-time models. (ii) Interacting populations – A classical predator-prey model; Stability of equilibrium positions; Derivation of Lotka-Volterra model; Two competing species model and its stability analysis;

Mutualism model and its stability. Harvest models and optimal control theory.

Reference Books

- T. Myint-U and L. Debnath, Linear Partial Differential Equation for Scientists and Engineers, Springer, Indian reprint, 2006.
- S.H. Strogatz, Nonlinear dynamics and chaos: with applications to physics, biology, chemistry, and engineering. CRC press, 2018.
- M. Kot, Elements of mathematical ecology. Cambridge University Press, 2001.
- S.L. Ross, Differential equations, John Wiley & Sons, 2007.
- F.R. Giordano, M.D. Weir and W.P. Fox, A First Course in Mathematical Modeling, Thomson Learning, London and New York, 2003.

3.3 DSE T3–Integral Transforms and Fourier Analysis

Integral Transforms and Fourier Analysis	
	6 Credits

Course Objectives: The course will enable the students to
i) know about piecewise continuous functions, Dirac delta function, Laplace transforms and its properties.
ii) solve ordinary differential equations using Laplace transforms.
iii) familiarize with Fourier transforms of functions, relation between Laplace and Fourier transforms.
iv) Explain Parseval's identity, Plancherel's theorem and applications of Fourier transforms to boundary value problems.

Course Specific Outcomes: The student acquires the knowledge of

i) Fourier series, Bessel's inequality, term by term differentiation and integration of Fourier series.
ii) application of this course in real life problems.

Unit 1

Laplace transform, Linearity, Existence theorem, Laplace transforms of derivatives and integrals, Shifting theorems, Change of scale property, Laplace transforms of periodic functions, Dirac delta function.

Unit 2

Differentiation and integration of transforms, Convolution theorem, Integral equations, Inverse Laplace transform, Lerch's theorem, Linearity property of inverse Laplace transform, Translations theorems of inverse Laplace transform, Inverse transform of derivatives, Applications of Laplace transform in obtaining solutions of ordinary differential equations and integral equations.

Unit 3

Fourier and inverse Fourier transforms, Fourier sine and cosine transforms, Inverse Fourier sine and cosine transforms, Linearity property, Change of scale property, Shifting property, Modulation theorem, Relation between Fourier and Laplace transforms.

Unit 4

Solution of integral equations by Fourier sine and cosine transforms, Convolution theorem for Fourier transform, Parseval's identity for Fourier transform, Plancherel's theorem, Fourier transform of derivatives, Applications of infinite Fourier transforms to boundary value problems, Finite Fourier transform, Inversion formula for finite Fourier transforms.

Unit 5

Fourier cosine and sine series, Fourier series, Differentiation and integration of Fourier series, Absolute and uniform convergence of Fourier series, Bessel's inequality, The complex form of Fourier series.

Reference Books

- J.W. Brown & R.V. Churchill, Fourier Series and Boundary Value Problems, McGraw-Hill Education, 2011.
- C.K. Chui, An Introduction to Wavelets. Academic Press, 1992.
- E. Kreyszig, Advanced Engineering Mathematics, 10th Ed., Wiley, 2011.
- W. Rudin, Fourier Analysis on Groups, Dover Publications, 2017.
- A. Zygmund, Trigonometric Series, 3rd Ed., Cambridge University Press, 2002.

3.4 DSE T4–Tensors and Differential Geometry

Tensors and Differential Geometry	
	6 Credits

Course Objectives: The course will enable the students to
i) explain the basic concepts of tensors.
ii) understand role of tensors in differential geometry.
iii) learn various properties of curves including Frenet-Serret formulae and their applications.
iv) know the Interpretation of the curvature tensor, Geodesic curvature, Gauss and Weingarten formulae.

Course Specific Outcomes: The student acquires the knowledge of

i) understanding the role of Gauss's Theorema Egregium and its consequences.
ii) application of problem-solving with differential geometry to diverse situations in physics, engineering and in other mathematical contexts.

Unit1

Contra variant and covariant vectors, Transformation formulae, Tensor product of two vector spaces, Tensor of type (r, s), Symmetric and skew-symmetric properties, Contraction of tensors, Quotient law, Inner product of vectors.

Unit2

Fundamental tensors, Associated covariant and contravariant vectors, Inclination of two vectors and orthogonal vectors, Christoffel symbols, Law of transformation of Christoffel symbols, Covariant derivatives of covariant and contravariant vectors, Covariant differentiation of tensors, Curvature tensor, Ricci tensor, Curvature tensor identities.

Unit3

Basic definitions and examples, Arc length, Curvature and the Frenet-Serret formulae, Fundamental existence and uniqueness theorem for curves, Non-unit speed curves.

Unit4

Basic definitions and examples, The first fundamental form, Arc length of curves on surfaces, Normal curvature, Geodesic curvature, Gauss and Weingarten formulae, Geodesics, Parallel vector fields along a curve and parallelism.

Unit5

The second fundamental form and the Weingarten map; Principal, Gauss and mean curvatures; Isometries of surfaces, Gauss's Theorema Egregium, The fundamental theorem of surfaces, Surfaces of constant Gauss curvature, Exponential map, Gauss lemma, Geodesic coordinates, The Gauss-Bonnet formula and theorem.

Reference Books

- C. Bär, Elementary Differential Geometry. Cambridge University Press, 2010.
- M.P. do Carmo, Differential Geometry of Curves & Surfaces, 2nd Ed., Dover Publications, 2016.
- A. Gray, Modern Differential Geometry of Curves and Surfaces with Mathematica, 4th Ed., Chapman & Hall/CRC Press, Taylor & Francis, 2018.
- R.S. Millman & G.D. Parkar, Elements of Differential Geometry. Prentice-Hall, 1977
- R.S. Mishra, A Course in Tensors with Applications to Riemannian Geometry. Pothishala Pvt. Ltd., 1965.
- S. Montiel & A. Ross, Curves and Surfaces. American Mathematical Society, 2009.

3.5 DSE T5–Advanced Mechanics

Advanced Mechanics

	6 Credits

Course Objectives: The course will enable the students to
i) understand the reduction of force system in three dimensions to a resultant force acting at a base point and a resultant couple.
ii) learn about a nul point, a nul line, and a nul plane with respect to a system of forces acting on a rigid body together with the idea of central axis.
iii) know the inertia constants for a rigid body and the equation of momental ellipsoid together with the idea of principal axes and principal moments of inertia to derive Euler's dynamical equations.

Course Specific Outcomes: The student acquires the knowledge of

i) studying the kinematics and kinetics of fluid motions to understand the equation of continuity in Cartesian, cylindrical polar and spherical polar coordinates which are used to derive Euler's equations and Bernoulli's equation.
ii) dealing with two-dimensional fluid motion using the complex potential and also to understand the concepts of sources, sinks, doublets and the image systems of these with regard to a line and a circle.

Unit1

Forces in three dimensions, Reduction to a force and a couple, Equilibrium of a system of particles, Central axis and Wrench, Equation of the central axis, Resultant wrench of two wrenches; Nul points, lines and planes with respect to a system of forces, Conjugate forces and conjugate lines.

Unit2

Moments and products of inertia of some standard bodies, Momental ellipsoid, Principal axes and moments of inertia; Motion of a rigid body with a fixed point, Kinetic energy of a rigid body with a fixed point and angular momentum of a rigid body, Euler's equations of motion for a rigid body with a fixed point, Velocity and acceleration of a moving particle incylindrical and spherical polar coordinates, Motion about a fixed axis, Compound pendulum.

Unit 3

Lagrangian and Eulerian approaches, Material and convective derivatives, Velocity of a fluid at a point, Equation of continuity in Cartesian, cylindrical polar and spherical polar coordinates, Cylindrical and spherical symmetry, Boundary surface, Streamlines and pathlines, Steady and unsteady flows, Velocity potential, Rotational and irrotational motion,Vorticity vector and vortex lines.

Unit 4

Euler's equations of motion in Cartesian, cylindrical polar and spherical polar coordinates; Bernoulli's equation, Impulsive motion.

Unit 5

Stream function, Complex potential, Basic singularities: Sources, sinks, doublets, complex potential due to these basic singularities; Image system of a simple source and a simple doublet with regard to a line and a circle, Milne-Thomson circle theorem.

Reference Books

- A.S. Ramsay, A Treatise on Hydromechanics, Part-II Hydrodynamics. G. Bell & Sons, 1960.
- F. Chorlton, A Textbook of Fluid Dynamics. CBS Publishers, 1967.
- M. Rieutord, Fluid Dynamics: An Introduction. Springer, 2015.
- E.A. Milne. Vectorial Mechanics, Methuen & Co. Limited. London, 1965.
- J.L. Synge & B. A. Griffith, Principles of Mechanics. McGraw-Hill, 1949.
- S. Ramsey, Statics. Cambridge University Press, 2009.
- S. Ramsey, Dynamics. Cambridge University Press, 2009.
- R.S. Varma, A Text Book of Statics. Pothishala Pvt. Ltd. Loney, 1962.

3.6 DSE T6–Advanced Algebra

Advanced Algebra	
	6 Credits

Course Objectives: The course will enable the students to
i) understand some advanced properties of group actions in formalizing Sylow theorem.
ii) learn polynomial ring and their properties.

Course Specific Outcomes: The student acquires the knowledge of

i) Sylow theorem and their application in simplicity test of groups.
ii) divisibility in polynomial rings and testing of irreducible polynomials.

Unit 1

Group actions, stabilizers, permutation representation associated with a given group action, Applications of group actions: Generalized Cayley's theorem, Index theorem.

Groups acting on themselves by conjugation, class equation and consequences, Cauchy's theorem (with the proof by class equation), Sylow's theorems (with proofs) and consequences, Simplicity of An for n_5, non-simplicity tests.

Unit 2

Divisibility in integral domains, irreducible, primes, unique factorization domains, Principal ideal domain, principal ideal ring, Euclidean domain, relation between Euclidean domain and principal ideal domain.
Greatest common divisor(gcd), least common multiple (lcm), expression of gcd, examples of a ring R and a pair of elements $a, b \in R$ such that $gcd(a, b)$ does not exist

Unit 3

Polynomial rings, division algorithm and consequences in polynomial rings, results regarding various domains in polynomial rings, Irreducibility in polynomial rings, Eisenstein criterion and unique factorization in Z[x].

Ring embedding and quotient field.

Reference Books

- J.B. Fraleigh, A First Course in Abstract Algebra,7th Ed., Pearson, 2002.
- M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.
- J.A. Gallian, Contemporary Abstract Algebra, 4th Ed., 1999.
- D.S. Dummit and Richard M. Foote, Abstract Algebra, 3rdEd., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2004.
- J.R. Durbin, Modern Algebra, John Wiley & Sons, New York Inc., 2000.
- D.A.R. Wallace, Groups, Rings and Fields, Springer Verlag London Ltd.,1998
- D.S. Malik, J.M. Mordeson and M. K. Sen, Fundamentals of Abstract Algebra, McGraw-Hill College, 1996.

3.7 DSE T7–Discrete Mathematics

Discrete Mathematics

	6 Credits

Course Objectives: The course will enable the students to
i) learn about partially ordered sets, lattices and their types.
ii) understand Boolean algebra, switching circuits and their applications.

Course Specific Outcomes: The student acquires the knowledge of
i)solving the real-life problems using finite-state and Turing machines.
ii) assimilating the various graph theoretic concepts and familiarize with their applications.

Unit 1

Definitions, examples and basic properties of partially ordered sets (poset), Order isomorphism, Hasse diagrams, Dual of a poset, Duality principle, Maximal and minimal elements, Least upper bound and greatest upper bound, Building new poset, Maps between posets.

Unit 2

Lattices as posets, Lattices as algebraic structures, Sublattices, Products and homomorphisms; Definitions, examples and properties of modular and distributive lattices; Complemented, relatively complemented and sectionally complemented lattices.

Unit 3

Boolean algebras, De Morgan's laws, Boolean homomorphism, Representation theorem, Boolean polynomials, Boolean polynomial functions, Disjunctive and conjunctive normal forms, Minimal forms of Boolean polynomials, Quine-McCluskey method, Karnaugh diagrams, Switching circuits and applications.

Unit 4

Finite-state machines with outputs, and with no output; Deterministic and nodeterministic finite-state automaton; Turing machines: Definition, examples, and computations.

Unit 5

Definition, examples and basic properties of graphs, Königsberg bridge problem; Subgraphs, Pseudo graphs, Complete graphs, Bipartite graphs, Isomorphism of graphs, Paths and circuits, Eulerian circuits, Hamiltonian cycles, Adjacency matrix, Weighted graph, Travelling salesman problem, Shortest path and Dijkstra's algorithm.

Reference Books

- B.A. Davey & H.A. Priestley, Introduction to Lattices and Order, 2nd Ed., Cambridge University Press, 2002.
- E.G. Goodaire & M.M. Parmenter, Discrete Mathematics with Graph Theory, 3rd Ed. Pearson Education, 2018.
- R. Lidl & G. Pilz, Applied Abstract Algebra, 2nd Ed., Springer, 1998.
- K.H. Rosen, Discrete Mathematics and its Applications: With Combinatorics and Graph Theory, 7th Ed., McGraw-Hill, 2012.
- C.L. Liu, Elements of Discrete Mathematics, 2nd Ed., McGraw-Hill, 1985.

3.8 DSE T8-Point Set Topology

Point Set Topology	
	6 Credits

Course Objectives: The course will enable the students to

i) understand the basic idea of topological spaces and its related topics.

ii) learn about the idea of countability and uncountbility.

Course Specific Outcomes: The student acquires the knowledge of
i)ordinal number and Zorns lemma.
ii) the Lebesgue Number lemma, local compactness.

Unit 1

Countable and Uncountable Sets, Schroeder-Bernstein Theorem, Cantor's Theorem. Cardinal Numbers and Cardinal Arithmetic. Continuum Hypothesis, Zorns Lemma, Axiom of Choice.

Well-Ordered Sets, Hausdorff's Maximal Principle. Ordinal Numbers.

Unit 2

Topological spaces, Basis and Sub basis for a topology, subspace Topology, Interior Points, Limit Points, Derived Set, Boundary of a set, Closed Sets, Closure and Interior of a set. Kuratowskii operators, Continuous Functions, Open maps, Closed maps and Homeomorphisms. Product Topology, Quotient Topology, Metric Topology, Baire Category Theorem.

Unit 3

Neighbourhood system, Connected and Path Connected Spaces, Connected Sets in $\mathbb{R}$, Components and Path Components, Local Connectedness. Compact Spaces with examples, Totally Bounded Spaces, Ascoli-Arzela Theorem, The Lebesgue Number Lemma, Local compactness.

Reference Books

- J.R. Munkres, Topology, A First Course, Prentice Hall of India Pvt. Ltd., New Delhi, 2000.
- B.C. Chatterjee, S. Ganguly and M.R. Adhikary, A Text Book of Topology, Asian Book Private, 2002.
- G.F. Simmons, Introduction to Topology and Modern Analysis, McGraw Hill, 1963.
- J. L. Kelley, General Topology, Van Nostr and Reinhold Co., New York, 1995.
- J. Hocking, G. Young, Topology, Addison-Wesley Reading, 1961.

- L. Steen, J. Seebach, Counter Examples in Topology, Holt, Reinhart and Winston, New York, 1970.
- A. Dasgupta, Set Theory: With an Introduction to Real Point Sets, Springer Nature, 2013

3.9 DSE T9–Special Theory of Relativity

Special Theory of Relativity	
	6 Credits

Course Objectives: The course will enable the students to
i) understand the basic elements of Newtonian mechanics including Michelson-Morley experiment and geometrical interpretations of Lorentz transformation equations.
ii) learn about length contraction, time dilation and Lorentz contraction factor.
iii) study of 4-dimensional Minkowskian space-time and its consequences.

Course Specific Outcomes: The student acquires the knowledge of
i) understanding the equations of motion as a part of relativistic mechanics.
ii) imbibing connections between relativistic mechanics and electromagnetism.

Unit 1

Inertial frames, Speed of light and Gallilean relativity, Michelson-Morley experiment, Lorentz-Fitzgerald contraction hypothesis, Relative character of space and time, Postulates of special theory of relativity, Lorentz transformation equations and its geometrical interpretation, Group properties of Lorentz transformations.

Unit 2

Composition of parallel velocities, Length contraction, Time dilation, Transformation equations for components of velocity and acceleration of a particle and Lorentz contraction factor.

Unit 3

Four dimensional Minkowskian space-time of special relativity, Time-like, light-like and space-like intervals, Null cone, Proper time, World line of a particle, Four vectors and tensors in Minkowiskian space-time.

Unit 4

Variation of mass with velocity. Equivalence of mass and energy. Transformation equations for mass momentum and energy. Energy-momentum four vector. Relativistic force and Transformation equations for its components. Relativistic equations of motion of a particle.

Unit 5

Transformation equations for the densities of electric charge and current. Transformation equations for electric and magnetic field strengths. The Field of a Uniformly Moving Point charge. Forces and fields near a current carrying wire. Forces between moving charges. The invariance of Maxwell`s equations.

Reference Books

- J.L. Anderson, Principles of Relativity Physics. Academic Press, 1973.
- P.G. Bergmann, Introduction to the Theory of Relativity. Dover Publications, 1976.
- C. Moller, The Theory of Relativity, 2nd Ed., Oxford University Press, 1972.
- R. Resnick, Introduction to Special Relativity. Wiley, 2007.
- W. Rindler, Essential Relativity: Special, General, and Cosmological. Springer-Verlag, 1977.
- V.A. Ugarov, Special Theory of Relativity. Mir Publishers, Moscow, 1979.

3.10 DSE T10– Number Theory

Number Theory

	6 Credits

Course Objectives: The course will enable the students to
i) learn about some important results in the theory of numbers including the prime number theorem, Chinese remainder theorem, Wilson's theorem and their consequences.
ii) learn about number theoretic functions, modular arithmetic and their applications.
iii) familiarize with Euler's phi-function and their consequences.

Course Specific Outcomes: The student acquires the knowledge of
i) knowing about the concept of the congruences with composite moduli.
ii) application of public key encryption, in particular, RSA.

Unit1

Linear Diophantine equation, prime counting function, statement of prime number theorem, Goldbach conjecture, linear congruences, complete set of residues, Chinese Remainder theorem, Fermat's Little theorem, Wilson's theorem.

Unit 2

Number theoretic functions, sum and number of divisors, totally multiplicative functions, definition and properties of the Dirichlet product, the Mobius Inversion formula, the greatest integer function, Euler's phi-function, Euler's theorem, reduced set of residues. Some properties of Euler's phi-function.

Unit 3

Order of an integer modulo n, primitive roots for primes, composite numbers having primitive roots, Euler's criterion, the Legendre symbol and its properties, quadratic reciprocity, quadratic congruences with composite moduli. Public key encryption, RSA encryption and decryption, the equation $x^2 + y^2 = z^2$, Fermat's Last theorem.

Reference Books

- D.M. Burton, Elementary Number Theory, 6thEd., Tata McGraw-Hill, Indian reprint, 2007.
- N. Robinns, Beginning Number Theory, 2nd Ed., Narosa Publishing House Pvt. Ltd., Delhi, 2007.

3.11 DSE T11–Dissertation

Dissertation

	6 Credits

Course Objectives: The aim of this course is to engage the student in a study or research on a topic of mathematics which is beyond the regular mathematics courses offered in regular classroom teaching in our Department. The students need to produce a document (paper or report) containing the result of this study and present the content orally to a group consisting of the faculty members and an external expert.

Course Specific Outcomes: After completion of this course, the students learn about:
i) basic components of academic research such a literature survey, self-study to identify a problem, solve it and produce report on his/her work etc.
ii)Prepare a scientific presentation and deliver it to a group of audience consisting of faculty members.
iii) Prepare and successfully taking part in a viva voce.

Dissertation has to be prepared on any topic of the Mathematics and its Applications and submitted to the corresponding supervisor(s) in doc(pdf) format. Finally, it should be presented.

DSET11-Dissertation on any topic of Mathematics is related with any topic of Mathematics and its Applications and the Marks distribution is 15 Marks for written Material (electronic document) submission and 15 Marks for Seminar Presentation and 10 Marks for Viva-Voce.

4. Skill Enhancement Subjects Syllabus

4.1 SEC T1–Mathematical Logic

Mathematical Logic	
	4 Credits
Course Objectives: The course will enable the students to i) learn the syntax of first-order logic and semantics of first-order languages. ii) understand the propositional logic and basic theorems like compactness theorem, meta theorem and post-tautology theorem. iii) familiarize with syntax of propositional logic and their consequences.	
Course Specific Outcomes: The student acquires the knowledge of i) knowing about the concept of the post tautology theorem. ii) assimilating the concept of completeness interpretations and their applications with special emphasis on applications in algebra.	
Unit1	
First-order languages, Terms of language, Formulas of language, First order theory.	
Unit2	
Structures of first order languages, Truth in a structure, Model of a theory, Embeddings and isomorphism.	
Unit 3	
Syntax of propositional logic, Semantics of propositional logic, Compactness theorem for propositional logic, Proof in propositional logic, Meta theorem in propositional logic, Post tautology theorem.	
Unit 4	
Proof in first-order logic, Meta theorems in first-order logic, Some meta theorem in arithmetic, Consistency and completeness.	
Unit 5	
Completeness theorem, Interpretation in a theory, Extension by definitions, Compactness theorem and applications, Complete theories, Applications in algebra.	
Reference Books	

- R.E. Hodel, An Introduction to Mathematical Logic. Dover Publications, 2013.
- Y.I. Manin, A Course in Mathematical Logic for Mathematicians, 2nd Ed., Springer, 2010.
- E. Mendelson, Introduction to Mathematical Logic, 6th Ed., Chapman & Hall/CRC, 2015.
- S. Mohan, Srivastava, A Course on Mathematical Logic, 2nd Ed., Springer, 2013.

4.2 SEC T2–Programming Using C

Programming Using C

	4 Credits

Course Objectives: The course will enable the students to
i) understand and apply the programming concepts of C which are important for mathematical investigation and problem solving.
ii) use mathematical library functions for computational objectives.
iii) familiarize with syntax and/or error of the different command and their consequences.

Course Specific Outcomes: The student acquires the knowledge of
i) representing the outputs of programs visually in terms of well formatted text and plots.
ii) identifying the specific decision making loops and commands.

Unit 1

An overview of theoretical computers, history of computers, overview of architecture of computer, compiler, assembler, machine language, high level language, object-oriented language, programming language and importance of C programming.

Unit 2

Constants, Variables and Data type of C-Program: Character set. Constants and variables data types, expression, assignment statements, declaration.
Operation and Expressions: Arithmetic operators, relational operators, logical operators.

Unit 3

Decision Making and Branching: decision making with if statement, if-else statement, Nesting if statement, switch statement, break and continue statement.
Control Statements: While statement, do-while statement, for statement.

Unit 4

Arrays: One-dimension, two-dimension and multidimensional arrays, declaration of arrays, initialization of one and multi-dimensional arrays.

Unit 5

User-defined Functions: Definition of functions, Scope of variables, return values and their types, function declaration, function call by value, Nesting of functions, passing of arrays to functions, Recurrence of function.
Introduction to Library functions: stdio.h, math.h, string.h, stdlib.h, time.h etc.

Unit 6

Some hands-on examples.

Reference Books

- B.W. Kernighan and D.M. Ritchi, The C-Programming Language, 2nd Ed.(ANSI Refresher), Prentice Hall, 1977.
- E. Balagurnsamy, Programming in ANSI C, Tata McGraw Hill, 2004.
- Y. Kanetkar, Let Us C ; BPB Publication, 1999.
- C. Xavier, C-Language and Numerical Methods, New Age International, 1999.
- V. Rajaraman, Computer Oriented Numerical Methods, Prentice Hall of India, 1980.

4.3 SEC T3–Graph Theory

Graph Theory

	4 Credits

Course Objectives: The course will enable the students to
i) study graph theory with various types of graphs and their application.
ii) study the mathematical applications to the real world.

Course Specific Outcomes: The student acquires the knowledge of
i) path and circuits of the Graph theory specifically Eulerian circuits.
ii) shortest path and the problem of Travelling salesman.

Unit 1

Definition, examples and basic properties of graphs, pseudo graphs, complete graphs, bi-partite graphs, isomorphism of graphs.

Unit 2

Path and circuits, Eulerian circuits, Eulerian graph, semi-Eulerian graph, theorems, Hamiltonian cycles, theorems.

Representation of a graph by matrix, the adjacency matrix, incidence matrix, weighted graph.

Unit 3

Travelling salesman's problem, shortest path, Tree and their properties, spanning tree, Dijkstra's algorithm, Warshall algorithm.

Reference Books

- B.A. Davey and H.A. Priestley, Introduction to Lattices and Order, Cambridge University Press, Cambridge, 1990.
- E.G. Goodaire and Michael M. Parmenter, Discrete Mathematics with Graph Theory, 2nd Ed., Pearson Education (Singapore) P. Ltd., Indian Reprint 2003.
- R.Lidl and G. Pilz, Applied Abstract Algebra, 2nd Ed., Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.

4.4 SEC T4–Operating System: Linux

Operating Systems: Linux	
	4 Credits

Course Objectives: The course will enable the students to
i) understand and apply the operating system: linux which is important for mathematical investigation and problem solving.
ii)use mathematical library functions for computational objectives.
iii) familiarize with Syntax and/or error of the different command and their consequences.

Course Specific Outcomes: The student acquires the knowledge of
i) representing the outputs of programs visually in terms of well formatted text and plots.
ii) identifying the specific decision making commands.

Unit1

Linux – The Operating System: Linux history, Linux features, Linux distributions, Linux's relationship to Unix, Overview of Linux architecture, Installation, Start up scripts, system processes (an overview), Linux Security.

Unit2

The Ext2 and Ext3 File systems: General Characteristics of The Ext3 Filesystem, file permissions. User Management: Types of users, the powers of Root, managing users (adding and deleting): using the command line and GUI tools.

Unit 3

Resource Management in Linux: file and directory management, system calls for files Process

Management, Signals, IPC: Pipes, FIFOs, System V IPC, Message Queues, system calls for processes, Memory Management, library and system calls for memory.

Reference Books

- A. Robbins, Linux Programming by Examples The Fundamentals, 2nd Ed., Pearson Education, 2008.
- K. Cox, Red Hat Linux Administrator's Guide, PHI, 2009.
- R. Stevens, UNIX Net work Programming, 3rd Ed., PHI, 2008.
- S. Das, UNIX Concepts and Applications,4th Ed., TMH, 2009.
- E. Siever, S. Figgins, R. Love, A. Robbins, Linux in a Nutshell, 6th Ed., O'Reilly Media, 2009.
- N. Matthew, R. Stones, A. Cox, Beginning Linux Programming, 3rdEd., 2004.

4.5 SEC T5- Programming Using C - Practical

Programming Using C - Practical	
	4 Credits

Course Objectives: The course will enable the students to
i) use and apply the programming concepts of C in laboratory which is important for mathematical investigation and problem solving.
ii) use library functions of programming language C for computational purposes.
iii) familiarize with Syntax and/or error of the programming language.

Course Specific Outcomes: The student acquires the knowledge of
i) representing the inputs and outputs of programs in terms of well formatted text and plots.
ii) identifying the specific decision making loops and commands.

List of practical

1. Calculate the sum 1/1+1/2+1/3+1/4+ ------------------ +1/N.
2. Calculate power: x^y.
3. Enter 100 integers into an array and sort them in an ascending order.
4. GCD of two positive integers.
5. Finding maximum among some numbers.
6. Testing of prime number.
7. Finding prime numbers within a range.
8. Generating Fibonacci Series.
9. Matrix addition.
10. Matrix multiplication.

Note: For any of the CAS (Computer aided software) Data types-simple data types, floating data types, character data types, arithmetic operators and operator precedence, variables and constant declarations, expressions, input/output, relational operators, logical operators and logical expressions, control statements and loop statements, Arrays should be introduced to the students.