MAR IVANIOS COLLEGE (AUTONOMOUS)

Affiliated to the University of Kerala,
Thiruvananthapuram
Kerala

SCHEME AND SYLLABUS FOR THE FIRST DEGREE PROGRAMME
BACHELOR OF SCIENCE IN MATHEMATICS

(With effect from 2021 Admissions)

Approved by the Board of Studies in
Mathematics and Statistics

FIRST DEGREE PROGRAMME IN MATHEMATICS (CORE)

Programme Specific Outcomes

- **PSO1 :** Provide students with a thorough knowledge of fundamental Mathematical facts
- **PSO2 :** To enhance the students reasoning, analytical and problem-solving skills
- **PSO3 :** Adequately prepare students to pursue further studies in Mathematics and allied areas
- **PSO4 :** Instill in the students the spirit of doing research in Pure and Applied Mathematics and allied areas
- **PSO5 :** To prepare graduates with the capabilities to teach the Mathematics curriculum at the higher secondary level
- **PSO6 :** To encourage students to uphold scientific integrity and objectivity in professional endeavors

GENERAL STRUCTURE

(ESE-End Semester Exam), CE (Continuous Evaluation) L-Lecture, P-Practical

FDP B.Sc. MATHEMATICS (Core)			**Instructional h/week**	**Credit**	**ESE/ ESA duration (h)**	**CE / CA %**	**ESE/ ESA %**
Semester	**Paper Code**	**Title of Course**					
1.	AUMM 141	Methods of Mathematics	4	4	3	20	80
2.	AUMM 221	Foundations of Mathematics	4	3	3	20	80
3.	AUMM 341	Elementary Number Theory and Calculus - I	5	4	3	20	80
4.	AUMM 441	Elementary Number Theory and Calculus - II	5	4	3	20	80
5.	AUMM 541	Real Analysis - I	5	4	3	20	80
	AUMM 542	Complex Analysis - I	4	3	3	20	80
	AUMM 543	Abstract Algebra - Group Theory	5	4	3	20	80
	AUMM 544	Differential Equations	3	3	3	20	80
	AUMM 54PI	Computer Programming - I (Practical Examination only)	4	3	3	20	80
	AUMM 581.a/b/c/d	Actuarial Science / Business Mathematics/ Operations Research/ Basic Mathematics (Open Course)	3	2	3	20	80
	------	Project Preparation	1	--	--	--	--
6.	AUMM 641	Real Analysis – II	5	4	3	20	80
	AUMM 642	Complex Analysis - II	4	3	3	20	80
	AUMM 643	Abstract Algebra - Ring Theory	4	3	3	20	80
	AUMM 644	Linear Algebra	5	4	3	20	80
	AUMM 645	Graph Theory	4	3	3	20	80
	AUMM 691.a/b/c/d AUMM 64PI	Integral Transforms / Linear Programming with SageMath / Numerical Methods and Hands-On SageMath / Fuzzy Mathematics / Computer Programming - II (Practical Examination only)	3	2	3	20	80
	AUMM 646	Project	--	4	3	-	100

TOTAL CREDITS

	Semester 1	Semester 2	Semester 3	Semester 4	Semester 5	Semester 6
Total Credits (120)	17	17	18	26	19	23

QUESTION PAPER PATTERN (For all Semesters)

Question Type	Total number of Questions	Number of Questions to be answered	Marks for each Question	Total Marks
Very short answer type (Probably Objective type)	10	10	1	10
Short answer type (simple and short answer problems-knowledge level)	12	8	2	16
Long answer type (simple and long answer problems - understanding level)	9	6	4	24
Long essay (theory/ problems eliciting applications - knowledge, understanding and application levels)	4	2	15	30
Total	**35**	**26**	**---**	**80**

SEMESTER - 1

AUMM 141: Methods of Mathematics

Total Teaching Hours: 72	**No of Lecture Hours/Week: 4**
Max Marks: 80	**Credits: 4**

Course Outcomes:

CO1: Gaining practice in solving problems in limits.
CO2: Finding the rate of changes through differentiation method.
CO3: Finding the area under a curve through the integration method.

Text: H Anton, I Bivens, S Davis, *Calculus*, 10th Edition, John Wiley & Sons	
Module I Methods of Differential Calculus	**Total Teaching Hours: 36**

In the beginning of this module, the basic concepts of calculus like limit of functions especially infinite limits and limits at infinity, continuity of functions, basic differentiation, derivatives of standard functions, implicit differentiation etc. should be reviewed with examples.

(The above topics which can be found in Chapter 2 of the text are not to be included in the end semester examination. A maximum of 5 hours should be devoted for the review of the above topics.)

After this quick review, the main topics to discuss in this module are the following:

Differentiating equations to relate rates, how derivatives can be used to approximate non-linear functions by linear functions, error in local linear approximation, differentials; Increasing and decreasing functions and their analysis, concavity of functions, points of inflections of a function and applications, finding relative maxima and minima of functions and graphing them, critical points, first and second derivative tests, multiplicity of roots and its geometrical interpretation, rational functions and their asymptotes, tangents and cusps on graphs.

Absolute maximum and minimum, their behavior on various types of intervals, applications of extrema problems on infinite and infinite intervals, and in particular, applications to Economics.

Motion along a line, velocity and speed, acceleration, Position - time curve, Rolle's, Mean Value theorems and their consequences, Indeterminate forms and L'Hopital's rule.

[The topics to be discussed in this module can be found in Chapters 2, 3 & 6]

Module II Methods of Integral Calculus	Total Teaching Hours: 36

The module should begin with revising integration techniques, like integration by substitution, fundamental theorem of calculus, integration by parts, integration by partial fractions, integration by substitution and the concept of definite integrals.

(The above topics which can be found in Chapters 4 and 7 of Text 1 below are not to be included in the end semester examination. A maximum of 5 hours should be devoted for the review of the above topics).

After this quick review, the main topics to discuss in this module are the following:
Finding position, velocity, displacement, distance travelled of a particle by integration, analyzing the distance - velocity curve, position and velocity when the acceleration is constant, analyzing the free-fall motion of an object, finding average value of a function and its applications.

Area, volume, length related concepts: Finding area between two curves, finding volumes of some three - dimensional solids by various methods like slicing, disks and washers, cylindrical shells, finding length of a plane curve, surface of revolution and its area.

Work done: Work done by a constant force and a variable force, relationship between work and energy;

Relation between density and mass of objects, center of gravity, Pappus theorem and related problems Fluids, their density and pressure, fluid force on a vertical surface.
Introduction to hyperbolic functions and their applications in hanging cables.
Improper integrals, their evaluation, applications such as finding arc length and area of surface.

[The topics to be discussed in this module can be found in Chapters 4, 5, 6 & 7]

References:

1. G B Thomas, R L Finney, *Calculus*, 9th Edition, Addison-Wesley Publishing Company.
2. J Stewart, *Calculus with Early Transcendental Functions*, 7th Edition, Cengage India Private Limited.
3. Tom M. Apostol, *Calculus*, Volume 1, 2nd Edition, John Wiley & Sons.
4. Tom M. Apostol, *Calculus*, Volume 2, John Wiley & Sons.

SEMESTER - 2

AUMM 221: Foundations of Mathematics

Total Teaching Hours: 72	**No of Lecture Hours/Week: 4**
Max Marks: 80	**Credits: 3**

Course Outcomes:

CO1 : Review of concepts of sets and functions.

CO2 : Understand the way in which a mathematician formally makes statements and proves or disproves it.

CO3 : Review of vector calculus.

Texts:

1. **S R Lay, *Analysis with an Introduction to Proof*, 5th Edition, Pearson Education Limited.**
2. **H Anton, I Bivens, S Davis, *Calculus*, 10th Edition, John Wiley & Sons.**

Module I Foundations of Logic and Proof	**Total Teaching Hours: 24**

The following are the main topics in this module:

Statements, logical connectives, and truth tables, conditional statements and parts of it, tautology and contradiction, using various quantifiers like universal and existential quantifiers in statements, writing negations, determining truth value of statements.

Proof: Various techniques of proof like inductive reasoning, counter examples, deductive reasoning, hypothesis and conclusion, contrapositive statements, converse statements, contradictions, indirect proofs.

Sets and relations: A review of basic set operations like union, intersection, subset, superset concepts, equality of sets, complements, disjoint sets, indexed family of sets and operations on such families, ordered pairs, relations on sets, cartesian products (finite case only), various types of relations (reflexive, symmetric, transitive, equivalence), partitions of sets.

Functions: domain, codomain, range of functions, one - one, onto, bijective functions, image, preimage of functions, composing functions and the order of composition, inverse functions.

[The topics to be discussed in this module can be found in Chapters 1 & 2 of Text 1]

Module II Foundations of Co - ordinate Geometry	Total Teaching Hours: 24

The following are the main topics in this module:

Parametric equations of a curve, orientation of a curve, expressing ordinary functions parametrically, tangent lines to parametric curves, arc length of parametric curves.

Polar co-ordinate systems, converting between polar and rectangular co-ordinate systems, graphs in the polar co-ordinate system, symmetry tests in the polar co-ordinate system, families of lines, rays, circles, other curves, spirals.

Tangent lines to polar curves, arc length of the curve, area, intersections of polar curves.

Conic sections: definitions and examples, equations at standard positions, sketching them, asymptotes of hyperbolas, translating conics, reflections of conics, applications, rotation of axes and eliminating the cross-product term from the equation of a conic, polar equations of conics, sketching them, applications in astronomy such as Kepler's laws, related problems.

[The topics to be discussed in this module can be found in Chapter 10 of Text 2]

Module III Foundations of Vector Calculus	Total Teaching Hours:24

To begin with, the three-dimensional rectangular co-ordinate system should be discussed and how distance is to be calculated between points in this system. Basic operations on vectors like their addition, cross and dot products should be introduced next. The concept of projections of vectors and the relation with dot product should be given emphasize.

Equations of lines determined by a point and vector, vector equations in lines, equations of planes using vectors normal to be should be discussed. Quadric surfaces which are three dimensional analogues of conics should be discussed next. Various co-ordinate systems like cylindrical, spherical should be discussed next with the methods for conversion between various co-ordinate systems.

[The topics to be discussed in this module can be found in Chapter 11 of Text 2]

References:

1. J P D'Angelo, D B West, *Mathematical Thinking - Problem Solving and Proofs*, 2nd Edition, Prentice Hall.
2. Daniel J Velleman, *How to Prove it: A Structured Approach*, 2nd Edition, Cambridge University Press.
3. Elena Nardi, Paola lannonne, *How to Prove it: A brief guide for teaching Proof to Year 1 mathematics undergraduates*, University of East Anglia, Centre for Applied Research in Education.
4. G B Thomas, R L Finney, *Calculus*, 9th Edition, Addison-Wesley Publishing Company.
5. J Stewart, *Calculus with Early Transcendental Functions*, 7th Edition, Cengage India Private Limited.

SEMESTER - 3

AUMM 341: Elementary Number Theory and Calculus – I

Total Teaching Hours: 90	No of Lecture Hours/Week: 5
Max Marks: 80	Credits: 4

Course Outcomes:

CO1: Understand fundamental facts in elementary number theory.
CO2: Understand the methods of calculus of vector valued functions.
CO3: Evaluation of multiple integrals and finding its applications

Texts: 1. **H Anton, I Bivens, S Davis, *Calculus*, 10th Edition, John Wiley & Sons**

2. **Thomas Koshy, *Elementary Number Theory with Applications*, 2nd Edition, Academic Press**

Module I Divisibility in Integers and Congruences	Total Teaching Hours: 18

The topic of elementary number theory is introduced for further developing the ideas in abstract algebra. The following are the main topics in this module:

The division algorithm, Pigeonhole principle, divisibility relations, inclusion - exclusion principle, base-b representations of natural numbers, prime and composite numbers, infinitude of primes, GCD, linear combination of integers, pairwise relatively prime integers, the Euclidean algorithm for finding GCD, the fundamental theorem of arithmetic, canonical decomposition of an integer into prime factors, LCM.

Linear Diophantine Equations and existence of solutions, Euler's Method for solving LDE's.

Defining congruence classes, complete set of residues, modulus exponentiation, finding reminder of big numbers using modular arithmetic, cancellation laws in modular arithmetic.

[The topics to be discussed in this module can be found in Chapter 2 Sections 1, 2, 5; Chapter 3 Sections 1 - 5 & Chapter 4 Section 1 of Text 2]

Module II Vector Valued Functions	Total Teaching Hours: 30

Towards going to the calculus of vector valued functions, we define such functions. Other topics in this module are the following:

Parametric curves in the three-dimensional space, limits, continuity and derivatives of vector valued functions, geometric interpretation of the derivative, basic rules of differentiation of such functions, derivatives of vector products, integrating vector functions, length of an arc of a parametric curve, change of parameter, arc length parametrizations, various types of vectors that can be associated to a curve such as unit vectors, tangent vectors, binormal vectors, definition and various formulae for curvature, the geometrical interpretation of curvature, motion of a particle along a curve and geometrical interpretation of various vectors associated to it, various laws in astronomy like Kepler's laws and problems.

[The topics to be discussed in this module can be found in Chapter 12 of Text-1]

Module III Multivariable Calculus	Total Teaching Hours: 42

After introducing the concept of functions of more than one variable, the sketching of them in three dimensional cases with the help of level curves should be discussed. Contours and level surface plotting also should be discussed. The other topics in this module are the following:

Limits and continuity of Multivariable functions, various results related to finding the limits and establishing continuity, continuity at boundary points, partial derivatives of functions, partial derivative as a function, its geometrical interpretation, implicit partial differentiation, changing the order of partial differentiation and the equality conditions.

Differentiability of a multivariate function, differentiability of such a function implies its continuity, local linear approximations, chain rules - various versions, directional derivative and differentiability, gradient and its properties, applications of gradients.

Tangent planes and normal vectors to level surfaces, finding tangent lines to intersections of surfaces, extrema of multivariate functions, techniques to find them, critical and saddle points, Lagrange multipliers to solve extremum problems with constrains.

[The topics to be discussed in this module can be found in Chapter 13 of Text 1]

References:

1. G. B. Thomas, R. L. Finney, *Calculus*, 9th Edition, Addison-Wesley Publishing Company.
2. J. Stewart, *Calculus with Early Transcendental Functions*, 7th Edition, Cengage India Private Limited.
3. G. A. Jones, J. M. Jones, *Elementary Number Theory*, Springer.

SEMESTER – 4

AUMM 441: Elementary Number Theory and Calculus – II

Total Teaching Hours: 90	**No of Lecture Hours/Week: 5**
Max Marks: 80	**Credits: 4**

Course Outcomes:

- **CO1:** Study abstract algebraic structures.
- **CO2:** Study the fundamental facts in elementary number theory.
- **CO3:** Learn to evaluate multiple integrals and get a knowledge on calculus of vector valued functions.

Texts: 1. **H Anton, I Bivens, S Davis, *Calculus*, 10th Edition, John Wiley & Sons.**
2. **Thomas Koshy, *Elementary Number Theory with Applications*, 2nd Edition, Academic Press.**

Module I Congruence Relations in Integers	Total Teaching Hours: 30

Towards defining the congruence classes in Z, we begin with defining the congruence relation. Its various properties should be discussed, and then the result that no prime of the form 4n + 3 is a sum of two squares should be discussed. The other topics in this module are the following:

Linear congruences and existence of solutions, solving Mahavira's puzzle, modular inverses, Pollard Rho factoring method.

Certain tests for divisibility - The numbers here to test are powers of 2, 3, 5, 7, 9, 10, 11, testing whether a given number is a square.

Linear system of congruence equations, Chinese Remainder Theorem and some applications.

Some classical results like Wilson's theorem, Fermat's little theorem, Pollard factoring method, Eulers' theorem.

Congruence Applications: Divisibility tests, Modular designs, Check digits, the p-Queens puzzle, Round-Robin tournaments, the perpetual calendar.

[Chapter 4 Sections 2, 3; Chapter 5 Sections 1, 2; Chapter 6 Section 1 & Chapter 7 Sections 1, 2, 4 of Text 2]

Module II Multiple Integrals	Total Teaching Hours: 30

Here we discuss double and triple integrals and their applications. The main topics in this module are the following:

Double integrals: Defining and evaluating double integrals, its properties, double integrals over non rectangular regions, determining limits of integration, revising the order of integration, area and double integral, double integral in polar coordinates and their evaluation, finding areas using polar double integrals, conversion between rectangular to polar integrals, finding surface area, surface of revolution in parametric form, vector valued function in two variables, finding surface area of parametric surfaces.

Triple integrals: Properties, evaluation over ordinary and special regions, determining the limits, volume as triple integral, modifying order of evaluation, triple integral in cylindrical co-ordinates, Converting the integral from one co-ordinate system to other.

Change of variable in integration (single, double, and triple), Jacobians in two variables.

[The topics to be discussed in this module can be found in Chapter 14 of Text 1]

Module III Vector Calculus	**Total Teaching Hours: 30**

After the differentiation of vector valued functions in the last semester, here we introduce the concept of integrating vector valued functions. Some important theorems are also to be discussed here. The main topics are the following:

Vector fields and their graphical representation, various type of vector fields (inverse-square, gradient, conservative), potential functions, divergence, curl, the operator, Laplacian.

Integrating a function along a curve (line integrals), integrating a vector field along a curve, defining work done as a line integral, line integrals along piecewise-smooth curves, integration of vector fields and independence of path, fundamental theorem of line integrals, line integrals along closed paths, test for conservative vector fields, Green's theorem and applications.

Defining and evaluating surface integrals, their applications, orientation of surfaces, evaluating flux integrals, The divergence theorem, Gauss' Law, Stoke's theorem, applications of these theorems.

[The topics to be discussed in this module can be found in Chapter 15 of Text 1]

References:

1. G. B. Thomas, R. L. Finney, *Calculus*, 9th Edition, Addison-Weseley Publishing Company.
2. J. Stewart, *Calculus with Early Transcendental Functions*, 7th Edition, Cengage India Private Limited.
3. G. A. Jones, J M Jones, *Elementary Number Theory*, Springer.

SEMESTER - 5

AUMM 541: Real Analysis – I

Total Teaching Hours: 90	**No of Lecture Hours/Week: 5**
Max Marks: 80	**Credits: 4**

Course Outcomes:

CO1 : Studying the basis of the metric space structure of R so as to serve as a stepping stone into the idea of abstract topological spaces.

CO2 : Know the realization of the set R of real numbers as a field.

CO3 : Acquire skill in using plotting software such as Geogebra to plot various functions.

Text: Stephen Abbot, *Understanding Analysis*, 2nd Edition, Springer.

Module I	**Total Teaching Hours: 25**

This module introduces the basic concepts about the real number system with some introduction to sets, functions, and proof techniques. The following are the main topics to be discussed: existence of an irrational number, the axiom of completeness, upper lower bounds of sets in R, consequences of completeness like Archimedean property of real numbers, Density of Q in R, existence of square roots, countability of Q and uncountability of R, various cardinality results, Cantor's original proof for uncountability of R, and Cantor's theorem on power sets.

The first section 1.1 may be briefly discussed and is not meant for examination purposes.

[The topics to be discussed in this module can be found in Chapter 1]

Module II	**Total Teaching Hours: 40**

Students must have already encountered the idea of infinite series through the example of geometric progression. After discussing the rearrangement concept of infinite series, the following topics are to be introduced rigorously:

Limit of a sequence, diverging sequences, examples, algebraic operations on limits, and order properties of sequences and limits, the Monotone Convergence Theorem, Cauchy's condensation test for convergence of a series, various other tests for the convergence series, the Bolzano-Weierstrass theorem, the Cauchy criterion for convergence of a sequence, rearrangement of absolutely convergent series.

The first Section 2.1 may be briefly discussed and is not meant for examination purposes.

[The topics to be discussed in this module can be found in Chapter 2]

Module III	**Total Teaching Hours: 25**

This module is intended to be a beginning for learning abstract metric spaces. To motivate the students, the Cantor set should be constructed and shown in the beginning. Then move to the topics open and closed sets in R, and what about their complements, Compactness of sets (defined using sequential convergence), open covers and compactness, perfect and connected sets in R, and finally the Baire's theorem.

The first Section 3.1 may be briefly discussed and is not meant for examination purposes.

[The topics to be discussed in this module can be found in Chapter 3]

References:

1. R G Bartle, D Sherbet, *Introduction to Real Analysis*, 3rd Edition, John Wiley & Sons
2. W. Rudin, *Principles of Mathematical Analysis*, Second Edition, McGraw-Hill
3. Terrence Tao, *Analysis I*, Hindustan Book Agency

SEMESTER - 5

AUMM 542: Complex Analysis – I

Total Teaching Hours: 72	No of Lecture Hours/ Week: 4
Max Marks: 80	Credits: 3

Course Outcomes:

CO1: To review the basic properties of complex numbers

CO2: To get a better knowledge on analytic functions

CO3: Extend knowledge of the notions of differentiation and integration of complex functions.

Text: **Edward B. Saff, Arthur David Snider, *Fundamentals of Complex Analysis with Applications to Engineering and Science*, 3rd Edition, Pearson Education India.**

Module I	Total Teaching Hours: 27

Complex numbers: The algebra of Complex Numbers, Point Representation of Complex Numbers, Vectors and Polar forms, The Complex Exponential, Powers and Roots, Planar Sets.

Analytic Functions: Functions of a complex variable, Limits and Continuity, Analyticity, The Cauchy Riemann Equations, Harmonic Functions, Steady-State Temperature as a Harmonic Function, Iterated Maps: Julia and Mandelbrot sets.

[The topics to be discussed in this module can be found in Chapter 1 Sections: 1 - 6 & Chapter 2 Sections: 1 - 7]

Module II	Total Teaching Hours: 15

Elementary Functions: Polynomials and rational Functions (Proof of the theorem on partial fraction decomposition need not be discussed), The Exponential, Trigonometric and Hyperbolic Functions, The Logarithmic Function, Washers, Wedges and Walls, Complex Powers and Inverse Trigonometric Functions, Application to Oscillating Systems.

[The topics to be discussed in this module can be found in Chapter 3, Sections: 1 - 6]

Module III	Total Teaching Hours: 30

Complex Integration: Contours, Contour Integrals, Independence of Path, Cauchy's Integral Theorem (Section 4.4a on deformation of Contours Approach is to be discussed, but Section 4.4 b on Vector Analysis Approach need not be discussed), Cauchy's Integral Formula and its Consequences, Bounds of Analytic Functions, Applications to Harmonic Functions.

[The topics to be discussed in this module can be found in Chapter 4, Sections: 1 - 3, 4.a, 5 - 7]

References:

1. John H. Mathews, Russel W. Howell, *Complex Analysis for Mathematics and Engineering*, Jones and Bartlett Publishers.
2. Erwin Kreyszig, *Advanced Engineering Mathematics*, 10^{th} Edition, Wiley-India.
3. James Brown, Ruel Churchill, *Complex Variables and Applications*, Eighth Edition, McGraw-Hill.

SEMESTER - 5

AUMM 543: Abstract Algebra – Group Theory

Total Teaching Hours: 90	No of Lecture Hours/ Week: 5
Max Marks: 80	Credits: 4

Course Outcomes:

CO1: To get a very strong foundation in the theory of groups.

CO2: To understand the classic result of Cayley on finite groups.

CO3: Acquire the ability to classify groups based on the fundamental theorem of Isomorphism for Finitely Generated Abelian Groups.

Text: **Joseph Gallian, Contemporary *Abstract Algebra*, 8th Edition, Cengage Learning.**

Module I	Total Teaching Hours: 30

The concept of group is to be introduced before rigorously defining it. The symmetries of a square can be a starting point for this. After that, definition of group should be stated and should be clarified with the help of examples. After discussing various properties of groups, finite groups and their examples should be discussed. The concept of subgroups with various characterizations also should be discussed. After introducing the definition of cyclic groups, various examples, and important features of cyclic groups and results on order of elements in such groups should be discussed.

[The topics to be discussed in this module can be found in Chapters 1, 2, 3 and 4]

Module II	Total Teaching Hours: 24

This module starts with defining and analyzing various properties permutation groups which forms one of the most important class of examples for non - abelian, finite groups. After defining operations on permutations, their properties are to be discussed. To motivate the students, the example of check-digit scheme should be discussed (This section on check-digit scheme is not meant for the examinations). Then we proceed to define the notion of equivalence of groups viz. isomorphisms. Several examples are to be discussed for explaining this notion. The properties of isomorphisms are also to be discussed together with special classes of isomorphisms like automorphisms and inner automorphisms before finishing the module with the classic result of Cayley on finite groups.

[The topics to be discussed in this module can be found in Chapters 5 and 6]

Module III	**Total Teaching Hours: 18**

In this module we prove one of the most important results in group theory which is the Langrange's theorem on counting cosets of a finite group. The concept of cosets of a group should be defined giving many examples before proving the Lagrange's theorem. As some of the applications of this theorem, the connection between permutation groups and rotations of cube and soccer ball should be discussed. The section on Rubik's cube and section on internal direct products need not be discussed.

[The topics to be discussed in this module can be found in Chapters 7 and 9]

Module IV	**Total Teaching Hours: 18**

Here the concept of group homomorphisms should be defined with sufficient number of examples. After proving the first isomorphism theorem, the fundamental theorem of isomorphism for finitely generated abelian groups should be introduced and proved. Classifying groups based on the fundamental theorem of finitely generated abelian groups should be discussed in detail.

[The topics to be discussed in this module can be found in Chapters 10 and 11]

References:

1. D. S. Dummit, R. M. Foote, *Abstract Algebra*, 3rd Edition, Wiley-India.
2. I. N. Herstein, *Topics in Algebra*, Vikas Publications.

SEMESTER - 5

AUMM 544: Differential Equations

Total Teaching Hours: 54	**No of Lecture Hours/ Week: 3**
Max Marks: 80	**Credits: 3**

Course Outcomes:

CO1: Study how differential equations arise in various physical problems.

CO2: Study some methods to solve first order differential equations and second order linear differential equations.

CO3: Study the applications of differential equations in various areas.

Text: **Erwin Kreyszig, *Advanced Engineering Mathematics*, 10th Edition, Wiley-India.**

Module I	**Total Teaching Hours: 27**

In this module we discuss first order equations and various methods to solve them. Sufficient number of exercises also should be done for understanding the concepts thoroughly. The main topics in this module are the following:

Modelling a problem, basic concept of a differential equation, its solution, initial value problems, geometric meaning (direction fields), separable ODE, reduction to separable form, exact ODEs and integrating factors, reducing to exact form, homogeneous and non-homogeneous linear ODEs, special equations like Bernoulli equation, orthogonal trajectories, understanding the existence and uniqueness of solutions theorem.

[The topics to be discussed in this module can be found in Chapter 1]

Module II	**Total Teaching Hours: 27**

As in the first module, we discuss second order equations and various methods to solve them. Sufficient number of exercises also should be done for understanding the concepts thoroughly. The main topics in this module are the following:

homogeneous linear ODE of second order, initial value problem, basis, and general solutions, finding a basis when one solution is known, homogeneous linear ODE with constant coefficients (various cases that arise depending on the characteristic equation), differential operators, Euler-Cauchy Equations, existence and uniqueness of solutions with respect to Wronskian, solving nonhomogeneous ODE via the method of undetermined coefficients, various applications of techniques, solution by variation of parameters, modelling of mass - spring system, forced oscillation and resonance.

[The topics to be discussed in this module can be found in Chapter 2]

References:

1. G. F. Simmons, *Differential Equations with applications and Historical notes*, Tata McGraw-Hill, 2003.
2. H. Anton, I Bivens, S Davis, *Calculus*, 10th Edition, John Wiley & Sons.
3. Peter V. O' Nei, *Advanced Engineering Mathematics*, Thompson Publications, 2007.

SEMESTER - 5

AUMM 54PI: Computer Programming – I

(Practical Examination only)

Total Teaching Hours: 72	No of Lecture Hours/ Week: 4
Max Marks: 80	Credits: 3

Course Outcomes:

CO1: Enable students to typeset the project report which is a compulsory requirement for finishing their undergraduate mathematics programme successfully.

CO2: Enable students to acquire a basic programming skill.

CO3: To learn the C programming language.

Text: **No prescribed texts. See the list of Reference texts given below.**

Module I : LaTex for preparing a Project Report in Mathematics	Total Teaching Hours: 36

Graphical User Interface (GUI)/ Editor like Kile or TeXstudio should be used for providing training to the students. The main topics in this module are following:

Typesetting a simple article and compiling it. How spaces are treated in the document.

Document layout: various options to be included in the documentclass command, page styles, splitting files into smaller files, breaking line and page, using boxes (like, mbox) to keep text unbroken across lines, dividing document in to parts like frontmatter, mainmatter, backmatter, chapters, sections, etc, cross referencing with and without page number, adding footnotes.

Emphasizing words with \emph, \texttt, \textsl, \textit, \underline etc.

Basic environments like enumerate, itemize, description, flushleft, flusuright, center, quote, quotation.

Controlling enumeration via the enumerate package.

Tables: preparing a table and floating it, the longtable environment.

Typesetting mathematics: basic symbols, equations, operators, the equation environment and reference to it, the displaymath environment, exponents, arrows, basic functions, limits, fractions, spacing in the mathematics environments, matrices, aligning various objects, multi-equation environments, suppressing numbering for one or more equations, handling long equations, phantoms, using normal text in math mode, controlling font size, typesetting theorems, definitions, lemmas, etc, making text bold in math mode, inserting symbols and environments (array, pmatrix, etc) using the support of GUIs.

Figures: Including JPG, PNG graphics with graphicx package, controlling width, height etc.,

Floating figures, adding captions, the wrapfig package.

Adding references/bibliography and citing them, using the package hyperref to add and control hypertext links, creating presentations with pdf screen, creating new commands.

Fonts: changing font size, various fonts, math fonts.

Spacing: changing line spacing, controlling horizontal, vertical spacing, controlling the margins using the geometry package, fullpage package.

Preparing a dummy project with titlepage, acknowledgement, certificates, table of contents (using

\tableofcontents), list of tables, table of figures, chapters, sections, bibliography (using the the bibliography environment). This dummy project should contain atleast one example from each of the topic in the syllabus, and should be submitted for internal evaluation before the end semester practical examination.

Module II : Computer Programming using C	Total Teaching Hours: 36

Text Book: Yashavant Kanetkar, *Let Us C*, 14th Edition, BPB Publications.

A brief introduction to C programming, C instructions - types of instructions, type declaration instruction, arithmetic instruction, integer and float conversions, type conversion in assignments, hierarchy of operations, associativity of operators, control instructions, decision control instruction - if, if-else, nested if-else, else-if etc. and conditional operators, loop control instruction - while, do-while, for, nesting of loops, break and continue statements, switch-case etc., functions - introducing functions, type of functions, passing values between functions, return type of functions etc.

The topics are discussed based on Chapters 1 to 8 and 11 of the Text. Each topic should be explained using simple programs from the text and mathematics.

Pointers - call by value and call by reference, pointer definition, notation etc. recursion, arrays - one dimensional and multi - dimensional arrays, functions and arrays, pointers and arrays etc. strings - more about strings, pointers and strings, string library functions, multiple strings etc. structures - declaration, storing and accessing elements, array of structures, use and additional features etc. console input/output - console I/O functions, formatted and unformatted console I/O functions etc. the C preprocessor - features, conditional compilation, build process etc.

The topics are discussed based on Chapters 9, 10 and 12 to 18 of the Text. Each topic should be explained using simple programs from the text and mathematics.

Note: An assignment on file input/output operations should be submitted based on Chapter 19 of the text. This topic is exempted from the end semester evaluation.

List of suggested C programs

1. Temperature of a city in Fahrenheit degrees is input through the keyboard. Write a program to convert this temperature into Centigrade degrees.

2. Paper of size $A0$ has dimensions 1189mm × 841mm. Each subsequent size $A(n)$ is defined as $A(n-1)$ cut in half parallel to its shorter sides. Thus, paper of size $A1$ would have dimensions $841mm \times 594mm$. Write a program to calculate and print paper sizes $A0, A1, A2, \ldots, A8$.

3. If a five-digit number is input through the keyboard, write a program to calculate the sum of its digits, to reverse the number and to determine whether the original and reversed numbers are equal or not.

4. If the three sides of a triangle are entered through the keyboard, write a program to check whether the triangle is valid or not.

5. Program to find the factorial value of any number entered through the keyboard.

6. A program to print all prime numbers from 1 to 300.

7. Using a C program produce the following output:

```
        1
      1   1
    1   2   1
  1   3   3   1
1   4   6   4   1
```

8. Write a function power (a, b), to calculate the value of a raised to b.

9. Write a C function to evaluate the series $Sin\ x = x - \frac{x^3}{3!} + \frac{x^5}{5!} - \frac{x^7}{7!} + \cdots$ up to 10 terms.

10. Write a function to compute the greatest common divisor given by Euclid's algorithm.

11. Write a program to copy the contents of one array into another in the reverse order.

12. Write a program to sort an array of numbers in ascending order.

13. Write a program to find if a square matrix is symmetric.

14. Write a program to add two 6×6 matrices.

15. Write a program to multiply any two 3×3 matrices.

16. Write a program that converts a string like "124" to an integer 124.

17. Write a program to delete all vowels from a sentence. Assume that the sentence is not more than 80 characters long.

18. Write a program to reverse the strings stored in the following array of pointers to strings:

```
char *s[] = {
To err is human…,
But to really mess things up…,
One needs to know C!!
};
```

References:

1. Brian W. Kernighan, Dennis M. Ritchie, *The C Programming Language*, Second Edition, Prentice Hall.
2. Greg Perry and Dean Miller, *C Programming Absolute Beginner's Guide*, Third Edition, Que Corporation.
3. https://www.tutorialspoint.com/cprogramming/index.htm.
4. https://stackoverflow.com/questions/tagged/c.

Internal Evaluation: A dummy project report prepared in LATEX should be submitted as assignment for internal evaluation for 5 marks. Another practical record should be submitted the content of which should be C programs and their outputs. This record should be awarded a maximum of 10 marks which is earmarked for the internal evaluation examination.

SEMESTER - 5

AUMM 581.a: Actuarial Science (Open Course)

Total Teaching Hours: 54	**No of Lecture Hours/ Week: 3**
Max Marks: 80	**Credits: 2**

Course Outcomes:

CO1: Study the concept of Risk.

CO2: Learn the role of statistics in Insurance.

CO3: Understand Insurance business in India.

Text: **Shylaja R. Deshmukh, *Actuarial Statistics*, University press. [Chapters 1 - 6].**

Module I	**Total Teaching Hours: 12**

Introduction to Insurance Business: What is Actuarial Science? Concept of Risk, Role of statistic in Insurance, Insurance business in India. Introductory Statistics: Some important discret distributions, Some important continuous distributions, Multivariate distributions.

Module II	**Total Teaching Hours: 21**

Feasibility of Insurance business and risk models for short terms: Expected value principle, Notio of utility, risk models for short terms Future Lifetime distribution and Life tables: Future life tim random variable, Curate future-life time, life tables, Assumptions for fractional ages, select an ultimate life tables.

Module III	**Total Teaching Hours: 21**

Actuarial Present values of benefit in Life insurance products: Compound interest, Discount facto Benefit payable at the moment of death, Benefit payable at the end of year of death, relatio between A and A¯. Annuities, certain, continuous life annuities, Discrete life annuities, Lif annuities with mthly payments.

References:

1. Bowers, Jr., N. L et al: *Actuarial Mathematics*, 2nd Edition, The society of Actuaries, Illinois Sahaumberg,1997.
2. Palande, P. S. et al: *Insurance in India: Changing policies and Emerging Opportunities* Response Books, New Delhi, 2003
3. Purohit, S. G. et al: *Statistics using R*, Narosa, New Delhi, 2008, www.actuariesindia.org

SEMESTER - 5

AUMM 581.b: Business Mathematics (Open Course)

Total Teaching Hours: 54	**No of Lecture Hours/ Week: 3**
Max Marks: 80	**Credits: 2**

Course Outcomes:

CO1: Basic Mathematics of Finance.

CO2: Differentiation and their applications to Business and Economics.

CO3: Methods of construction of index numbers.

Text: **B M Aggarwal, *Business Mathematics and Statistics*, Vikas Publishing House, New Delhi, 2009.**

Module I	**Total Teaching Hours: 18**

Basic Mathematics of Finance: Nominal rate of Interest and effective rate of interest, Continuous Compounding, force of interest, compound interest calculations at varying rate of interest, present value, interest and discount, Nominal rate of discount, effective rate of discount, force of discount, Depreciation.

[The topics to be discussed in this module can be found in Chapter 8 of Unit I, Sections: 1 - 7 & 9 of the Text].

Module II	**Total Teaching Hours: 18**

Differentiation and their applications to Business and Economics: Meaning of derivatives, rules of differentiation, standard results.

Maxima and Minima, concavity, convexity and points of inflection, elasticity of demand, Price elasticity of demand. (basics only for doing problems of Chapter 5 of Unit 1).

Integration and their applications to Business and Economics: Meaning, rules of integration, standard results, Integration by parts, definite integration (basics only for doing problems of Chapter 7 of Unit 1 of text).

Marginal cost, marginal revenue, Consumer's surplus, producer's surplus, consumer's surplus under pure competition, consumer's surplus under monopoly.

[The topics to be discussed in this module can be found in Chapter 4 of unit I, Sections: 3 - 6; Chapter 5 of Unit I, Sections: 1- 7; Chapter 6 of unit I, Sections: 1, 2, 4, 10, 11 & Chapter 7 of unit I, Sections: 1 - 5]

Module II	**Total Teaching Hours: 18**

Index Numbers: Definition, types of index numbers, methods of construction of price index numbers, Laspeyer's price index number, Paasche's price index number, Fisher ideal index number, advantages of index numbers, limitations of index numbers.

Time series: Definition, Components of time series, Measurement of Trend

[The topics to be discussed in this module can be found in Chapter 6 of Unit II, Sections: 1, 3, 4, 5, 6, 8, 16, 17 & Chapter 7 of Unit II Sections: 1, 2 and 4 of the Text]

References:

1. Qazi Zameeruddin, et al: *Business Mathematics*, Vikas Publishing House, New Delhi, 2009
2. Alpha C. Chicny, Kevin Wainwright, *Fundamental methods of Mathematical Economics*, Mc-Graw Hill, Singapore, 2005.

SEMESTER – 5

AUMM 581.c: Operations Research (Open Course)

Total Teaching Hours: 54	No of Lecture Hours/Week: 3
Max Marks: 80	Credits: 2

Course Outcomes:

- **CO1:** Formulation and solution of Linear Programming models
- **CO2:** Solution of Transportation problems and Assignment problems
- **CO3:** Project management using PERT and CPM

Text: Ravindran, Philips, Solberg, *Operations Research - Principles and Practice.*

Module I Linear Programming	Total Teaching Hours: 18

Formulation of Linear Programming models, Graphical solution of Linear Programs in two variables, Linear Programs in standard form - basic variable - basic solution - basic feasible solution - feasible solution, Solution of a Linear Programming problem using simplex method (Since Big-M method is not included in the syllabus, avoid questions in simplex method with constraints of $\geq$ or = type).

[The topics to be discussed in this module can be found in Chapter 2 of the Text]

Module II Transportation Problems	Total Teaching Hours: 18

Linear programming formulation - Initial basic feasible solution (Vogel's approximation method/ North-west corner rule) – degeneracy in basic feasible solution - Modified distribution method – optimality test.

Assignment problems: Standard assignment problems - Hungarian method for solving an assignment problem.

[The topics to be discussed in this module can be found in Chapter 3 Sections 2 & 3 of the Text]

Module III Project Management	Total Teaching Hours: 18

Activity -dummy activity - event - project network, CPM (solution by network analysis only), PERT.

[The topics to be discussed in this module can be found in Chapter 3 Section 7 of the Text]

References:

1. Hamdy A. Taha, *Operations Research: An Introduction*, 10^{th} Edition.
2. Kanti Swarup, P. K. Gupta, Man Mohan, *Operations Research.*
3. J. K. Sharma, *Operations Research - Theory and Applications.*

SEMESTER – 5

AUMM 581.d: Basic Mathematics (Open Course)

Total Teaching Hours: 54	**No of Lecture Hours/Week: 3**
Max Marks: 80	**Credits: 2**

Course Outcomes:

- **CO1:** Getting a working knowledge in basic arithmetic of whole numbers, fractions and decimals.
- **CO2:** Understanding of ratios, proportions, percent and the relation among them.
- **CO3:** Understanding basic Statistics.

Texts: 1. J. Miller, M O'Neil, N. Hyde, *Basic College Mathematics*, 2nd Edition, McGraw- Hill, Higher Education.

2. Steven T Karris, *Mathematics for Business*, Science and Technology, 2nd Edition, Orchard Publications.

Module I Basic Arithmetic of Whole Numbers, Fractions and Decimals	**Total Teaching Hours: 24**

Place Value of numbers, standard Notation and Expanded Notation, Operations on whole numbers, exponentiation, square roots, order of operations, computing averages, rounding, estimation, applications of estimation, estimating product of numbers by rounding, exponents, square roots, order of operations, computing averages.

Fractions: multiplication and division of fractions, applications, primes and composites, factorization, simplifying fractions to lowest terms, multiplication of fractions, reciprocal of fractions, division of fractions, operations of mixed fractions, LCM, Decimal notation and rounding of numbers, fractions to decimals, multiplication of decimals, division of decimals, order of operations involving decimals, Scientific notation of numbers, operations in scientific notations, square and cube roots of numbers, laws of exponents and logarithms.

[The topics to be discussed in this module can be found in Chapters 1, 2, 3 of Text - 1 and Chapters 1, 2 of Text 2]

Module II Ratios, Proportions, Percent and the relation among them	**Total Teaching Hours: 15**

Ratio and proportions: Simplifying ratios to lowest terms, ratios of mixed numbers, unit rates and cost, ratios and proportion, similar figures.

Percent: Fractions - decimals - percent, converting between these three relations with proportions, equations involving percent, increase and decrease in percent, finding simple and compound interests.

[The topics to be discussed in this module can be found in Chapters 4, 5 of Text 1]

Module 3 Basic Statistics, Simple Equations	Total Teaching Hours: 15

Basic Statistics: Data and tables, various graphs like bar graphs, pictographs, line graphs, frequency distributions and histograms, circle graphs (pie charts), interpreting them, circle graphs and percent, mean, median, mode, weighted mean. Solving simple equations, quadratic equations (real roots only), cubic equations, arithmetico geometric series, systems of two and three equations, matrices and system of equations.

[The topics to be discussed in this module can be found in Chapter 9 of Text-1 and Chapters 2, 3 of Text 2]

Reference:

Charles P. McKeague, *Basic Mathematics*, 7^{th} Edition, Cengage Learning.

SEMESTER - 5

Project Preparation

Total Teaching Hours: 18	No of Lecture Hours/Week: 1
Max Marks: 80	Credits: --

Course Outcomes:

- **CO1:** Making the students understand various concepts behind undertaking a project
- **CO2:** To study the way of preparing the final report.
- **CO3:** Make the students able to choose and prepare topics in their own and they should understand the layout of a project report.

Text: Daniel Holtom, Elizabeth Fisher, *Enjoy Writing Your Science Thesis or Dissertation -A step by step guide to planning and writing dissertations and theses for undergraduate and graduate science students*, Imperial College Press.

To complete the undergraduate programme, the students should undertake a project and prepare and submit a project report on a topic of their choice in the subject mathematics or allied subjects. The work on the project should start in the beginning of the 5th semester itself, and should end towards the middle of the 6th semester. This course (without any examination in the 5th semester, with a project report submission and project viva in the 6th semester) is introduced for making the students understand various concepts behind undertaking such a project and preparing the final report. Towards the end of this course the students should be able to choose and prepare topics in their own and they should understand the layout of a project report. To quickly get into the business, the first chapter of text [1] may be completely discussed. Apart from that, for detailed information, the other chapters in this book may be used in association with the other references given below.

The main topics to discuss in this course are the following:

Quick overview: The structure of Dissertation, creating a plan for the Dissertation, planning the results section, planning the introduction, planning and writing the abstract, composing the title, figures, tables, and appendices, references, making good presentations, handling resources like notebooks, library, computers etc., preparing an interim report.

Topics in detail: Planning and Writing the Introduction, Planning and Writing the Results, Figures and Tables, Planning and Writing the Discussion, Planning and Writing the References, deciding on a Title and Planning and Writing the Other Bits, Proofreading, Printing, Binding and Submission, oral examinations, preparing for viva, Taking the Dissertation to the Viva.

Layout: Fonts and Line Spacing, Margins, Headers, and Footers, Alignment of Text, Titles and Headings, Separating Sections and Chapters.

References:

1. Kathleen McMillan, Jonathan Weyers, *How to write Dissertations & Project Reports*, Pearson Education Limited.
2. Peg Boyle Single, *Demystifying dissertation writing: a streamlined process from choice of topic to final text*, Stylus Publishing, Virginia.

SEMESTER - 6

AUMM 641: Real Analysis-II

Total Teaching Hours: 90	**No of Lecture Hours/Week: 5**
Max Marks: 80	**Credits: 4**

Course Outcomes:

- **CO1:** Get better knowledge of continuity of real valued functions.
- **CO2:** Get better knowledge of differentiability of real valued functions.
- **CO3:** Get better knowledge of Riemann integrability of real valued functions.

Text: Stephen Abbot, *Understanding Analysis*, 2nd Edition, Springer.

Module I	**Total Teaching Hours: 35**

Here we move towards the basic notion of limits of functions and their continuity. Various version of definition of limits are to be discussed here. The algebra of limits of functions and the divergence criterion for functional limits are to be discussed next. The other topics to be discussed in this module are the discontinuity criterion, composition of functions and continuity, continuity and compact sets, results on uniform continuity, the intermediate value theorem, Monotone functions and their continuity.

(The first Section 4.1 may be briefly discussed and is not meant for examination purposes).

[The topics to be discussed in this module can be found in Chapter 4 of the Text]

Module II	**Total Teaching Hours: 25**

Here we discuss the derivative concept more rigorously than what was done in the previous calculus courses. After (re)introducing the definition of differentiability of functions, we verify that differentiability implies continuity. Algebra and composing of differentiable functions should be discussed next. The interior extremum theorem and Darboux's theorem should be discussed after that. The mean value theorems should be discussed and proved, and the module ends with L' Hospitals results.

(A continuous everywhere but nowhere differentiable function should be discussed, but it is not meant for the examination. It may be in fact used for student seminars. The Sections 5.1 and 5.4 may be briefly discussed and is not meant for examination purposes).

[The topics to be discussed in this module can be found in Chapter 5 of the Text]

Module III	**Total Teaching Hours: 30**

In the last module, the theory of Riemann integration is to be discussed. Main topics to be included in this module are defining the Riemann integral using upper, lower Riemann sums, and the integrability criterion, continuity and the existence of integral, algebraic operations on integrable functions, (The results and examples on convergence of sequence of functions and integrability may be omitted), the fundamental theorem of calculus and its proof, Lebesgue's criterion for Riemann integrability.

(The Section 7.1 may be briefly discussed and is not meant for examination purposes).

[The topics to be discussed in this module can be found in Chapter 7 of the Text]

References:

1. R. G. Bartle, D. Sherbert, *Introduction to real analysis*, 3^{rd} Edition, John Wiley & Sons.
2. W. Rudin, *Principles of Mathematical Analysis*, Second Edition, McGraw-Hill.
3. Terrence Tao, *Analysis I*, Hindustan Book Agency.

SEMESTER - 6

AUMM 642: Complex Analysis- II

Total Teaching Hours: 72	**No of Lecture Hours/Week: 4**
Max Marks: 80	**Credits: 3**

Course Outcomes:

- **CO1:** To study the basic properties of analytic functions.
- **CO2:** Study of residues and applications of residue theory
- **CO3:** Learn about conformal mappings and its significance

Text: Edward B. Saff, Arthur David Snider, *Fundamentals of Complex Analysis with Applications to Engineering and Science*, 3rd Edition, Pearson Education India.

Module I	**Total Teaching Hours: 32**

Series Representations for Analytic Functions: Sequences and Series, Taylor Series, Power Series, Mathematical Theory of Convergence, Laurent series, Zeros and Singularities, The point at infinity.

[The topics to be discussed in this module can be found in Chapter 5, Sections 1 - 5 of the Text]

Module II	**Total Teaching Hours: 20**

Residue Theory: The Residue Theorem, Trigonometric Integrals over $[0, 2\pi]$, Improper integrals of Certain functions over $(-\infty, \infty)$, Improper integrals involving Trigonometric Functions, Indented Contours.

[The topics to be discussed in this module can be found in Chapter 6, Sections 1 - 5 of the Text]

Module III	**Total Teaching Hours: 20**

Conformal Mapping: Invariance of Laplace’s Equation, Geometric Considerations, Mobius Transformations, Applications in electrostatics, Heat Flow and Fluid Mechanics.

[The topics to be discussed in this module can be found in Chapter 7, Sections 1 - 4, 6]

References:

1. John H. Mathews, Russel W Howell, *Complex Analysis for Mathematics and Engineering*, 6th Edition, Jones and Bartlett Publishers.
2. Murray R. Spiegel, *Complex variables: with an introduction to conformal mapping and its applications*, Schaum's outline.
3. Erwin Kreyszig, *Advanced Engineering Mathematics*, 10th Edition, Wiley-India.
4. James Brown, Ruel Churchill, *Complex Variables and Applications*, Eighth Edition, McGraw-Hill.

SEMESTER - 6

AUMM 643: Abstract Algebra – Ring Theory

Total Teaching Hours: 72	**No of Lecture Hours/Week: 4**
Max Marks: 80	**Credits: 3**

Course Outcomes:

- **CO1 :** Getting the definition and properties of integral domains, fields, and the characteristic of rings.
- **CO2 :** Understanding irreducibility and reducibility and the unique factorization of polynomials over special rings
- **CO3 :** Study Unique factorization domains and the Euclidean domains.

Text: Joseph Gallian, *Contemporary Abstract Algebra*, 8th Edition, Cengage Learning

Module I	**Total Teaching Hours: 24**

The concept of rings, subrings with many examples should be discussed here. Next comes the definition and properties of integral domains, fields, and the characteristic of rings. Ideals, how factor rings are defined using ideals, should be explained next. The definition of prime and maximal ideals with examples should be discussed after that.

[The topics to be discussed in this module can be found in Chapters 12, 13 and 14]

Module II	**Total Teaching Hours: 24**

After introducing the definition of ring homomorphisms, their properties should be discussed. The field of quotients of an integral domain should be discussed next. The next topic is the definition and various properties of polynomial rings over a commutative ring. Various results on operations on polynomials such as division algorithm, factor theorem, remainder theorem etc., should be discussed next. The definition and examples of PID's should be discussed next, before moving to the factorization of polynomials. Tests of irreducibility and reducibility and the unique factorization of polynomials over special rings should be discussed.

[The topics to be discussed in this module can be found in Chapter 15, 16 and 17]

Module III	**Total Teaching Hours: 24**

In the last module, we introduce more rigorous topics like various type of integral domains. The divisibility properties of integral domains and definition of primes in a general ring should be introduced. Unique factorization domains and the Euclidean domains should be discussed next with examples. Results on these special integral domains are also to be discussed.

[The topics to be discussed in this module can be found in Chapter 18]

References:

1. D. S. Dummit, R M Foote, *Abstract Algebra*, 3rd Edition, Wiley-India.
2. I. N. Herstein, *Topics in Algebra*, Vikas Publications.

SEMESTER-6

AUMM 644: Linear Algebra

Total Teaching Hours: 90	No of Lecture Hours/Week: 5
Max Marks: 80	Credits: 4

Course Outcomes:

- **CO1:** To study the basics of linear algebra
- **CO2:** To study matrix theory with emphasis on their geometrical aspects.
- **CO3:** To use the methods studied for solving practical problems.

Text: Gilbert Strang, *Linear Algebra and Its Applications*, 4^{th} Edition, Cengage Learning.

Module I	Total Teaching Hours: 15

This module deals with a study on linear equations and their geometry. After introducing the geometrical interpretation of linear equations, following topics should be discussed:

Various operations on column vectors, technique of Gaussian elimination, operations involving elementary matrices, interchanging of rows using elementary matrices, triangular factorization of matrices and finding inverse of matrices by the elimination method.

[The topics to be discussed in this module can be found in Chapter 1 (excluding Sec.7)]

Module II	Total Teaching Hours: 25

Towards the study of vector spaces, specifically R^n, we define them with many examples. Subspaces are to be defined next. After discussing the idea of null space of a matrix. The solving linear equations (which was one to some extent in the first module) and finding solutions to non- homogeneous systems from the corresponding homogeneous systems. After this, linear independence and dependence of vectors, their spanning, basis for a space, its dimension concepts are to be introduced. The column, row, null, left null spaces of a matrix is to be discussed next. When inverses of a matrix exist related to its column/row rank should be discussed. Towards the end of this module, linear transformations (through matrices) and their properties are to be discussed. Types of transformations like rotations, projections, reflections are to be considered next.

[The topics to be discussed in this module can be found in Chapter 2 (excluding Sec. 7)]

Module III	Total Teaching Hours: 25

This module is intended for making the idea and concepts of determinants stronger. Its properties like what happens when rows are interchanged, linearity of expansion along the first row, etc., are to be discussed. Breaking a matrix into triangular, diagonal forms and finding the determinants, expansion in cofactors, their applications like solving system of equations, finding volume etc. are to be discussed next.

[The topics to be discussed in this module can be found in Chapter 4]

Module IV	**Total Teaching Hours: 25**

Here we conclude our analysis of matrices. The problem of finding eigen values a matrix is to be introduced first. Next goal is to diagonalize a matrix. This concept should be discussed first, and move to the discussion on the use of eigen vectors in diagonalization.

Applications of finding the powers of matrices should be discussed next. The applications like the concept of Markov Matrices, Positive Matrices and their applications in Economics should be discussed. Complex matrices and operations on them are to be introduced next.

The concept orthogonality of vectors may be required here from one of the previous sections in text and it should be briefly introduced and discussed here. The module ends with similar matrices, and similarity transformation related ideas. How to diagonalize some special matrices like symmetric and Hermitian matrices are also to be discussed in this module.

[The topics to be discussed in this module can be found in Chapter 2 (excluding Sec. 4)]

References:

1. Video lectures of Gilber Strang Hosted by MIT Open Course ware available at https://ocw.mit.edu/courses/mathematics/18-06-linear-algebra-spring-2010/video-lectures/
2. Thomas Banchoff, John Wermer, *Linear Algebra Through Geometry*, 2nd Edition, Springer.
3. T. S. Blyth, E. F. Robertson, *Linear Algebra*, Springer, Second Edition.
4. David C Lay, *Linear Algebra*, Pearson.
5. K. Hoffman and R. Kunze, *Linear Algebra*, PHI.

SEMESTER - 6

AUMM 645: Graph Theory

Total Teaching Hours: 72	No of Lecture Hours/Week: 4
Max Marks: 80	Credits: 3

Course Outcomes:

- **CO1:** To build an awareness of some of the fundamental concepts in Graph Theory.
- **CO2:** To develop better understanding of the subject so as to use these ideas skillfully in solving real world problems.

Text: John Clark, Derek Allan Holton, *A first look at Graph Theory*, World Scientific.

Module I	Total Teaching Hours: 24

Basics: The Definition of a Graph, Graphs as Mathematical Models, other basic concepts and definitions, Vertex Degrees, Subgraphs, Paths and Cycles, The Matrix Representation of Graphs, fusing graphs (The fusion algorithm for connectedness need not be discussed).

Trees and Connectivity: Definitions and Simple Properties of trees, Bridges, Spanning Trees, Cut Vertices and Connectivity. Connector problems, Kruskal's algorithm, Prim's algorithm, Shortest path Algorithms, BFS, Dijkstra's Algorithm.

[The topics to be discussed in this module can be found in Chapter 1 Sections 1 - 8 & Chapter 2 Sections 1 - 6]

Module II	Total Teaching Hours: 24

Euler Tours and Hamiltonian Cycles: Euler Tours (Fleury's algorithm need not be discussed), The Chinese Postman Problem (Only Statement of the problem is to be discussed), Hamiltonian Graphs, The Travelling Salesman Problem (Only Statement of the problem is to be discussed, The Two-Optimal Algorithm and The Closest Insertion Algorithm need not be discussed).

Planar Graphs: Plane and Planar Graphs, Euler's Formula, The Platonic Bodies, Kuratowski's Theorem (Without proof).

[The topics to be discussed in this module can be found in Chapter 3 Sections 1 - 4 and Chapter 5: Sections 1 - 4]

Module III	Total Teaching Hours: 24

Directed Graphs and Networks: Directed graphs, Indegree and outdegree (Brujin Sequence need not be discussed), Tournaments, traffic flow, flows and cuts, the Ford and Fulkerson Algorithm, Separating sets

[The topics to be discussed in this module can be found in Chapter 7: Sections 1 - 4 and Chapter 8: Sections 1 - 3]

References:

1. Balakrishnan, Ranganatahan, *A Text Book of Graph Theory*, 2^{nd} Edition, Springer.
2. V. Balakrishnan, *Graph Theory*, Schaums Outlines.
3. J. A. Body, U. S. R. Murthy, *Graph Theory with Applications*, The Macmillan Press.
4. Robin J. Wilson, *Introduction to Graph Theory*, 5^{th} edition, Prentice Hall.

SEMESTER – 6

AUMM 691.a: Integral Transforms (Elective)

Total Teaching Hours: 54	No of Lecture Hours/Week: 3
Max Marks: 80	Credits: 2

Course Outcomes:

- **CO1:** Learn Differentiation and Integration of Transforms
- **CO2:** Study applications of Fourier Integrals
- **CO3:** Study Fourier Transform and its inverse; and linearity

Text: **1. Erwin Kreyszig. *Advanced Engineering Mathematics*, 10^{th} Edition, Wiley-India.**
2. M. K. Venkatraman, *Engineering Mathematics*, III year, Part3, 11^{th} Edition, National Publishing Co, Madras, 1992.

Module I	Total Teaching Hours: 24

Laplace Transforms: Laplace Transform. Linearity. First Shifting Theorem (s - Shifting). s- Shifting: Replacing s by in the transform, existence and uniqueness of Laplace Transforms, Transforms of Derivatives and Integrals. ODEs, Laplace Transform of the Integral of a Function, Differential Equations, Initial Value Problems, Unit Step Function (Heaviside Function), Second Shifting Theorem (t-Shifting). Time Shifting (t-Shifting): Replacing t by in f(t), Short Impulses. Dirac Delta Function. Partial Fractions Convolution, Application to Nonhomogeneous Linear ODEs, Differentiation and Integration of Transforms, ODEs with Variable Coefficients, Integration of Transforms, Special Linear ODEs with Variable Coefficients, Systems of ODEs.

[The topics to be discussed in this module can be found in Chapter 6 Sections 1 - 7 of Text 1]

Module II	Total Teaching Hours: 24

Fourier Series, Basic Examples, Derivation of the Euler Formulas, Convergence and Sum of a Fourier Series, Arbitrary Period. Even and Odd Functions. Half-Range Expansions from Period 2 to any Period P = 2L, Simplifications: Even and Odd Functions, Half - Range Expansions, Fourier Integral, From Fourier Series to Fourier Integral, Applications of Fourier Integrals, Fourier Cosine Integral and Fourier Sine Integral, Fourier Cosine and Sine Transforms, Linearity, Transforms of Derivatives, Fourier Transform, Complex Form of the Fourier Integral, Fourier Transform and Its Inverse, Linearity. Fourier Transform of Derivatives, Convolution.

[The topics to be discussed in this module can be found in Chapter 11 Sections 1 - 2, 7 - 9 of Text 1; Excluding Physical Interpretation: Spectrum and Discrete Fourier Transform (DFT) & Fast Fourier Transform (FFT))

Module III	**Total Teaching Hours: 06**

Harmonic Analysis

[The topics to be discussed in this module can be found in Text 2]

Reference

1. Peter V. O' Neil, *Advanced Engineering Mathematics*, Thompson Publications, 2007
2. M. Greenberg, *Advanced Engineering Mathematics*, 2^{nd} Edition, Prentice Hall.
3. B. S. Grewal, *Higher Engineering Mathematics*, Khanna Publishers.

SEMESTER – 6

AUMM 691.b: Linear Programming with SageMath (Elective)

Total Teaching Hours: 54	**No of Lecture Hours/Week: 3**
Max Marks: 80	**Credits: 2**

Course Outcomes:

- **CO1 :** To provide a strong introduction to various type of problems that can be solved via linear programming.
- **CO2 :** Workout examples on planning, transportation, assignment, workforce scheduling, portfolio optimization, Minimum Cost Flow Problem, Maximum Flow Problem.
- **CO3 :** Understand geometry of optimal solutions and geometric characterization of optimality.

Text: Roy H. Kwon, *Introduction to Linear Optimization and extensions with MATLAB*, 4th Edition, CRC Press, New York.

Module I	**Total Teaching Hours: 18**

This module is aimed at providing a strong introduction to various type of problems that can be solved via linear programming. Main topics in this module are the following:

Introduction to linear programming through problems, basic underlying assumptions like Proportionality, Divisibility, Additivity, Certainty, more general problems, standard form of a linear program, conversion rules to arrive at such a form like Converting unrestricted variables, Converting inequality constraints, Converting maximization to minimization, their examples, standard linear programming terminology, examples on planning, transportation, assignment, workforce scheduling, portfolio optimization, Minimum Cost Flow Problem, Maximum Flow Problem.

[The topics to be discussed in this module can be found in Chapter 1]

Module II	**Total Teaching Hours: 18**

This module begins with the geometry of linear programming and later proceeds to the Fundamental Theorem of Linear Programming which is a basis for algorithm development for linear programs. The main topics in this module are the following:

Geometry of the Feasible Set, graphically representing the solution space, hyperplane, polyhedron, polytope, convex sets, geometry of optimal solutions, geometric characterization of optimality, extreme points and basic feasible solutions, generating basic feasible solutions, resolution theorem, fundamental theorem linear programming.

[The topics to be discussed in this module can be found in Chapter 2]

Module III	Total Teaching Hours: 18

Here we introduce the simplex method, which is an important method to solve linear programming problems. The main topics in this module are the following:

Introducing the simplex method, examples, adjacent basic feasible solutions, checking optimality of a basic feasible solution, direction-step length theorem, its application in developing the steps of simplex method, examples, finite termination under non-degeneracy, generating an initial basic feasible solution using two phase and Big M method, degeneracy and cycling, anti-cycling rules like Bland's rule, and lexicographic rules.

[The topics to be discussed in this module can be found in Chapter 3]

Note:

1. There should not be any problems to solve using the SageMath software in the End Semester Examination (ESE). The ESE should be based only on the theory and problems to be solved either manually or using a non-programmable scientific calculator.
2. Students may be permitted to use non-programmable scientific calculator in the end semester examination.
3. One of the internal evaluation examinations should be done using SageMath Software, as a practical examination.
4. All the problems in this course should also be computationally solved using the software SageMath. The references provided below, especially Ref-1 and Chapter 4 of Ref-2 can be used mainly for this.

References:

1. Sage Reference Manual: Numerical Optimization, Release 7.6 by the Sage Development Team available online at http://doc.sagemath.org/pdf/en/ reference/numerical/ numerical.pd.
2. Gregory V. Bard, Sage for Undergraduates, American Mathematical Society, available online at http://www.gregorybard.com/Sage.html.
3. Frederick S Hillier, Gerald J. Lieberman, *Introduction to operations research*, 10th Edition, McGraw Hill Education.
4. Paul R. Thie, G. E. Keough, *An introduction to linear programming and game theory*, 3rd Edition, John Wiley & Sons.
5. Wayne L. Winston, *Operations Research Applications and Algorithms*, 4th Edition, Cengage Learning.

SEMESTER - 6

AUMM 691.c: Numerical Methods and Hands - on SageMath (Elective)

Total Teaching Hours: 54	No of Lecture Hours/Week: 3
Max Marks: 80	Credits: 2

Course Outcomes:

CO1 : Get introduced to Numerical analysis with particular emphasize to finding approximate solutions to problems.

CO2 : Study numerical methods in Linear Algebra

CO3 : Acquiring Hands-on experiences with SageMath

Text: 1. S. S. Sastry, *Introductory Methods of Numerical Analysis*, Prentice Hall India, New Delhi.

2. Erwin Kreyszig, *Advanced Engineering Mathematics*, 10th Edition, Wiley-India.

Module I	**Total Teaching Hours: 21**

General concepts in Numerical analysis: Introduction, Floating - Point Form of Numbers, Round off, Loss of Significant Digits, Errors of Numeric Results, Error Propagation, Basic Error Principle, Algorithm Stability.

Solution of Equations by Iteration: Fixed-Point Iteration for Solving Equations $f(x) = 0$, Bisection Method, Newton - Raphson Method for Solving Equations $f(x) = 0$, Generalized Newton's Method, Order of an Iteration Method Speed of Convergence, Convergence of Newton's Method.

Interpolation: Lagrange Interpolation for unevenly spaced points and Newton's Divided Difference Interpolation. Newton's Forward Difference and Back - ward Difference Interpolation Formula for evenly spaced points, Cubic Spline Interpolation.

[The topics to be discussed in this module can be found in Chapter 19 Sections 1 - 4 of Text 2 and Chapters 1 - 3 in Text 1.]

Module II	**Total Teaching Hours: 21**

Numerical Differentiation and Integration: Numerical Differentiation using forward differences, Trapezoidal Rule, Simpson's Rule of Integration, Romberg Integration. Numerical Solution of Ordinary Differential Equations, Methods for First - Order ODEs, Picard's Iteration Method, Euler's method (Numeric Method), Improved Euler Method, Runge - Kutta Methods (RK Methods) of fourth order.

Numerical Methods in Linear Algebra: Linear Systems: Gauss Elimination, Linear Systems: LU- Factorization, Matrix Inversion, Cholesky's Method, Gauss-Jordan Elimination. Matrix Inversion.
Linear Systems: Solution by Iteration, Gauss - Seidel Iteration Method, Jacobi Iteration.

[The topics to be discussed in this module can be found in Chapters 19, 20, 21 of Text 2 and Chapters 4, 5, 6 of Text 1]

Module III	Total Teaching Hours: 12

Hands-on experiences with SageMath s/w. Solution of Linear System of Equations, Matrix operations, Inverse of Matrices, Numerical Integration and numerical solution of ODE, RK4 methods.

Note:

1. **Internal Evaluation:** A dummy project report prepared in SageMath should be submitted as assignment for internal evaluation for 5 marks. A practical examination should be conducted with problems to be evaluated using SageMath. This practical session should be awarded a maximum of 10 marks which is earmarked for the internal evaluation examination.
2. There should not be any problems to solve using the SageMath software in the End Semester Examination (ESE). The ESE should be based only on the theory and problems to be solved either manually or using a non-programmable scientific calculator.
3. Students may be permitted to use non-programmable scientific calculator in the end semester examination.
4. One of the internal evaluation examinations should be done using SageMath Software, as a practical examination.

All the problems in this course should also be computationally solved using the software SageMath. The references provided below, especially Ref. Text 1 and Chapter 4 of Ref. Text 2 can be used mainly for this.

References:

1. *Sage Reference Manual: Numerical Optimization*, Release 7.6 by the Sage Development Team available online at http://doc.sagemath.org/pdf/en/reference/numerical/ numerical.pdf
2. Gregory V. Bard, *Sage for Undergraduates*, *American Mathematical Society*, available online at http://www.gregorybard.com/Sage.html
3. Richard L. Burden, J Douglas Faires, *Numerical Analysis*, 9th Edition, Cengate Learning.
4. E. Isaacson, H. B. Keller, *Analysis of Numerical Methods*, Dover Publications, New York.
5. W. Cheney, D. Kincaid, *Numerical Mathematics and Computing*, 6th Edition, Thomson Brooks/Cole.

SEMESTER - 6

AUMM 691.d: Fuzzy Mathematics (Elective)

Total Teaching Hours: 54	No of Lecture Hours/Week: 3
Max Marks: 80	Credits: 2

Course Outcomes:

- **CO1:** Get an overview of fuzzy sets
- **CO2:** Learn fuzzy arithmetic.
- **CO3:** Get the notion of fuzzy relations.

Text : George J Klir, Yuan, *Fuzzy sets and fuzzy logic: Theory and Applications*, Prentice Hall of India Pvt. Ltd., New Delhi, 2000.

Module I	Total Teaching Hours: 18

From crisp sets to fuzzy sets: a paradigm shift. Introduction - crisp sets: an overview - fuzzy sets: basic types and basic concepts of fuzzy sets, Fuzzy sets versus crisp sets, Additional properties of cuts, Representation of fuzzy sets, Extension Principle of Fuzzy Sets.

[The topics to be discussed in this module can be found in Chapters 1 and 2]

Module II	Total Teaching Hours: 18

Operations on fuzzy sets and Fuzzy Arithmetic: Operations on fuzzy sets - types of operations, fuzzy complements, fuzzy intersections: t - norms, fuzzy unions: t - conorms.

Fuzzy numbers, Linguistic variables, Arithmetic operations on intervals, Arithmetic operations on fuzzy numbers.

[The topics to be discussed in this module can be found in Chapter 3 Sections 1 – 4 & Chapter 4 Sections 1 - 4]

Module III	Total Teaching Hours: 18

Fuzzy relations: Crisp versus fuzzy relations, projections and cylindric extensions, Binary fuzzy relations, Binary relations on a single set, Fuzzy equivalence relations.

[The topics to be discussed in this module can be found in Chapter 5 Sections 1 - 5]

References:

1. Klir G. J. and T. Folger, *Fuzzy sets*, *Uncertainty and Information*, PHI Pvt. Ltd., New Delhi, 1998.
2. H. J. Zimmerman, *Fuzzy Set Theory and its Applications*, Allied Publishers, 1996.
3. Dubois D. and Prade H., *Fuzzy Sets and Systems*: Theory and Applications, Ac. Press, NY, 1988.

SEMESTER - 6

AUMM 64PI: Computer Programming - II (Elective) (Practical Examination only)

Total Teaching Hours: 54	No of Lecture Hours/Week: 3
Max Marks: 80	Credits: 2

Course Outcomes:

- **CO1 :** Enable students to see how the computational techniques they have learned in the previous semesters can be put into action with the help of software so as to reduce human effort.
- **CO2 :** To learn Python which is a programming language that works more quickly and integrate with mathematics more effectively.
- **CO3 :** To learn to use SageMath for further computations in their own.

Module 1: Computer Programming using Python	Total Teaching Hours: 18

We begin the discussion by introducing the basics of python. The feature of using python as a calculator, the supporting data types, variables, assignments, expressions, operations, indentation and comments etc. are to be discussed in detail. Then introduces list, tuple, set etc and their features and attributes. The strings, string operations, formatting of strings and related topics are to be discussed in detail. Then we introduce dictionaries too. The control flow elements including if, if - else, if – elif - else and for, while loops etc are discussed with more examples. We introduce the functions and related topics too.

[The topics are to be discussed based on Chapters 3 to 9 of the Text. In chapter 9, only Sections 9.1 to 9.5 need to be discussed.]

Text: Vernon L. Ceder, *The Quick Python Book*, Second Edition, Manning.

List of Suggested programs

1. Factorial of a number.
2. gcd of two integers using Euclidean Algorithm and coprime numbers.
3. Evaluating gcd and establishing the Bezout's identity.
4. Checking primality of a number.
5. Listing all prime numbers upto a given number.
6. Factors of a number.
7. Perfect numbers, Amstrong numbers, Ramanujan numbers etc.
8. Prime factorisation of a number
9. Base conversion problems.
    (a) conversion from base 10 to a given base b.
    (b) conversion from a given base b to base 10.

10. congruence problems

(a) printing all numbers congruent to a mod n for different values of a and n in a given range.

(b) Evaluating least nonnegative residue of a mod n, especially for large values of a.

(c) solving congruence equations namely $ax \equiv b(mod\ n)$.

11. Units and inverses of Z/mZ.

12. Order of units in Z/mZ.

13. Fibonacci sequence and Golden Ratio

Module II Doing Mathematics with SageMath	**Total Teaching Hours: 36**

Starting SageMath using a browser, how to use the sage cell server https://sagecell. sagemath.org/, how to use SageMath Cloud, creating and saving a sage worksheet, saving the worksheet to answers file, moving it and re - opening it in another computer system.

Using SageMath as a calculator, basic functions (square root, logarithm, numeric value, exponential, trigonometric, conversion between degrees and radians, etc.).

Plotting: simple plots of known functions, controlling range of plots, controlling axes, labels, gridlines, drawing multiple plots on a single picture, adding plots, polar plotting, plotting implicit functions, contour plots, level sets, parametric 2D plotting, vector fields plotting, gradients;

Matrix Algebra: Adding, multiplying two matrices, row reduced echelon forms to solve linear system of equations, finding inverses of square matrices, determinants, exponentiation of matrices, computing the kernel of a matrix.

Defining own functions and using it, composing functions, multi variate functions.

Polynomials: Defining polynomials, operations on them like multiplication and division, expanding a product, factorizing a polynomial, finding gcd.

Solving single variable equations, declaring multiple variables, solving multi variable equations, solving system of non-linear equations, finding the numerical value of roots of equations.

Complex number arithmetic, finding complex roots of equations.

Finding derivatives of functions, higher order derivatives, integrating functions, definite and indefinite integrals, numerical integration, partial fractions and integration.

Combinatorics & Number theory: Permutations, combinations, finding gcd, lcm, prime factorization, prime counting function, nth prime function, divisors of a number, counting divisors, modular arithmetic.

Vector calculus: Defining vectors, operations like sum, dot product, cross product, vector valued functions, divergence, curl, multiple integrals.

Computing Taylor, MacLaurin's polynomials, minimization and Lagrange multipliers, constrained and unconstrained optimization.

Problems to be included in the Examination:

1. Find all local extrema and inflection points of a function
2. Traffic flow optimization
3. Minimum surface area of packaging
4. Newton's method for finding approximate roots
5. Plotting and finding area between curves using integrals
6. Finding the average of a function
7. Finding volume of solid of revolution
8. Finding solution for a system of linear equations
9. Finding divergence and curl of vector valued functions
10. Using differential calculus to analyze a quintic polynomial's features, for finding the optimal graphing window
11. Using Pollard's $p - 1$ Method of factoring integers, to try to break the RSA cryptosystem.
12. Expressing gcd of two integers as a combination of the integers (Bezout's identity).

References:

1. The SageMathCloud, https://cloud.sagemath.com/
2. Gregory V. Bard, *Sage for Undergraduates, American Mathematical Society*, available online at http://www.gregorybard.com/Sage.html.
3. Tuan A. Le and Hieu D. Nguyen, *SageMath Advice for Calculus* available online at http://users.rowan.edu/~nguyen/sage/SageMathAdviceforCalculus.pdf.

Internal Evaluation: A practical record of python programs of at least 10 programs to be submitted as assignment for internal evaluation for 5 marks. Another practical record should be submitted the content of which should be problems and their outputs evaluated using SageMath. This record should be awarded a maximum of 10 marks which is earmarked for the internal evaluation examination.

FDP B.Sc. CHEMISTRY (Complementary)			Instructional h/week	Credit	ESE duration (h)	CE %	ESE %
Semester	**Paper Code**	**Title of Course**					
1.	AUMM 131.2b	Differential Calculus and Sequence and Series	4	3	3	20	80
2.	AUMM 231.2b	Integral Calculus and Vector Differentiation	4	3	3	20	80
3.	AUMM 331.2b	Linear Algebra, Probability Theory & Numerical Solutions	5	4	3	20	80
4.	AUMM 431.2b	Differential Equations, Vector Calculus, and Abstract Algebra	5	4	3	20	80

SEMESTER - 1

AUMM 131.2b: Mathematics -I

(Differential Calculus and Sequence and Series)

Total Teaching Hours: 72	No of Lecture Hours/Week: 4
Max Marks: 80	Credits: 3

Course Outcomes:

- **CO1:** Get knowledge on differential Calculus of one or more variable.
- **CO2:** Equipped to link the topic studied in Calculus to the real world and the student's own experience.
- **CO3:** Study Definition and Summation of series of various types.

Text: Anton, I Bivens, S Davis, *Calculus*, 10^{th} Edition, John Wiley & Sons.

Module I Differential Calculus of one variable	Total Teaching Hours: 18

We start with definition of limits as in 1.1.1 and then move on to discussion on one sided limit, two sided limits and infinite limits, techniques for computing limits may be done as in section 1.2. Limits at infinity for polynomials, rational functions and functions in- volving radicals are to be discussed as in Section 1.3. A general on continuity may be done as in Section 1.5. Various techniques for differentiation discussion are to be covered using Sections 2.1 to 2.8. This portion will cover the product and quotient rules, derivatives of trigonometric functions, chain rule and implicit differentiation.

Basic properties of exponential and logarithmic functions and techniques of differentiation involving these functions may be explored as in Sections 6.1 and 6.2 (avoid results on integration). Definition Evaluating and derivatives of inverse trigonometric functions has to be discussed as in Section 6.7 (avoid results on integration).

[The topics in this module can be found in Chapter 1; Sections 1.1, 1.2, 1.3, 1.5, Chapter 2; Sections 2.1 to 2.7 and Chapter 6; Sections 6.1, 6.2 and 6.7 of Text]

Module II Applications of derivatives	Total Teaching Hours: 18

Properties of functions like increase, decrease, concavity, maxima and minima has to be analyzed as in Sections 3.1, 3.2 and 3.4. Rolle's theorem and mean value theorem has to be discussed as in Section 3.8. This section ends with L'Höpital's rule for evaluating limits in case of indeterminate forms as in Section 6.5.

[The topics in this module can be found in Chapters 3 and 6 within Sections 3.1, 3.2, 3.4, 3.8 and Section 6.5 of Text]

Module III Differential calculus of functions of two variables	Total Teaching Hours: 18

This module begins with a study of functions of two or more independent variables. We describe the domains, graphs and level curves of such functions as in Section 13.1. A discussion about partial differentiation, without going into analytic details of continuity of partial derivatives can be conducted as in Section 13.3. Discuss problem 94 of Exercise set 13.3. A very short, but important mention has to be made about total differential of a function of two or more variables as in Section 13.4 (definition of total differential only). Chain rule for partial differentiation can be practiced as in Section 13.5. It is suggestible to transform 'Laplace's' and 'Cauchy-Riemann' equations from cartesian to polar forms (problems 55 and 57 of Exercise set 13.5). Section 13.8 can be used to provide a good course on maxima and minima of function of two or more variables. Section 13.9 will introduce the reader to Lagrange Multiplier method for constrained optimization. Problem 34 in Exercise set 13.9 will provide an easy application of this method.

[The topics in this module can be found in Chapter 13, Sections 13.1, 13.3, 13.4, 13.5, 13.8 and 13.9 of Text]

Module IV Sequence and Series	Total Teaching Hours: 18

Section 9.1 will introduce the reader to sequences, their limits, convergence and some related theorems. Infinite series, their convergence and sums, telescoping sums, geometric and harmonic series can be discussed as in Section 9.3. Sections 9.4 and 9.5 will present various tests for checking convergence of infinite series. Section 9.6 discusses alternating series. Sections 9.7 and 9.8 discusses polynomials and series known by the names of Taylor and Maclaurin.

[The topics in this module can be found in Chapter 9, Sections 9.1 and 9.3 to 9.8 of Text]

References:

1 George B. Thomas, Ross L. Finney, *Calculus and analytic geometry*, 9th Edition, Addison-wesley publishing Company.

2 K. F. Riley, M. P. Hobson, S. J. Bence, *Mathematical Methods for Physics and Engineering*, 3rd Edition, Cambridge University Press.

3. Mary L. Boas, *Mathematics Methods in the Physical Sciences*, 3rd Edition, Wiley.

4. Erwin Kreyszig, *Advanced Engineering Mathematics*, 10th Edition, Wiley-India.

SEMESTER-2

AUMM 231.2b: Mathematics -II

(Integral Calculus and Vector Differentiation)

Total Teaching Hours: 72	No of Lecture Hours/Week: 4
Max Marks: 80	Credits: 3

Course Outcomes:

- **CO1 :** Get knowledge on differential Calculus of one or more variable.
- **CO2 :** Understanding multiple integration and its applications in Chemistry.
- **CO3 :** Knowledge in Vector differentiation.

Text: Anton, I Bivens, S Davis. Calculus, 10^{th} Edition, John Wiley & Sons

Module I Integral Calculus of one variable	Total Teaching Hours: 18

We start this module with an introduction to indefinite integral as in Section 4.2. Integration techniques like substitution, hyperbolic functions, integration by parts, trigonometric substitution and partial fractions has to be dealt as in Sections 4.3, 4.5, 4.6, 4.9, 6.8 and 7.1 to 7.5.

[The topics in this module can be found in Chapter 4; Sections 4.2, 4.3, 4.5, 4.6, 4.9 Chapter 6; Section 6.8 and Chapter 7, Sections 7.1 to 7.5 of Text]

Module II Application of Integration	Total Teaching Hours: 18

We can proceed as in Section 5.1 to find area between two curves. Sections 5.2 and 5.3 discuss two method to find volumes involving integration in one variable. Arc lengths of curves and area of revolution must be covered as in Sections 5.4 and 5.5. The use of differentiation and integration to get new power series from already known series has to be discussed as in Section 9.10. In Exercise set 9.10 problem 41 on carbon dating and problem 44 on gravity has to be mentioned.

[The topics in this module can be found in Chapter 5, Sections 5.1 to 5.5 and Chapter 9; Section 9.10 of Text]

Module III Multiple Integrals	Total Teaching Hours: 18

A basic introduction to double integrals can be given as in Sections 14.1 and 14.2. For the purpose of evaluating double integral in polar coordinates as in 14.3, we shall first give an introduction to polar coordinates as in Section 10.2. For evaluating double integrals to find surface area and triple integrals to find volume as in Sections 14.4 and 14.5, a basic knowledge of quadric surfaces is necessary as in Section 11.7. For performing integrations in cylindrical and spherical coordinates as in Section 14.6 and change of variable as in Section 14.7, we first build up a knowledge on these coordinates as in Section 11.8.

[The topics in this module can be found in Chapter 14; Sections 14.1 to 14.7, Chapter 10; Section 10.2 and Chapter 11; Sections 11.7 and 11.8 of Text]

Module III Multiple Integrals	**Total Teaching Hours: 18**

After an introduction to vector valued functions as in Section 12.1, we can move to derivatives of such functions as in Section 12.2. Vector equations of tangent lines to graphs and derivatives of dot and cross products of functions are to be discussed; while results on integration may be avoided. Section 13.6 will provide enough material on directional derivatives and vector operator - gradient. Besides the usual exercise problems; problems 73, 74, and 76 of Exercise set 13.6 may be discussed.

[The topics in this module can be found in Chapter 12; Sections 12.1, 12.2, and Chapter 13; Section 13.6 of Text]

References:

1. George B. Thomas, Ross L. Finney, *Calculus and analytic geometry*, 9th Edition, Addison-wesley publishing Company.
2. K. F. Riley, M. P. Hobson, S. J. Bence, *Mathematical Methods for Physics and Engineering*, 3rd Edition, Cambridge University Press.
3. Mary L. Boas, *Mathematics Methods in the Physical Sciences*, 3rd Edition, Wiley.
4. Erwin Kreyszig, *Advanced Engineering mathematics*, 10th Edition, Wiley-India.

SEMESTER - 3

AUMM 331.2b: Mathematics - III

(Linear Algebra, Probability Theory & Numerical Solutions)

Total Teaching Hours: 90	**No of Lecture Hours/Week: 5**
Max Marks: 80	**Credits: 4**

Course Outcomes:

- **CO1:** To study linear vector spaces, eigen values and eigen vectors, diagonalizing matrices, applications of diagonalization
- **CO2:** Getting some basic ideas on Probability and Statistical methods
- **CO3:** Knowledge on Algebraic and transcendental equations and some interpolation methods.

Text: B.S. Grewal, *Higher Engineering Mathematics*, 42nd Edition, Khanna Publishers.

Module I Linear Algebra: Determinants, Matrices	**Total Teaching Hours: 24**

Introduction to Determinants and Matrices, Rank of a Matrix, Solution of Linear System of Equations (exclude Matrix Inversion Method), Consistency of Linear System of Equations, Linear Transformations, Vectors, Eigen Values, Properties of Eigen Values (Statements only), Cayley-Hamilton Theorem (Statement only), Reduction to Diagonal Form.

[The topics in this section can be found in Chapter 2; Sections 2.1, 2.2, 2.4, 2.7, 2.9, 2.10, 2.11,
2.12, 2.13, 2.14, 2.15, 2.16 of the Text]

Module II Probability and Statistics	**Total Teaching Hours: 30**

Probability and Distributions: - Introduction, Basic Terminology, Probability and Set Notations, Addition Law of Probability, Independent Events, Baye's Theorem, Random Variable, Discrete Probability Distribution, Continuous Probability Distribution, Binomial Distribution, Poisson Distribution, Normal Distribution.

[The topics in this module can be found in Chapter 26; Sections 26.1 to 26.9, 26.14 to 26.16 of the Text]

Module III Numerical Solutions	**Total Teaching Hours: 36**

Algebraic and transcendental equations (Rearrangement of the equation; linear interpolation; binary chopping; Newton - Raphson method).

Numerical Solution of Equations: - Introduction, Solution of Algebraic and Transcendental equations, Useful Deductions from the Newton-Raphson Formula, Solution of Linear Simultaneous Equations, Direct Methods of Solution (exclude Factorization Method), Iterative Methods of Solution (exclude relaxation method).

Finite Differences and Interpolation: - Finite Differences, To Find One or More Missing Terms (First method only), Newton's Interpolation Formulae, Lagrange's Interpolation Formula.
Numerical Integration: - Numerical Integration, Trapezoidal Rule, Simpson's One - Third Rule, Simpson's Three - Eighth Rule, Weddle's Rule.

Numerical Solution of Ordinary Differential Equations: - Taylor's Series Method, Runge - Kutta Method, Predictor - Corrector Methods, Milne's Method.

[The topics in this module can be found in Chapter 28; Sections 28.1 to 28.3, 28.5 to 28.7, Chapter 29; Sections 29.1, 29.5, 29.6, 29.10, Chapter 30; Sections 30.4, 30.6 to 30.8, 30.10 and Chapter 32; Sections 32.3, 32.7 to 32.9 of the Text]

References:

1. K. F. Riley, M. P. Hobson, S. J. Bence, *Mathematical Methods for Physics and Engineering*, 3rd Edition, Cambridge University Press.
2. H. Anton, I. Bivens, S. Davis, *Calculus*, 10th Edition, John Wiley & Sons.
3. George. B. Afken, Hans. J. Weber, Frank. E. Harris, *Mathematical Methods for Physicists*, 7th Edition, Academic Press.
4. Erwin Kreyszig, *Advanced Engineering Mathematics*, 10th Edition, Wiley-India.
5. Mary L. Boas, *Mathematical Methods in the Physical Sciences*, Third Edition, John Wiley & Sons.

SEMESTER - 4

AUMM 431.2b: Mathematics - IV

(Differential Equations, Vector Calculus, and Abstract Algebra)

Total Teaching Hours: 90	**No of Lecture Hours/Week: 5**
Max Marks: 80	**Credits: 4**

Course Outcomes:

- **CO1:** Study the formation and solution of first and higher order differential equations, and their applications, especially in Chemistry.
- **CO2:** Evaluating line, surface, volume integrals.
- **CO3:** Study about group and Representation theory.

Texts: 1. B. S. Grewal, *Higher Engineering Mathematics*, 42nd Edition, KhannaPublishers.
2. Howard Anton, Irl Bivens, Stephen Davis, *Calculus*, 10th Edition, John Wiley & Sons.
3. John B. Fraleigh, *A First Course in Abstract Algebra*, Seventh Edition,Pearson.

Module I Ordinary Differential Equations	**Total Teaching Hours: 36**

Differential Equations of the First Order: - Definitions, Solution of a Differential Equation, Equations of the First order and First-Degree Variables Separable, Homogeneous Equations, Equations Reducible to Homogeneous Form, Linear Equations, Bernoulli's Equation, Exact Differential Equations, Equations reducible to exact equations, Equations of the First Order and Higher Degree, Clairaut's Equation.

Applications of Differential Equations of First Order: - Orthogonal Trajectories.

Linear Differential Equations: - Definitions, Theorem without proof, Operator D, Rules for Finding the Complementary Function, Inverse Operator, Rules for Finding the Particular Integral, Working Procedure to Solve the Equation, Two Other Methods of Finding P.I, Equations reducible to Linear equations with Constant Coefficients, Linear Dependence of Solutions.

[The topics in this module can be found in Chapter 11; Sections 11.1, 11.4 - 11.14, Chapter 12; Section 12.3 and Chapter 13; Sections 13.1 - 13.10 of Text 1]

Module II Vector Integration	**Total Teaching Hours: 24**

Vector Fields, Line Integrals, Independence of Path and Conservative Vector Fields, Green's theorem, Surface Integrals, Applications of Surface Integrals; The Divergence Theorem, Stokes' Theorem.

[All theorems in this module should be discussed without proof].
[The topics in this module can be found in Chapter 15; Sections 15.1 to 15.8 of Text 2].

Module III Abstract Algebra	Total Teaching Hours: 30

Introduction and Examples, Binary Operations, Groups, Subgroups (only statements of theorems), Cyclic Groups (only statements of theorems except theorem 6.1).
Groups of Permutations [exclude the section Cayley's Theorem].
Rings and Fields [exclude the section Homomorphisms and Isomorphisms].

[The topics in this module can be found in Chapter 1; Sections 1, 2, 4, 5, 6, Chapter 2; Section 8 and Chapter 4 ; Section 18 of Text 3]

References:

1. K. F. Riley, M. P. Hobson, S.J. Bence, *Mathematical Methods for Physics and Engineering*, 3rd Edition, Cambridge University Press.
2. Mary. L. Boas, *Mathematics Methods in the Physical Sciences*, 3rd Edition, Wiley.
3. George. B. Arfken, Hans. J. Weber, Frank. E. Harris, *Mathematical Methods for Physicists*, 7th Edition, Academic Press.
4. Erwin Kreyszig, *Advanced Engineering Mathematics*, 10th Edition, Wiley-India.
5. David M Bishop, *Group theory and Chemistry*, Dover Publications.
6. J. A. Gallian, *Contemporary Abstract Algebra*, Narosa Publications.

FDP B.Sc. PHYSICS (Complementary)			Instructional h/week	Credit	ESE duration (h)	CE (%)	ESE (%)
Semester	**Paper Code**	**Title of Course**					
1.	AUMM 131.2d	Calculus and Sequence and Series.	4	3	3	20	80
2.	AUMM 231.2d	Application of Calculus and Vector Differentiation.	4	3	3	20	80
3.	AUMM 331.2d	Linear Algebra, Special Functions and Calculus.	5	4	3	20	80
4.	AUMM 431.2d	Fourier Series, Complex Analysis and Probability Theory	5	4	3	20	80

SEMESTER - 1

AUMM 131.2d: Mathematics - I

(Calculus and Sequences and Series)

Total Teaching Hours: 72	No of Lecture Hours/Week: 4
Max Marks: 80	Credits: 3

Course Outcomes:

- **CO1 :** Get knowledge on the application of mathematical methods to Physics.
- **CO2 :** Equipped to link the topic studied in Calculus to the real world and the student's own experience.
- **CO3 :** A basic knowledge in differential calculus and integral calculus.

Text: H Anton, I Bivens, S Davis. ***Calculus*****, 10th Edition, John Wiley & Sons.**

Module I Differential and integral Calculus of One Variable	Total Teaching Hours: 18

We start with definition of limits as in 1.1.1 and then move on to discussion on one sided limit, two sided limits and infinite limits, techniques for computing limits may be done as in Section 1.2. Limits at infinity for polynomials, rational functions and functions involving radicals are to be discussed as in Section 1.3. A general discussion on continuity may be done as in Section 1.5. Various techniques for differentiation are to be covered using Sections 2.1 to to 2.8. This portion will cover the product and quotient rules, derivatives of trigonometric functions, chain rule and implicit differentiation. Basic properties of exponential and logarithmic functions and techniques of differentiation involving these functions may be explored as in Sections 6.1 and 6.2. Definition Evaluating and derivatives of inverse trigonometric functions has to be discussed as in Section 6.7.

2; Sections 2.1 to 2.7 and Chapter 6; Sections 6.1, 6.2 and 6.7 of Text.

[**The topics in this module can be found in Chapter 1; Sections 1.1, 1.2, 1.3 and 1.5]**

Module II Integral Calculus of one variable	Total Teaching Hours: 18

We start this module with an introduction to indefinite integral as in Section 4.2. Integration techniques like substitution, hyperbolic functions, integration by parts, trigonometric substitu tion and partial fractions has to be dealt as in Sections 4.3, 4.5, 4.6, 4.9, 6.8 and 7.1 to 7.5.

[The topics in this module can be found in Chapter 4; Sections 4.2, 4.3, 4.5, 4.6, 4.9, Chapter 6; Section 6.8 and Chapter 7, Sections 7.1 to 7.5 of Text]

Module III Differential Calculus of functions of two or more variables	Total Teaching Hours: 18

This module begins with a study of functions of two or more independent variables. We describe the domains, graphs and level curves of such functions as in Section 13.1. A discussion about partial differentiation, without going into analytic details of continuity of partial derivatives can be conducted as in Section 13.3. Discuss problem 94 of Exercise set 13.3. A very short, but important mention has to be made about total differential of a function of two or more variables as in Section 13.4 (definition of total differential only). Chain rule for partial differentiation can be practiced as in section 13.5. It is suggestible to transform 'Laplace's' and 'Cauchy-Riemann' equations from cartesian to polar forms (problems 55 and 57 of Exercise set 13.5). Section 13.8 can be used to provide a good course on maxima and minima of function of two or more variables. Section 13.9 will introduce the reader to Lagrange Multiplier method for constrained optimization. Problem 34 in Exercise set 13.9 will provide an easy application of this method.

[The topics in this module can be found in Chapter 13; sections 13.1, 13.3, 13.4, 13.5, 13.8 and 13.9 of Text]

Module IV Sequence and Series	Total Teaching Hours: 18

Section 9.1 will introduce the reader to sequences, their limits, convergence and some related theorems. Infinite series, their convergence and sums, telescoping sums, geometric and harmonic series can be discussed as in Section 9.3. Sections 9.4 and 9.5 will present various tests for checking convergence of infinite series. Section 9.6 discusses alternating series. Sections 9.7 and 9.8 discusses polynomials and series known by the names of Taylor and Maclaurin.

[The topics in this module can be found in Chapter 9, Sections 9.1 and 9.3 to 9.8 of Text]

References:

1. George B. Thomas, Ross L. Finney, *Calculus and analytic geometry*, 9th Edition, Addison-wesley publishing Company.
2. K F Riley, M P Hobson, S J Bence, *Mathematical Methods for Physics and Engineering*, 3rd Edition, Cambridge University Press.
3. Mary L Boas, *Mathematics Methods in the Physical Sciences*, 3rd Edition, Wiley.
4. Erwin Kreyszig, *Advanced Engineering Mathematics*, 10th Edition, Wiley-India.

SEMESTER - 2

AUMM 231.2d: Mathematics - II

(Applications of Calculus and Vector Differentiation)

Total Teaching Hours: 72	**No of Lecture Hours/Week: 4**
Max Marks: 80	**Credits: 3**

Course Outcomes:

- **CO1:** Acquiring knowledge in Vector differentiation
- **CO2:** Studying application of differentiation and integration.
- **CO3:** Understanding multiple integration and its application.

Text: H Anton, I Bivens, S Davis. *Calculus*, 10^{th} Edition, John Wiley & Sons.

Module I Applications of derivatives	**Total Teaching Hours: 18**

Properties of functions like increase, decrease, concavity, maxima and minima has to be analyzed as in Sections 3.1, 3.2 and 3.4. Rolle's theorem and mean value theorem has to be discussed as in Section 3.8. This section ends with L'H¨opital's rule for evaluating limits in case of indeterminate forms as in Section 6.5.

[The topics in this module can be found in Chapters 3 and 6 within Sections 3.1, 3.2, 3.4, 3.8 and section 6.5 of Text]

Module II Applications of Integration	**Total Teaching Hours: 18**

We can proceed as in Section 5.1 to find area between two curves. Sections 5.2 and 5.3 discuss two method to find volumes involving integration in one variable. Arc lengths of curves and area of revolution must be covered as in Sections 5.4 and 5.5. The use of differentiation and integration to get new power series from already known series has to be discussed as in Section 9.10. In Exercise set 9.10 problem 41 on carbon dating and problem 44 on gravity has to be mentioned.

[The topics in this module can be found in Chapter 5; Sections 5.1 to 5.5 and Chapter 9; Section 9.10 of Text]

Module III Multiple Integrals	**Total Teaching Hours: 18**

A basic introduction to double integrals can be given as in Sections 14.1 and 14.2. For the purpose of evaluating double integral in polar coordinates as in 14.3, we shall first give an introduction to polar coordinates as in Section 10.2. For evaluating double integrals to find surface area and triple integrals to find volume as in Sections 14.4 and 14.5, a basic knowledge of quadric surfaces is necessary as in Section 11.7. For performing integrations in cylindrical and spherical coordinates as in Section 14.6 and change of variable as in Section 14.7, we first build up a knowledge on these coordinates as in Section 11.8.

[The topics in this module can be found in Chapter 14; Sections 14.1 to 14.7, Chapter 10; Section 10.2 and Chapter 11; Sections 11.7 and 11.8 of Text]

Module IV Vector Differentiation	Total Teaching Hours: 18

After an introduction to vector valued functions as in Section 12.1, we can move to derivatives of such functions as in Section 12.2. Vector equations of tangent lines to graphs and derivatives of dot and cross products of functions are to be discussed; while results on integration may be avoided. Section 13.6 will provide enough material on directional derivatives and vector operator - gradient. Besides the usual exercise problems; problems 73, 74, and 76 of Exercise set 13.6 may be discussed.

[The topics in this module can be found in Chapter 12; Sections 12.1, 12.2 and chapter 13; Section 13.6 of Text]

References:

1. George B. Thomas, Ross L. Finney, *Calculus and analytic geometry*, 9th Edition, Addison-wesley publishing Company.
2. K. F. Riley, M. P. Hobson, S. J. Bence, *Mathematical Methods for Physics and Engineering*, 3rd Edition, Cambridge University Press.
3. Mary L. Boas, *Mathematics Methods in the Physical Sciences*, 3rd Edition, Wiley.
4. Erwin Kreyszig, *Advanced Engineering Mathematics*, 10th Edition, Wiley-India.

SEMESTER - 3

AUMM 331.2d: Mathematics - III

(Differential Equations, Vector Integration, Fourier Series and Linear Algebra)

Total Teaching Hours: 90	No of Lecture Hours/Week: 5
Max Marks: 80	Credits: 4

Course Outcomes:

- **CO1:** Study different methods of solving differential equations and modelling situations in Physics using differential equations.
- **CO2:** Learn integration of vector valued functions, and thus learn to evaluate line, surface, volume integrals.
- **CO3:** Understand special functions like, Factorial Function, Gamma Function and Beta Functions and study their properties.

Texts:

1. **B. S. Grewal, *Higher Engineering Mathematics*, 42nd Edition, Khanna Publishers.**
2. **Howard Anton, Irl Bivens, Stephen Davis, *Calculus*, 10th Edition, John Wiley & Sons.**
3. **Mary L. Boas, *Mathematical Methods in the Physical Sciences,* Third Edition, John Wiley & Sons.**

Module I Linear Algebra: Determinants and Matrices	Total Teaching Hours: 24

Introduction to Determinants and Matrices, Rank of a Matrix, Solution of Linear System of Equations (exclude Matrix Inversion Method), Consistency of Linear System of Equations, Linear Transformations, Vectors, Eigen Values, Properties of Eigen Values (Statements only), Cayley - Hamilton Theorem (Statement only), Reduction to Diagonal Form.

[The topics in this section can be found in Chapter 2; Sections 2.1, 2.2, 2.4, 2.7, 2.9, 2.10, 2.11, 2.12, 2.13, 2.14, 2.15, 2.16 of Text]

Module II Ordinary Differential Equations	Total Teaching Hours: 36

Differential Equations of the First Order: - Definitions, Solution of a Differential Equation, Equations of the First order and First-Degree Variables Separable, Homogeneous Equations, Equations Reducible to Homogeneous Form, Linear Equations, Bernoulli's Equation, Exact Differential Equations, Equations reducible to exact equations, Equations of the First Order and Higher Degree, Clairaut's Equation.

Applications of Differential Equations of First Order: - Orthogonal Trajectories.

Linear Differential Equations: - Definitions, Theorem without proof, Operator D, Rules for Finding the Complementary Function, Inverse Operator, Rules for Finding the Particular Integral, Working Procedure to Solve the Equation, Two Other Methods of Finding P.I, Equations reducible to Linear equations with Constant Coefficients, Linear Dependence of Solutions.

[The topics in this module can be found in Chapter 11; Sections 11.1, 11.4-11.14, Chapter 12; Section 12.3 and chapter 13; Sections 13.1 - 13.10 of Text.]

Module III Vector Integration and special Functions	Total Teaching Hours: 30

Vector Integration

Vector Fields, Line Integrals, Independence of Path and Conservative Vector Fields, Green's theorem, Surface Integrals, Applications of Surface Integrals; The Divergence Theorem, Stokes' Theorem.

[All theorems in this section should be discussed without proof].

[The topics in this section can be found in Chapter 15; Sections 15.1 to 15.8 of Text 2]

Special Functions

The Factorial Function, Definition of the Gamma Function; Recursion Relation, The Gamma Function of Negative Numbers, Some Important Formulas Involving Gamma Functions, Beta Functions, Beta Functions in Terms of Gamma Functions.

[The topics in this section can be found in Chapter 11; Sections 2 to 7 of Text 3]

References:

1. K. F. Riley, M. P. Hobson, S.J. Bence, *Mathematical Methods for Physics and Engineering*, 3rd Edition, Cambridge University Press.
2. George. B. Arfken, Hans. J. Weber, Frank. E. Harris, *Mathematical Methods for Physicists*, 7th Edition, Academic Press.
3. Erwin Kreyszig, *Advanced Engineering Mathematics*, 10th Edition, Wiley-India.

SEMESTER - 4

AUMM 431.2d: Mathematics - IV
(Fourier Series, Complex Analysis and Probability Theory)

Total Teaching Hours: 90	No of Lecture Hours/Week: 5
Max Marks: 80	Credits: 4

Course Outcomes:

- **CO1:** Learn analytic functions, evaluation of definite integrals using residue theorem, conformal mapping and some of its applications.
- **CO2:** Getting some basic ideas on Probability and Statistical methods.
- **CO3:** Intended for Physics students to lay emphasis on applications Fourier Series.

Text: B. S. Grewal, *Higher Engineering Mathematics*, 42nd Edition, Khanna Publishers.

Module I Fourier Series	Total Teaching Hours: 24

Introduction, Euler's Formulae (without proof), Conditions for a Fourier Expansion, Functions Having Points of Discontinuity, Change of Interval, Even and Odd Functions, HalfRange Series, Fourier Transforms, Properties of Fourier Transforms.

[The topics in this module can be found in Chapter 10; Sections 10.1 to 10.7 and Chapter 22; Sections 22.4 and 22.5 of the Text]

Module II Complex Analysis	Total Teaching Hours: 36

Complex Numbers and Functions: - Complex Numbers, Geometric Representation of Imaginary Numbers, Geometric Representation of z_1+z_2, De-Moivre's Theorem (without proof), Roots of a Complex Number, Complex Function, Exponential Function of a Complex variable.

Calculus of Complex Functions: - Introduction, Limit of a Complex Function, Derivative of $f(z)$, Analytic Functions, Harmonic Functions, Complex Integration, Cauchy's Theorem, Cauchy's Integral Formula, Laurent's Series, Zeros of an Analytic Function, Residues, Calculation of Residues, Evaluation of Real Definite Integrals.

[All Theorems in this module should be considered without proof]

[The topics in this module can be found in Chapter 20; Sections 20.1 to 20.5, 20.12 to 20.14, 20.16 (Laurent Series only), 20.17 to 20.20 of the Text]

Module III Probability and Statistics	Total Teaching Hours: 30

Probability and Distributions: - Introduction, Basic Terminology, Probability and Set Notations, Addition Law of Probability, Independent Events, Baye's Theorem, Random Variable, Discrete Probability Distribution, Continuous Probability Distribution, Binomial Distribution, Poisson Distribution, Normal Distribution.

[The topics in this module can be found in Chapter 26; Sections 26.1 to 26.9, 26.14 to 26.16 of the Text]

References:

1. K.F. Riley, M. P. Hobson, S. J. Bence. Mathematical Methods for Physics and Engineering, 3rd Edition, Cambridge University Press.
2. H. Anton, I. Bivens, S. Davis. Calculus, 10th Edition, John Wiley & Sons.
3. George. B. Afken, Hans. J. Weber, Frank. E. Harris. Mathematical Methods forPhysicists, 7th Edition, Academic Press.
4. Erwin Kreyszig. Advanced Engineering Mathematics, 10th Edition, Wiley-India.
5. Mary L. Boas. Mathematical Methods in the Physical Sciences, Third Edition, JohnWiley & Sons.

FDP B. A. ECONOMICS/ ANALYTICAL ECONOMICS (Complementary)			Instructional h/week	Credit	ESE duration (h)	CE (%)	ESE (%)
Semester	**Paper Code**	**Title of Course**					
1.	AUMM 131.1a/ AUMM131.1c	Differential Calculus of Functions of one Variable	3	2	3	20	80
2.	AUMM 231.1a/ AUMM231.1c	Multivariate Differential Calculus, Sequences and Series	3	3	3	20	80
3.	AUMM 331.1a/ AUMM331.1c	Integral Calculus and Linear Algebra	3	3	3	20	80
4.	AUMM 431.1a/ AUMM431.1c	Differential Equations, Difference Equations and Linear Programming	3	3	3	20	80

SEMESTER - 1

AUMM 131.1a/131.1c: Mathematics for Economics - I (Differential Calculus of Functions of One Variable)

Total Teaching Hours: 54	No of Lecture Hours/Week: 3
Max Marks: 80	Credits: 2

Course Outcomes:

- **CO1:** Intended for Economics students lays emphasis on the increased use of mathematical methods in Economics.
- **CO2:** To get working knowledge on limits, continuity and functions.
- **CO3:** Learn Differentiation and its basic applications in Economics, to study how quickly quantities change over time, understand slope of a curve as rate of change.
- **CO4**: Study the concepts of increasing and decreasing functions, maxima and minima, and find its applications through functions familiar in Economics.

Text: **Knut Sydsaeter, Peter J. Hammond, *Mathematics for Economic Analysis*, Pearson, 1995.**

Module I	Total Teaching Hours: 18

(Make a quick review and discussion on the following topics from Chapter - 1. These topics may not be included in the end semester examination; but, be used as Seminar topics or topics for Assignments. The topics are: Why Economists use Mathematics, Scientific Method in the Empirical science, the use of symbols in Mathematics, the real number system, a few aspects of Logic, Mathematical proof, Set theory.)

After this review, the main topics to be discussed in the module are the following:

Functions of one variable: Introduction, Functions of one real variable, graphs, graphs of functions, linear functions.
(Now make a quick review of Chapter 3. These topics may not be included in the end semester examination; but, be used as Seminar topics or topics for Assignments. The topics are: quadratic functions, examples of quadratic optimization problems, polynomials, power functions, exponential functions, the general concept of a function).
After this review, the main topics to be discussed in the module are the following:

Limits, Continuity and Series: Limits, continuity, continuity and differentiability.

[The topics to be discussed in this module can be found in Chapters 1, 2, 3, Chapter 6; Sections 1 – 3]

Module II	Total Teaching Hours: 18

Single Variable Differentiation: Slopes of curves, the slope of the tangent and the derivative, rates of change and their economic significance, a dash of limits, simple rules for differentiation, differentiation of sums, products and quotients, second and higher order derivatives.

More on Differentiation: The generalized power rule, composite functions and the chain rule, implicit differentiation, linear approximations and differentials, polynomial approximation, elasticities.

[The topics to be discussed in this module can be found in Chapters 4 and 5]

Module III	**Total Teaching Hours: 18**

Implications of Continuity and Differentiability: The intermediate-value theorem, the extreme value theorem, the mean value theorem, Taylor's formula, intermediate forms and L' Hopital's rule, inverse functions.

Single-Variable Optimization: Some basic definitions, a first-derivative test for extreme points, alternative ways of finding maxima and minima, local maxima and minima, convex and concave functions and inflection points.

[The topics to be discussed in this module can be found in Chapter 7, Chapter 9; Sections 1 – 5]

References:

1. G. D. Allen, *Mathematical Analysis for Economics*, AITBS Publishers, New Delhi.
2. Taro Yamane, *Mathematics for Economists*, An Elementary Survey, PHI, New Delhi.
3. Chiang A.C. and K.Wainwright, *Fundamental Methods of Mathematical Economics*, 4th Edition, McGraw-Hill, New York, 2005.
4. Dowling E.T, *Introduction to Mathematical Economics*, 2nd Edition, Schaum's Series, McGraw- Hill, New York, 2003.
5. Mary George, Thomaskutty, *A Text Book of Mathematical Economics*, Discovery Publishers, New Delhi.

SEMESTER - 2

AUMM 231.1a/231.1c: Mathematics for Economics - II
(Sequences, Series and Multivariate Differential Calculus)

Total Teaching Hours: 54	No of Lecture Hours/Week: 3
Max Marks: 80	Credits: 3

Course Outcomes:

- **CO1:** Learn sequences and infinite series and apply it in determining the present discounted values and investment projects.
- **CO2:** Learn exponentials and logarithms and their applications in solving economic problems such as, compound interest and present discounted values.
- **CO3:** Understand partial differentiation and its applications in Economics.

Text: Knut Sydsaeter, Peter J. Hammond, *Mathematics for Economic Analysis*, Pearson, 1995.

Module I	Total Teaching Hours: 18

Sequences and Series: Infinite sequences, geometric series, general series, present discounted values and investment projects.

Exponential and Logarithmic Functions: The natural exponential function, the natural logarithmic function, generalizations, applications of exponentials and logarithms, compound interest and present discounted values.

[The topics to be discussed in this module can be found in Chapter 6; Sections -6 & Chapter 8]

Module II	Total Teaching Hours: 18

Functions of Several Variables: Functions of two or more variables, geometric representations of functions of several variables, partial derivatives with two variables, partial derivatives and tangent planes, partial derivatives with many variables, partial derivatives in Economics, linear models with quadratic objectives.

[The topics to be discussed in this module can be found in Chapter 15 ; Sections 1 – 7]

Module III	Total Teaching Hours: 18

Tools for Comparative Statics: The chain rule, more general chain rules, derivatives of functions defined implicitly, partial elasticities, homogeneous functions of two variables, linear approximations and differentials, systems of equations.

Multivariable Optimization: Simple two-variable optimization.

[The topics to be discussed in this module can be found in Chapter 16; Sections 1 - 5, 8, 9 & Chapter 17; Section 1]

References:

1. G D Allen, *Mathematical Analysis for Economics*, AITBS Publishers, New Delhi.
2. Taro Yamane, *Mathematics for Economists*, An Elementary Survey, PHI, New Delhi.
3. Chiang A.C. and K. Wainwright, *Fundamental Methods of Mathematical Economics*, 4th Edition, McGraw-Hill, New York, 2005.
4. Dowling E. T., *Introduction to Mathematical Economics*, 2nd Edition, Schaum's Series, McGraw- Hill, New York, 2003.
5. Mary George, Thomaskutty, *A Text Book of Mathematical Economics*, Discovery Publishers, New Delhi.

SEMESTER - 3

AUMM 331.1a/331.1c: Mathematics for Economics - III (Integral Calculus and Linear Algebra)

Total Teaching Hours: 54	No of Lecture Hours/Week: 3
Max Marks: 80	Credits: 3

Course Outcomes:

- **CO1:** Learn different methods integration and apply it to find the area under a curve.
- **CO2:** Understand the applications of integration through functions familiar in Economics.
- **CO3:** Learn basics of matrix algebra.

Text: Knut Sydsaeter, Peter J. Hammond, *Mathematics for Economic Analysis*, Pearson, 1995.

Module I	Total Teaching Hours: 18

Linear Algebra - Vectors and Matrices: Systems of linear equations, vectors, geometric interpretation of vectors, the scalar product, lines and planes, matrices and matrix operations, matrix multiplication, rules for matrix multiplication, the transpose.

Determinants and Matrix Inversion: Determinants of order 2, determinants of order 3, determinants of order n, basic rules for determinants, expansion by cofactors, inverse of a matrix, a general formula for the inverse, Cramer's rule.

[The topics to be discussed in this module can be found in Chapters 12 and 13]

Module II	Total Teaching Hours: 18

Further Topics in Linear Algebra: Linear independence, The rank of a matrix, Eigen values. Cayley Hamilton theorem and its applications, power of a matrix.

[The topics to be discussed in this module can be found in Chapter 14 Sections 1 – 4]

Module III	Total Teaching Hours: 18

Integration: Areas under curves, indefinite integrals, the definite integral, economic application of integration.

Further Topics in Integration: Integration by parts, integration by substitution, extending the concept of the integral, a note on income distribution and Lorenz curves.

[The topics to be discussed in this module can be found in Chapters 10 and 11]

References:

1. G D Allen, *Mathematical Analysis for Economics*, AITBS Publishers, New Delhi.
2. Taro Yamane, *Mathematics for Economists, An Elementary Survey*, PHI, New Delhi.
3. Chiang A.C. and K.Wainwright, *Fundamental Methods of Mathematical Economics*, 4th Edition, McGraw-Hill, New York, 2005.
4. Dowling E.T, *Introduction to Mathematical Economics*, 2nd Edition, Schaum's Series, McGraw- Hill, New York, 2003.
5. Mary George, Thomaskutty, *A Text Book of Mathematical Economics*, Discovery Publishers, New Delhi.

SEMESTER - 4

AUMM 431.1a/431.1c: Mathematics for Economics - IV (Linear Programming, Differential Equations and Difference Equations)

Total Teaching Hours: 54	No of Lecture Hours/Week: 3
Max Marks: 80	Credits: 3

Course Outcomes:

- **CO1:** To use linear programming methods in economic decision problems.
- **CO2:** To solve problems in Economics using difference equations.
- **CO3:** To learn various types of differential equations and methods to solve them.

Text: Knut Sydsaeter, Peter J. Hammond, *Mathematics for Economic Analysis*, Pearson, 1995.

Module I	Total Teaching Hours: 18

Linear programming: Preliminaries, introduction to duality theory, the duality theorem, a general economic interpretation, complementary slackness.

[The topics to be discussed in this module can be found in Chapter 19]

Module II	Total Teaching Hours: 18

Difference Equations: First order difference equations, compound interest and present discounted values, linear equations with a variable coefficient, second order equations, second order equations with constant coefficients.

[The topics to be discussed in this module can be found in Chapter 20]

Module III	Total Teaching Hours: 18

Differential Equations: First order differential equations, the direction is given – find the path, separable differential equations-I, separable differential equations-II, first order linear differential equations-I, first order linear differential equations-II, qualitative theory and stability, second order differential equations, second order differential equations with constant coefficients.

[The topics to be discussed in this module can be found in Chapter 21]

References:

1. G. D. Allen, *Mathematical Analysis for Economics*, AITBS Publishers, New Delhi.
2. Taro Yamane, *Mathematics for Economists, An Elementary Survey*, PHI, New Delhi.
   Chiang A. C. and K. Wainwright, *Fundamental Methods of Mathematical Economics*, 4th Edition, McGraw-Hill, New York, 2005.
4. Dowling E.T, *Introduction to Mathematical Economics*, 2nd Edition, Schaum's Series, McGraw-Hill, New York, 2003.

5. Mary George, Thomaskutty, *A Text Book of Mathematical Economics*, Discovery Publishers, New Delhi.
6. J. K. Sharma, *Operations Research-Theory and Applications*, 3rd, MacMillan India Ltd, Delhi.