GOA UNIVERSITY
Taleigao Plateau, Goa 403 206

REVISED MINUTES

of the 9th Special Meeting of the

X ACADEMIC COUNCIL

Day & Date

Saturday, 30th July, 2022

Time

10.00 a.m.

Council Hall
Goa University

	2. The Course Codes for the PG programmes to be revised/changed. The Controller of Examination was requested to draw up a uniform pattern to be made applicable across all disciplines in consultation with a few Deans and the Chairpersons of the Boards of Studies. 3. The Chairperson, Board of Studies was requested to rework on the following Elective Courses giving more details: a) MMO-22-213 'Field Trip/Study Tour – Practical' b) MMO-22-214 'Internship' **(Action: Assistant Registrar Academic – PG)**
D 3.2	**Minutes of the Board of Studies in Marine Science meeting held on 28.04.2022.** The Academic Council approved the minutes of the Board of Studies in Marine Science meeting held on 28.04.2022 with the following suggestions: 1. The month and year mentioned in the heading of the Syllabus document to be corrected from September 2022 to August 2022. 2. The Course Codes for the PG programmes to be revised/changed. 3. Total Number of Credits indicated as a footnote to the Programme Structure to be deleted. **(Action: Assistant Registrar Academic – PG)**
D 3.3	**Minutes of the Board of Studies in Earth Science (Applied Geology) meeting held on 29.04.2022.** The Academic Council approved the minutes of the Board of Studies in Earth Science (Applied Geology) meeting held on 29.04.2022 with the following suggestions: 1. The number of hours to be assigned to each module in Courses. 2. Theory component of one credit to be included for the Practical Courses. 3. Course GLC-22-107 Geological Field Mapping to be offered as a new Theory Course. 4. Course Code: GLC-22-207 Geological Field Training to be included as a part of the Dissertation. **(Action: Assistant Registrar Academic – PG)**
D 3.4	**Minutes of the Board of Studies in Mathematics meeting held on 22.04.2022.** The Academic Council approved the minutes of the Board of Studies in Mathematics meeting held on 22.04.2022 with the following suggestions: 1. The Course Codes for the PG programmes to be revised/changed. 2. The word 'Optional Courses' to be replaced with 'Elective Courses'. 3. The Chairperson, Board of Studies was requested to resubmit the syllabus incorporating the suggestions. The Vice-Chancellor was authorized to approve the same on behalf of the Academic Council. The proposed syllabus for Semester III and Semester IV was deferred. **(Action: Assistant Registrar Academic – PG)**

X AC- 9 (Special)
30.07.2022

GOA UNIVERSITY
Taleigao Plateau, Goa 403 206

F I N A L U P D A T E D A G E N D A

For the 9th Special Meeting of the

X ACADEMIC COUNCIL

Day & Date

30th July, 2022

Time

10.00 a.m.

Venue
Conference Hall
Administration Block

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D 3.4

Minutes of the Board of Studies in Mathematics meeting held on 22.04.2022.

Part A

i) Recommendations regarding courses of study in the subject or group of subjects at the undergraduate level:

Syllabus of Analytical Geometry paper modified. Attached as **Annexure II** **(refer page no. 132)**

ii) Recommendations regarding courses or group of subjects at postgraduate level:

BOS discussed about New PG program to be introduced from June 2022.

List of the courses and the syllabus of Semester 1 and 2 is attached as **Annexure I** **(refer page no. 115)**

Part B :

i) Scheme of the Examinations at Undergraduate Level: Nil
ii) Panel of examiners for different examinations at Undergraduate Level: Nil
iii) Scheme of the examinations at post-graduate level: Nil
iv) Panel of examiners for different examinations at post-graduate Level: Nil

Part C

i) Recommendations regarding preparation and publication and selection of Anthologies in any subject or group of subjects and the names of person recommended for appointment to make the selection: Nil

Part D

i) Recommendations regarding general academic requirements in the Departments of University or affiliated colleges: Nil
ii) Recommendation of Academic Audit committee and status thereof: Nil

Part E

i) Recommendations of text books for the course for study at the Undergraduate level:Nil
ii) Recommendations of text books for the courses of study at the post Graduate level: Nil

Part F

Important points for consideration/approval of Academic Council:

New PG course approved by BoS in Mathematics
Modified Syllabus of Analytical Geometry for UG

The declaration by the Chairman, that the minutes were read out by the Chairman at the meeting itself.

Sd/-
Signature of Chairman

Date: 22.04.2022
Place: Goa University

Part G: The remarks of the Dean of the Faculty.

	i) The minutes are in order. ii) The minutes may be placed before the Academic Council with remarks if any. iii) May be recommended for approval of Academic Council iv) Special remarks if any: Nil Sd/- Signature of the Dean Date: 22-04-2022 Place: Goa University (Back to Index)
D 3.5	**Minutes of the Board of Studies in Environmental Science meeting held on 20.04.2022.** **Part A**. i. Recommendations regarding courses of study in the subject or group of subjects at the undergraduate level: Nil ii. Recommendations regarding courses of study in the subject or group of subjects at the postgraduate level: 1. **BOS members met on 20.04.2022 at 1430hrs in CF 20, Marine science Wing, School of Earth, Ocean and Atmospheric Sciences and discussed the following.** **i. Approval of M.Sc. / M.A. Environmental Program Structure and Syllabus of Semester I & II.** **ii. Any other business with the permission of the chair.** **Part B** i) Scheme of Examinations at undergraduate level: Nil ii) Panel of examiners for different examinations at the undergraduate level: Nil iii) Scheme of Examinations at postgraduate level: Nil iv) Panel of examiners for different examinations at post-graduate level: Nil **Part C.** 1. Recommendations regarding preparation and publication of selection of reading material in the subject or group of subjects and the names of the persons recommended for appointment to make the selection: Nil **Part D** i. Recommendations regarding general academic requirements in the Departments of University or affiliated colleges: Nil ii. Recommendations of the Academic Audit Committee and status thereof: Nil **Part E.** i. Recommendations of the text books for the course of study at undergraduate level: Nil ii. Recommendations of the text books for the course of study at post graduate level: Nil **Part F.** <u>Important points for consideration/approval of Academic Council</u> i. The important points/recommendations of BOS that require consideration/approval of Academic Council (points to be highlighted) as mentioned below.

D 3.4 Minutes of the Board of Studies in Mathematics meeting held on 22.04.2022.

Annexure I

Goa University
School of Physical and Applied Sciences,
MSc Mathematics

New PG courses starting from June 2022 onwards

Semester 1	
Paper Code	**Paper Title**
MTC-101	Real Analysis (4 Credit)
MTC-102	Linear Algebra (4 Credit)
MTC-103	Algebra (4 Credit)
MTC-104	Complex Analysis (4 Credit)
MTO-	Discipline specific optional paper (4 Credit)
Semester 2	
Paper Code	**Paper Title**
MTC-201	Topology (4 Credit)
MTC-202	Differential Equations (4 Credit)
MTC-203	Several variable calculus (4 Credit)
MTC-204	Functional Analysis (4 Credit)
MTO-	Discipline specific optional paper (4 Credit)
Semester 3	
Paper Code	**Paper Title**
MTO-	Research Specific Optional Course (4 Credit)
MTO-	Research Specific Optional Course (4 Credit)
MTO-	Optional Generic Course (4 Credit)
MTO-	Optional Generic Course (4 Credit)
MTO-	Optional Generic Course (4 Credit)
Semester 4	
Paper Code	**Paper Title**
MTO-	Research Specific Optional Course (4 Credit)
	Discipline Specific Dissertation (16 Credit)

The syllabus for the papers of Semesters 3 and 4 will be given later

SPAS, MSc Mathematics

List of Courses:

(1) Discipline specific optional papers

Semesters 1 and 2	
MTO-101	Mathematical Methods
MTO-102	Difference Equations
MTO-103	Special Functions
MTO-104	Partial Differential Equations
MTO-105	Integral Equations

(2) Research Specific Optional Courses

Semesters 3 and 4	
MTO-	Number Theory
MTO-	Lie Algebra
MTO-	Measure Theory
MTO-	Advanced Functional Analysis
MTO-	Advanced Graph Theory
MTO-	Graphs and Networks
MTO-	Operational Research
MTO-	Computational Models

(3) Optional Generic Courses

Semester 3	
MTOG-	Actuarial Science
MTOG-	Mathematics for Finance
MTOG-	Latex
MTOG-	Probability and Statistics

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M.Sc. Mathematics Discipline Specific Core Papers Syllabus (to be implemented from June 2022)

Programme: M. Sc. (Mathematics)
Course Code: MTC-101 **Title of the Course:** REAL ANALYSIS
Number of Credits: 4
Effective from AY: 2022-2023

Prerequisites	Basic Mathematical Analysis	
Objective	This course will develop fundamental concepts in Real Analysis and make the student acquainted with tools of analysis which is essential for the study and appreciation of many related branches of mathematics and applications.	
Content	**1.Real Number System** Peano's Axioms for Natural Numbers and Induction Principle, equivalence of induction, strong induction and the well-ordering principle, Finite sets, cardinality of finite sets, Subset of finite sets , a proper subset of a finite set has cardinality strictly less that the super set, Integers and Rational numbers (Discussion), Ordered sets and LUB Property, Ordered Field Axioms, Field of Real Numbers and Completeness, Archimedean property, integral part of a real number, density of rationals, and irrationals in the reals, Existence of n^{th} roots of nonnegative reals, proof of existence of decimal representation of reals, Countable sets – definition and equivalent reformulations of countability, Countability of unions and Cartesian products of sets, Uncountable sets, Countabilty of Rationals, Uncountability of Reals, Extended Real Number System. **2.Elements of Point Set Toplogy** Metric Spaces, Euclidean Spaces, Open balls and Open sets in $\mathbb{R}^n$, Structure of open sets in $\mathbb{R}^1$, Adherent points and Accumulation points, Closed sets, Perfect sets, Every non-empty perfect set of $\mathbb{R}^n$ is uncountable, Bolzano- Weierstrass Theorem, Cantor Intersection Theorem, Lindel$\ddot{o}$f Covering Theorem, The Heine-Borel Covering Theorem, Compactness in $\mathbb{R}^n$, Compactness in metric spaces, Connected sets in metric spaces, Connected subsets of $\mathbb{R}$, Cantor set-constrction and basic properties, Cantor set and ternary expansion. **3.Limits and Continuity** Convergent sequences in a Metric space , Cauchy sequences and Complete metric spaces, Limit inferior and Limit superior of a sequence, Limit of a Function- (Real valued, complex valued, vector valued functions), Continuous Functions, Continuity and Compactness, Continuity and Connectedness, Bolzano's Theorem and Intermediate value Theorem, Uniform Continuity, Uniform Continuity and Compactness, Discontinuities of Real valued	18 Hours 14 Hours 14Hours

	Functions, Monotonic Functions, Infinite limits and Limits at infinity. **4.Derivatives** Derivatives and Continuity, Algebra of Derivatives and Chain rule (Statements only),One sided derivatives and Infinite Derivatives, Functions with non-zero derivatives, Zero derivatives and Local extrema, Rolle's Theorem, Mean value Theorems and consequences, Intermediate value Theorem for Derivatives, Taylor's Formula with Remainder, Derivatives of Vector valued Functions and Complex valued Functions, Derivatives of Higher Order, L'Hospital's Rules with proof.	14 Hours
Pedagogy	Lectures/ Tutorials/Assignments/Self-study	
References/ Readings	1. Mathematical Analysis, Tom M. Apostol, Narosa Publishing House, 1996. 2. Principles of Mathematical Analysis, Walter Rudin, McGraw-Hill International Editions,1976. 3.A Foundation Course in Mathematics, Ajith Kumar, S.Kumaresan, B.K. Sarma, Narosa Publishing House, 2018. 4. A Basic Course in Real Analysis, Kumar and Kumaresan, CRC Press, 2015. 5. Real Analysis, N.L. Carothers, Cambridge University Press, 2000. 6.Calculus with Applications, Peter D. Lax, Maria Shea Terrel, Springer, 2014.	
Learning Outcomes	On Completion of this course the student will be able to • Describe the difference between rational numbers and real numbers. • Understand LUB property and apply it to proofs and solutions of problems. • Calculate limit inferior and limit superior • Understand and use concepts related to metric spaces such as continuity, compactness and connectedness • Apply mean value theorem to problems in the context of Real Analysis	

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Programme: M. Sc. (Mathematics)
Course Code: MTC-102 **Title of the Course: LINEAR ALGEBR**A
Number of Credits: 4
Effective from AY: 2022-2023

Prerequisites	Should have passed B.Sc. with Linear Algebra as subject and familiar with the notions of vector spaces, basis, dimension, Linear maps, matrix representation and their algebra, and Rank-Nullity theorem	

Objective	To prepare students to handle solving problems involving linear equations and determining the qualitative properties of the solution set.	
Content	1. **Review:** System of linear equations, Vector spaces, Basis and Dimension, Linear Transformations, Matrix of a Linear Transformation. 2. **Linear Functionals**: Linear Functional on Vector Spaces, Dual of Vector Spaces and Properties, Double Dual, Annihilator, The Transpose of a Linear Transformation and the Matrix, Row Rank equal to Column Rank. 3. **Algebra of Polynomials**: Polynomial Algebra, Polynomial Ideals, Greatest Common Divisors of Polynomials and Prime Factorization of Polynomials. (Quick review) 4. **Elementary Canonical Forms**: Characteristic Values and Characteristic Vectors, Characteristic Spaces, Annihilating Polynomials, Invariant Subspaces, Simultaneous Triangulation; Simultaneous Diagonalization, Direct Sum Decompositions, Invariant Direct Sums, The Primary Decomposition Theorem. 5. **The Rational and Jordan Forms**: Cyclic Subspaces and Annihilators, Cyclic Decompositions and the Rational Form, The Jordan Form, Computation of Invariant Factors. Summary; Semi-Simple Operators.	10 Hours 12 Hours 4 Hours 16 Hours 18 Hours
Pedagogy	Lectures/ Tutorials/Assignments/Self-study	
References/ Readings	1. Kenneth Hoffmann and Ray Kunze, Linear Algebra, PHI, 1997. 2. S. Kumaresan, Linear Algebra, PHI, 2000. 3. I.R.Shafarevich and A. O. Remiz Linear Algebra and Geometry, Springer Verlag., 2012 4. Y.I. Manim, Linear Algebra and Geometry, CRC Press., 1997	
Learning Outcomes	The students will be equipped to learn basic Functional analysis, Several Variable Calculus, Advanced Algebra, Differential Equations, etc.	

Programme: M. Sc. (Mathematics)
Course Code: MTC-103 **Title of the Course:** ALGEBRA
Number of Credits: 4
Effective from AY: 2022-2023

Prerequisites	Basic Group Theory	
Objective	This course develops concepts in advanced Group Theory, Basics of Ring Theory and their applications., This course will also be a prerequisite for courses such as Field Theory and Galois Theory and Commutative Algebra.	

Content	**1. Permutation Group** Symmetric groups, Permutations; Alternating groups; Group actions, Orbits and stabilizers; Caley's Theorem; **2, Series of groups**Subnormal Normal series. Jordan Holder Theorem. **3. Sylow Theorems** Conjugacy Classes. The Class Equation, Cauchy's Theorem, p-groups. The Sylow Theorems. Applications of Sylow Theorems. Finite Simple Groups . Non simplicity Tests. The simplicity of A_5 **4. Rings and Fields** Rings. Fields. Integral Domains-definitions and Examples. Characteristic of Rings. Ideals and Factor Rings. Prime ideals and Maximal ideals. Ring Homomorphisms. Field of Quotients of an Integral Domain. **5. Polynomial Rings and Factorization of Polynomials** Polynomial Rings-Notations and Terminologies, The Division algorithm and Consequences, Mod p Test for irreducibility over UFD. Gauss Lemma over UFD, Eienstein Criterion, g.c.d., l.c.m., in UFD. In UFD R, f(x) in R[x] is irreducible iff f(x) is irreduclible over the field of quotients of R, R is a UFD implies R[x] is a UFD. **6. Divisibility in Integral Domains** Irreducibles. Primes. Unique Factorization Domains. Principal Ideal Domains. PID implies UFD. Euclidean Domains. Euclidian Domain implies PID. Gaussian Integers and Fermat's $p = a^2+b^2$ Theorem.	4 Hours 8 Hours 8 Hours 8 Hours 16 Hours 16 Hours
Pedagogy	Lectures/ Tutorials/Assignments/Self-study	
References/ Readings	1. Contemporary Abstract Algebra, Joseph A. Gallian, Narosa Publishing House,1999. 2. A First Course in Absract Algebra, John B. Fraleigh, Pearson (India), 2014. 3. Topics in Algebra, I.N.Herstein, Wiley India Edition,2006. 4. Abstract Algebra, David S.Dummit and Richard M. Foote, Second Edition, John Wiley & Sons, 1999.	
Learning Outcomes	On completion of this course ,the student will be able to • Explain Concepts in Algebra regarding Groups, Rings and related structures, and develop the ability to work with various algebraic structures. • Lay foundation for research topics in Algebra, Number Theory, Algebraic Geometry etc.	

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Programme: M. Sc. Mathematics
Course Code: MTC-104 **Title of the Course:** COMPLEX ANALYSIS
Number of Credits: 04
Effective from AY: 2022-2023

Prerequisites	Should have studied a basic course in Complex Analysis familiarising the students with the notions of Analytic Functions, Cauchy's Integral Formula, convergence series, Taylor/Laurent series.	
Objective	This course will further enhance the knowledge of the student in the fundamental concepts in complex analysis and prepare them to apply it to problems involving complex analysis and also gives the foundation for advanced courses in complex analysis.	
Content	**Introduction to the Concept of Analytic Function**: (Limits and Continuity, Analytic Functions, Polynomials, Rational Functions), **Elementary Theory of Power Series**: (Sequences, Series, Uniform Convergence, Power Series, Abel's Limit Theorem), The Exponential and Trigonometric Functions, Periodicity & Logarithm.	12 Hours
	Analytic Functions: Conformality, Arcs and Closed Curves, Analytic Functions in Regions, Conformal Mapping, Linear Transformations, Oriented Circles, Families of Circles, Elementary Conformal Mappings, A Survey of Elementary Mappings.	16 Hours
	Complex Integration: Line Integrals, Rectifiable Arcs, Line Integrals as Functions of Arcs, Cauchy's Theorem for a Rectangle, Cauchy's Theorem in a Disk. Cauchy's Integral Formula, Higher Derivatives. **Local Properties of Analytical Functions:** Removable Singularities. Taylor's Theorem, Laurents Theorem, Zeros, and Poles, Local Mapping, Maximum Principle.	19 Hours
	The General Form of Cauchy's Theorem: Chains and Cycles, Simple Connectivity. **The Calculus of Residues**: The Residue Theorem, The Argument Principle, Evaluation of Definite Integrals.	13 Hours
Pedagogy	Classroom lectures, tutorials, assignments, and library references.	
References/ Readings	1. Ahlfors, L. V. (1979). *COMPLEX ANALYSIS*. McGraw-Hill Book Company 2. J B Conway, *Functions of a Complex Variable*, Narosa. 1995 3. S Kumaresan. *A Pathway to COMPLEX ANALYSIS*. Techno World, Kolkata. 2021 4. James Ward Brown and Ruel V. Churchill, *Complex Variables and Applications*, Sixth Edition, McGraw-Hill International, 1996. 5. A.R. Shastri, *Complex Analysis*. MacMillan, 2011	

	6. S. Ponnusamy, Foundations of Complex Analysis, Narosa Publisher, 2011
Learning Outcomes	This course will equip students for problem-solving and serve as a foundation for an advanced course in Complex Analysis and studies in Applied Mathematics.

Programme: M.Sc. Mathematics
Course Code: MTC -201 **Title of the Course: TOPOLOGY**
Number of Credits: 04
Effective from: 2022-2023

Prerequisites	Should have undergone a basic course in Real Analysis. Should be familiar with the notions of set theory. It is desirable to have familiarity with the metric topology.
Objectives	To prepare students to handle courses involving topology and geometry including complex analysis, functional analysis and several variable calculus.
Contents	**1. Topological Spaces and Continuous Functions**: 32 hours Topological spaces, Basis for a Topology, The Order Topology, The Product Topology on $X \times Y$, The Subspace Topology, Closed Sets and Limit Points, Continuous Functions, The Product Topology, The Metric Topology, The Quotient Topology. **2. Connectedness**: Connected Spaces, Connected Subspaces of $\mathbb{R}$, Components and Local Connectedness. 8 hours **3. Compactness**: Compact Topological Spaces, Compact Subspaces of $\mathbb{R}$, Limit Point Compactness, Local Compactness, 12 hours **4. Countability and Separation Axioms**: Countability Axioms, Separation Axioms, Hausdorff Spaces, Regular Spaces, Normal Spaces. 8 hours
Pedagogy	Class room lectures and tutorials, assignments and library reference.
References	1. James Munkres, Topology and Introduction, Pearson Education, 2002. 2. Stephen Willard, General Topology, Dover, 1941 3. M AAmstrong, Basic Topology, Springer Verlag, 1983. 4. J. Dugunji, Topology, Allyn and Bcon, 1966
Learning Outcomes	Students will be prepared to undertake basic courses in Complex Analysis, Functional Analysis, Several Variable Calculus, Measure Theory etc. and advanced courses in Topology and Geometry.

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Programme: M.Sc. Mathematics
Course Code: MTC-202 Title of the Course: DIFFERENTIAL EQUATIONS
Number of Credits: 04
Effective from: 2022-2023**.**

Prerequisites	Knowledge of basic Real Analysis , Linear Algebra and Differential equations.	
Objectives	This course develops the ability to understand the qualitative theory and some properties of solution of differential equations.	
Contents	Linear equations of first order: Introduction, Differential equations, Problems associated with differential equations, Linear equation of first order: homogenous and non-homogenous, Bernoulli's equation, The general linear equation of first order.	8 hours
	Linear Equations with constant coefficients: Introduction, Second order homogenous and non- homogenous equation, Initial value problems for second order equations, Linear dependence and independence, Formula for Wronskian, The homogenous and non- homogenous equation of order n, Various methods to solve non homogenous equation, Initial value problems for nth order equations, Equations with real constants.	10 hours
	Linear Equations with variable coefficients: Introduction, Initial value problems for homogenous and non-homogenous equation and its solution, Wronskian and linear independence, Reduction of order of homogenous equations, The homogenous equations with analytic coefficients. Legendre's Equation, Legendre's Polynomials $P_n(x)$ and $Q_n(x)$, Generating functions for $P_n(x)$, Rodrigue's formula, Recurrence formula.	14 hours
	Linear Equations with regular singular points: Introduction, Euler's equation, Second order equation with regular singular point, Bessel's Equation, Definition of $J_n(x)$, Recurrence formula, generating function,	10 hours
	Existence and Uniqueness of Solutions of First Order Equations: Introduction, Equations with variable separated, Exact equations, The Lipschitz Condition, System of Linear differential Equations , Vector matrix form, Linear systems with constant and variable coefficients, Fundamental matrix, Method of successive approximations, Picards Method, Conversion of nth order equation to system of first order.	12 hours
	Self adjoint Second order differential Equation, Strum Liouville Problem, Green's function, Comparision Theorems	6 hours
Pedagogy	Lectures/ tutorials/assignments/self-study	
References	Main and ReferenceTexts: 1. E.A. Coddington; An Introduction to Ordinary Differential Equations, Prentice Hall, India, 2003	

	2. Simmons G.F.; Differential Equations with Historical Notes, Tata M H., 2017 3. Deo S.G.; Raghuvendra V.; RasmitaKar, Lakshmikantantham V., Textbook of Ordinary Differential Equations, 3rd edition, Tata M.H. New Delhi 2015 4. Kelly W., Patterson A.C.; Theory of Differential Equations, Springer, 2010
Learning Outcomes	Students will learn to solve system of ordinary differential equations and to analyse the properties of solution.

Programme: M.Sc. Mathematics
Course Code: MTC-203 **Title of the Course:** SEVERAL VARIABLE CALCULUS
Number of Credits: 04
Effective from: 2022-2023

Prerequisites	Knowledge of basic Real Analysis and Linear Algebra. Knowledge of Integration of real-valued functions on a subset of R is desirable.		
Objectives	This course develops the ability to understand concepts of functions of severable variables.		
Contents	**1.Derivative of Function of more than one Variable:** Partial Derivative. Total derivative of a function of more than one Variable. Jacobian. Sufficient Condition for differentiability. Mean Value Theorem. Higher-order derivatives. Condition for Equality of Mixed Partial Derivatives. Taylor's Theorem.	08 hours	
	2.Maximum Minimum: Critical Point, Maximum Minimum, Second Derivative Condition for Maximum/minimum, Conditional Optimum, and Lagrange Multipliers.	08 hours	
	3.Inverse Function Theorem: Regular and Singular Points, Open Mapping Theorem, Inverse Function Theorem, Implicit Function Theorem.	08 hours	
	4.Riemann Integration: Rectangles in IRn and Riemann sums over Rectangles. Upper and Lower Riemann Sums. Riemann Integral of a bounded Function. Algebra of Riemann Integrals. Sets of Jordan Measure Zero. Oscillation of a Function at a point, Integrability versus points of discontinuity of a Function.	18 hours	
	5.Fubini's Theorem. Mean value theorem for multiple integrals. Partitions of unity (Statement only). Change of variable formula	06 hours	
Pedagogy	Classroom lectures, tutorials, assignments, and library references.		

References	**Main Texts:** 1. Tom M Apostol, Mathematical Analysis, Addison Wesley Publishing Company, 1996. 2. M.Spivak, Calculus on Manifolds, Benjamin Cummings, London. 1965 **Reference texts :** 1. Walter Rudin, Principles of Mathematical Analysis, International Student Edition.1976 2. James Munkres, Analysis on Manifolds, Addison Wesley Publishing Company,1991. 3. T. M. Apostol, Calculus Vol.II. John Wiley and sons.1969 4. B.V.Limaye&S.Ghorpade, A course in multivariable calculus, Springer 2006
Learning Outcomes	Learn to understand the concepts of functions of several variables. Compute the maximum/minimum of functions of several variables and evaluate multiple integrals.

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Programme: M. Sc. (Mathematics)
Course Code: MTC-204
Title of the Course: FUNCTIONAL ANALYSIS
Number of Credits: 4
Effective from AY: 2022-2023

Prerequisites	A first course in Real Analysis, Linear Algebra and Metric Toplogy. Basic understanding of Lebesgue Integral Theory is desirable.	
Objective	Starting with the basics this course will cover the foundations of Functional Analysis such as normed spaces, inner product spaces, Banach spaces, Hilbert spaces, bounded linear operators and bounded functional, and the four fundamental theorems-Hahn-Banach Theorem. Uniform Boundedness Principle, Open Mapping Theorem and Closed Graph Theorem.	
Content	**1.Preliminaries from Metric Spaces** Definition of the standard sequence spaces $s, c,\ c_0, c_{00}, l^p; 1 \leq p \leq \infty$, and standard function spaces $C[a,b]$and $B[a,b]$. Idea of completion of a metric space, completeness and separability properties of these standard spaces **2.Normed Spaces, Banach Spaces** Normed spaces- Properties and Banach spaces, Standard normed spaces –Sequence spaces , Function spaces and subspaces, Finite dimensional normed spaces and subspaces, Equivalence of norms, Compactness and finite dimension, Linear Operators-Boundedness and Continuity. Linear functional. Normed spaces of Operators, Dual space-Algebraic and Topological duals.	12Hours 16 Hours 16 Hours

	3.Inner Product Spaces, Hilbert Spaces Inner Product Spaces- Properties and Hilbert spaces, Orthogonal Complement and Direct Sums, Orthonormal Sets and Sequences, Total Orthonormal Sets and Sequences, Representation of Functional on Hilbert Spaces, Hilbert - Adjoint Operator, Self Adjoint, Unitary and Normal Operators. **4.Fundamental Theorems for Normed and Banach Spaces** Hahn-Banach Theorem **(**Statements and idea of proof for the case of vector spaces, statement and proof for normed spaces**)**,Applications to Existence of Functionals, Adjoint Operators, Reflexivity of Spaces, Baire Category Theorem **(**Statement only**)**, Uniform Boundedness Theorem, Open Mapping Theorem, Closed Graph Theorem.	16 Hours
Pedagogy	Lectures/ Tutorials/Assignments/Self-study	
References/ Readings	1. Introductory Functional Analysis with Applications, Ervin Kreyszig, John Wiley & Sons, 1978. 2.Functional Analysis, Balmohan V. Limaye, III edition. 1996 3. Functional Analysis, A First Course, S.Kumaresan and D.Sukumar, Narosa, 2020 4.Functional Analysis, George Bachman and Lawrence Narici, DoverPublishing House, 2000 5. Basic Operator Theory, IsrayelGohberg and Seymour Goldberg, Birkh$\ddot{a}$user, 1981. 6. Linear Real analysis for Scientists and Engineers, B.V.Limaye, Springer. 2016	
Learning Outcomes	On completion of the course the student will have • Understanding of the basic concepts and fundamental theorems of Functional Analysis • Appreciation of Functional Analysis as an important field for application oriented Mathematics. • Ability to relate and apply the concepts learnt in the course to problems. • Foundation for higher courses in Functional analysis, Operator Theory, PDE etc.	

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M.Sc. Mathematics Discipline Specific Optional Papers
Programme: M.Sc. Mathematics
Course Code: MTO-101 **Title of the Course: Mathematical Methods**
Number of Credits: 04
Effective from: 2022-2023

Prerequisites	Knowledge of basic Real Analysis, Linear Algebra, Differential Equations.	
Objectives	This course develops the ability to apply mathematics to some of the problems of Mathematics and Physics.	
Contents	**1. Improper Integrals**. Review , Properties and L^2 convergence.	08 hours
	2. Fourier series: Generalized Fourier series, Fourier sine/cosine series. Point wise and uniform convergence. Differentiation and integration of Fourier series.	08 hours
	3. Fourier Transforms and its properties: : Fourier Transform of L^1 (IR)—functions. Basic properties related to translation, dilation and linearity. Computation of Fourier transform of simple functions. Fourier Inversion. Statement of Fourier inversion Theorem. Convolution. Convolution Theorem. Examples. Parsevaal's Identity. Fourier Integral Formula. An Integration Formula and Lemmas. Fourier Integral Theorem. The Cosine and Sine Integrals.	14 hours
	4. Variational problems: Variational problems with fixed boundaries. Euler-Lagrange equations and Brachistochrone problem, Elementary variational problems with moving boundaries. One-side variation, Isoperimetric problem, Canonical forms of Euler equations. Sufficient conditions for extremum.	30 hours
Pedagogy	Lectures/ tutorials/assignments/self-study	
References	**Main Texts:** 1. J.W.Brown and R.V.Churchill, Fourier series and Boundary Value Problems, McGraw Hill. (2012) [Chapters 2 and 6] 2. K.SankaraRao, Introduction to Partial Differential Equations, Prentice Hall of India, 1995. 3. Lev Elsgolts, Introduction to the Calculus of Variations, MIR Publications. 2003 4. T. Apostal Mathematical analysis, Narosa Publishers. 1973 **Reference texts :** 4. G.B.Arfken and H. Weber, Mathematical methods for Physicists. Elsevier Publications. 2012 5. R. Weinstock, Calculus of Variations, Dover Publication. 1952 6. I.M.Gelfand and S.V.Fomin, Calculus of Variations. Dover Publication. 1963	
Learning Outcomes	1. Theory and applications of Fourier Series 2. Learns techniques of applying Fourier Transform. 3. Understands basic concepts of variational problems	

Programme: M.Sc. Mathematics
Course Code: MTO -102 **Title of the Course: DIFFERENCE EQUATIONS**
Number of Credits: 04
Effective from AY: 2022-2023

Prerequisites	Knowledge of basic Real Analysis, Linear Algebra and Differential equations..	
Objectives	This course helps in understanding basic concepts of discrete calculus. It develops the ability to solve difference equations by standard methods. It will help students to take up further studies in discrete dynamical systems and numerical modeling.	
Contents	1. Calculus of finite differences: Review of basic concepts.	10 hours
	2. Nonlinear Difference Equations. Equilibrium Points and their dynamics. Logistic equation.	12 hours
	3. Linear difference equations. Basic theory. Method of Undetermined Coefficients and Variation of Parameters Formula. Higher Order equations. Behaviour of Solutions. Nonlinear equations transformable to linear equations	16 hours
	4. Systems of linear Difference Equations. Basic Theory. Linear Periodic systems. Stability theory of Linear Systems.	12 hours
	5. Z-Transforms and its applications. Volterra Difference Equation of Convolution Type.	10 hours
Pedagogy	Lectures/ tutorials/assignments/self-study..	
References	**Main Texts:** 1 . S.N .Elaydi, An Introduction to Difference Equations, Springer Verlag. 1996 **Reference texts :** 2. S.Goldberg , Introduction to Difference equations, Wiley Publication.1987 3. V.Lakshmikantham and D.Trigiante, Theory of difference equations, Academic Press. 1988 4. K.Miller, Linear Difference equations, W.A.Benjam. 1968	
Learning Outcomes	1. Learn to solve difference equations. 2. Analyses the properties of solution. 3. Learns about discrete models and their stability	

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Programme: M. Sc. (Mathematics)
Course Code: MTO-103 **Title of the Course:** Special Functions
Number of Credits: 4
Effective from AY: 2022-2023

Prerequisites for the course:	Some basic Complex Analysis and Differential Equations.	

Objective:	This course develops concepts in Gamma, Beta functions and also studies Legendre polynomials and Bessels functions.	
Content:	1. **Infinite products**:- Introduction, definition of an infinite product, a necessary condition for convergence, the associated series of logarithms, absolute convergence, uniform convergence. 2. **The Gamma and Beta functions**:- The Euler and Mascheroni constant, the Gamma function, a series for Γ'(z)/ Γ(z), evaluation of Γ(1) and Γ'(1), the Euler product for Γ(z), the difference equation Γ(z + 1) = zΓ(z), evaluation of certain infinite products, Euler's integral for Γ(z), the Beta function, the value of Γ(z) Γ(1 - z), the factorial function, Legendre's duplication formulae, Gauss' multiplication theorem, a summation formula due to Euler. 3. **The hypergeometric function**:- The function F(a,b; c; z), a simple integral form, F(a,b,c,1) as a function of the parameters, evaluation of F(a,b,c,1), the contiguous function relations, the hypergeometric differential equation, F(a,b,c,z) as a function of its parameters, elementary series manipulations, simple transformations. 4. **Series solution of differential equations**. Method of Frobenius. **Legendre Polynomials and Functions**. Legendre equation and its solution. Generating function. Legendre series. Associated legendre functions. Properties of associated Legendre functions. **Bessel function, Bessel's equatin and its solutions**. Generating function. Integral representation. Recurrence relations. Hankel functions. Equations reducible to Bessel's equation. Modified Bessels functions. Recurrence relations for modified Bessels functions. Hermite Polynomials, Lauerre Polynomials	6 hours 12 hours 10 hours 8 hours 8 hours 8 hours 8 hours
Pedagogy:	lectures/ tutorials/assignments/self-study.	
References/Readings	1. E.D. Rainville, Special functions, Chelsa Publishing Company, New York, 1960. 2. W.W. Bell, Special Functions for scientists and engineers, Dover Publications, New York, 2004. 3. G.E. Andrews, R. Askey, R. Roy, Special .Functions, Encyclopedia of Mathematics and its Applications 71, Cambridge University Press, Cambridge.1999.	
Learning Outcomes	Taking this course students	

	(i) get acquainted with Gamma, Beta functions. Also they study Legendre and Bessel Functions. (ii) can study some Engineering Mathematics.	

Programme: M.Sc. Mathematics
Course Code: MTO-104 Title of the Course: PARTIAL DIFFERENTIAL EQUATIONS
Number of Credits: 04
Effective from AY: 2022-2023

Prerequisites	Knowledge of Real Analysis, Calculus of Several Variables, Ordinary differential equations, Methods of Applied Mathematics.	
Objectives	This course develops the ability to solve partial differential equations of first and second order by standard methods.	
Contents	**1.Simultaneous differential equations of the first and first degree in three variables:** Methods of solutions of $dx/P = dy/Q = dz/R$. Pfaffian differential forms and equations. Solution ofPfaffian differential equations in three variables.	6 hours
	2. First order PDE's: Origin and classifications. Solution of Linear and Nonlinear First order PDE's. Methods of characteristics. Charpit's Methods. Jacobi's method.	14 hours
	3. Second Order Linear Partial Differential Equations: Origin. Linear equations with constant coefficients in two independence Variables. Linear equations with variable coefficients. Classification.Reduction to Canonical Form. (only for the case of two independent variables).	8 hours
	4. Methods of solving PDE : Method of Separation of variables. Use of Integral transforms (Laplace and Fourier).	10 hours
	5. Wave Equation. One dimensional Wave equation.D' Alembert' solution, Wave equation-Infinite string case. **Laplace Equation :**Harmonic function. Basic properties of harmonic functions. Laplace equation.Translational and rotational invariance of Laplace equation. Boundary value problems. Uniqueness of solutions of Dirichlet and Neumann problems. Mean value theorem for harmonic functions. Maximum and minimum principle for harmonic functions. Uniqueness and stability for Dirichlet problem. **Heat equation**- Infinite rod case. Non homogeneous equation.	22 hours
Pedagogy	Lectures/ tutorials/assignments/self-study	
References	**Main Texts:** 1. I. Sneddon, Elements of Partial Differential Equations, McGrow Hill. 1957 2. T.Amarnath, An elementary course in Partial Differential Equations, Narosa Publishing company, 1997**.** **Reference texts :** 3.K.SankaraRao, Introduction to Partial Differential Equations, Prentice Hall of India, 1995. 4. F.John, Partial Differential equations, Springer Verlag Ltd. 1952	

	5. C.R. Chester, Techniques of Partial Differential Equations. McGraw Hill. 1970 6. R.Dennemeyer, *Introduction to Partial Differential Equations and Boundary Value Problems*, McGraw Hill. 1968 7. T.M. Hu, L. Debnath, Linear Partial differential equations for scientists and Engineers, Birkhauser. 2007
Learning Outcomes	Learns to solve partial differential equations of first and second order. Learns to model initial and boundary value problems. Analyses the properties of solution.

Programme: M.Sc. Mathematics
Course Code MTO -105 **Title of the Course: INTEGRAL EQUATIONS**
Number of Credits: 04
Effective from AY: 2022-2023

Prerequisites	Knowledge of Real Analysis, Linear Algebra, Differential equations, Several variable calculus.	
Objectives	This course helps in understanding basic concepts of Integral Equations. It develops the ability to solve integral equations by standard methods.	
Contents	1. Basic concepts of Integral equations. Classification. Integral Equations with Separable Kernels. Method of Successive Approximations. Resolvent Kernel and its Properties. Decomposition methods.	18 hours
	2. Applications to Ordinary Differential Equations, Initial Value Problems and Boundary Value Problems, Green's functions.	14 hours
	3. Classical Fredholm Theory. Symmetric Kernels, Hilbert-Schmidt Theory.	12 hours
	4. Singular Integral Equations, Abel and Cauchy Type and Hilbert Kernel. Integral Transform Methods (Laplace, Fourier and Hilbert).	16 hours
Pedagogy	Lectures/ tutorials/assignments/self-study	
References	**Main Texts:** 1. Ram P Kanwal, Linear Integral Equations, Theory and applications. Springer. 1971 **Reference texts :** 2. Courant and Hilbertt, Methods of Mathematical Physics, Vol. I. 1989 3. S.G.Mikhilin, Integral Equations. Courier Dover Publisher, 2020 4. I.G.Petrovsky, Lectures on the theory of Integral equations. Mir Publisher, 1971 5. K.Yoshida, Lectures on Differential and Integral Equations Interscience Publisher, 1960	
Learning Outcomes	Students will learn to solve Integral equations by different methods. .	

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Annexure II

Semester – IV **Credits: 4**

SEC 2 : Analytical Geometry

1. **Metric Properties on the Plane**. (3 hours)
Distance formula, section ratio, slope or gradient, locus, area of plane figures

2. **Straight Lines in the Plane**. (3 hours)
Different forms of a straight line, point in relation to a straight line, pair of straight lines.

3. **Circles in Plane**. (3 hours)
Different forms of a circle equation, line in relation to a circle, tangents and normal, poleand polar.

4. **Conics in the Plane and its plane sections**. (12 hours)
Parabola – equation and properties, Ellipse – equation and properties, Hyperbola – equationand properties, tangents and normal, pole and polar.

5. **Classification of Conics**. (5 hours)
Conditions under which the equation representing a conic represents various geometricobjects – derivation and examples.

6. **Polar Co-ordinate System**. (3hours)
Polar coordinates, relation between polar and cartesian coordinates, equation of a straightline, intersection between straight lines, distance of a point from a straight line.

7. **Co-ordinates in 3-space**. (3 hours)
Coordinates of a point in space, angle between two lines, direction cosines of a line, relation between direction cosines.

8. **Plane in 3-space**. (4 hours)
Equation of the first degree representing a plane – necessary and sufficient condition, direction cosines of the normal to the plane, angle between two planes, plane through threepoints.

9. **Lines in 3-space**. (3 hours)
Equation of a line through a given point in a given direction, equation of a line through twopoints, angle between a line and plane, shortest distance between two lines.

10. **Transformation of Co-ordinates**. (4 hours)
Change of origin, change of the direction of a axes.

11. **Sphere**. (4 hours)
Equation of a sphere, sphere through four given points, intersection of two spheres, equation of a tangent plane.

12. **Cones**. (4 hours)
Equation of a cone, condition that the general equation of the second degree should

represent a cone, intersection of line with a cone – tangent line and condition for tangency,right circular cone – definition and equation.

13. **Cylinder**. (4 hours)
Equation of a cylinder, right circular cylinder – definition and equation.

14. **The Conicoid**. (5 hours)
General equation of second degree, shapes of some surfaces, intersection of a line with aconicoid – tangent line, tangent plane at a point and condition for tangency, plane of contact.

Reference:

i) Analytic Geometry: Two and Three Dimension, D. Chatterjee, Narosa Publishing House,2009. **(for chapters 1 to 6**)

ii) Analytic Geometry, Shanti Narayan and P. K. Mittal, S. Chand and Company Ltd, 2007.(for chapters 7 to 14)

Remark:

i) Tracing of general second degree conics/conicoids using the mathematical softwareGEOGEBRA, SAGE, MATH and PYTHON.

ii) Properties of pair of lines, circles, parabola, Ellipse etc., may be verified using mathematical softwates lime GEOGEBRA/SAGEMATH.

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