FOUR YEAR UNDERGRADUATE PROGRAMME

SUBJECT: MATHEMATICS

SEMESTER-I
Classical Algebra
Total Marks: 100 (Theory 80, Internal Assessment 20)
No. of Credits: 4

Base syllabus: MAT-HG-2016/MAT-RC-2016: Algebra (UG CBCS)

Course Level: 100-199

No. of Contact classes: 60

No. of Non-Contact classes: 0

Prerequisites: Mathematics in 10+2 or equivalent standard.

Course Objectives: The primary objective of this course is to introduce the basic tools of complex numbers, theory of equations, matrices and matrix method of solution of homogeneous linear equations up to four variables.

Course Learning Outcomes: This course will enable the students to:

- Employ De Moivre's theorem in a number of applications to solve numerical problems.
- Learn the basic concepts of exponential, logarithmic and hyperbolic functions of complex numbers.
- Learn how to find the nature of the roots of a given polynomial equation by Descartes' rule , also learn about symmetric functions of the roots for cubic and biquadratic equations.
- Learn how to solve cubic and biquadratic equations.
- Recognize consistent and inconsistent systems of linear equations by the row echelon form of the augmented matrix. Finding inverse and rank of a matrix.

Unit 1:

Polar representation of complex number, De Moivre's theorem (both integral and rational index), Roots of complex numbers, n^{th} roots of unity, Application of De Moivre's Theorem, Exponential and logarithmic functions of complex numbers, Hyperbolic functions.

[1] Chapter 2 (Sections 2.7-2.13, 2.16)

(No. of classes: 20, Marks: 25)

Unit 2:

Algebraic equations: Deduction from Fundamental Theorem of Classical Algebra, Descartes' rule of signs, relation between roots and coefficients of a polynomial equation of degree n,

symmetric functions of roots, Transformation of equations, Cardon's method of solution of a cubic equation, Euler's method of solution of a biquadratic equation.

[1] Chapter 5; Theorem 5.1.1, Theorem 5.2.1, Section 5.3 - 5.6, 5.11,5.12.

(No. of classes: 20, Marks: 30)

Unit 3:

Matrix Algebra, Addition, Transposition, Symmetry, Multiplication of matrices and their properties, Matrix inversion and properties, Row Echelon form and Rank of a matrix, Reduced row Echelon form, Consistency of linear systems, Solutions of system of homogeneous linear equations with number of equations and unknowns up to four.

[2] Chapter 3 (Sections 3.2, 3.5, and 3.7) Chapter 2 (Sections 2.1 to 2.4)

(No. of classes: 20, Marks: 25)

Text Books:

1. Mappa, S.K., Higher Algebra (Classical), Revised 8th Edition, 2011, Levant Books.

2. Meyer, Carl D. (2000). Matrix Analysis and Applied Linear Algebra. Society for Industrial and Applied Mathematics (Siam).

Reference Books:

1. Dickson, Leonard Eugene (2009). First Course in The Theory of Equations. The Project Gutenberg eBook (http://www.gutenberg.org/ebooks/29785)

2. Gilbert, William J., & Vanstone, Scott A. (1993). Classical Algebra (3rd ed.). Waterloo Mathematics Foundation, Canada.

3. Titu Andreescu and Dorin Andrica, Complex Numbers from A to Z, Birkhauser,2006.

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SEMESTER-II

Calculus

Total Marks: 100 (Theory 80, Internal Assessment 20)

No. of Credits: 4

Each unit carries equal credit

Base syllabus: MAT-HG-1016/ MAT-RC-1016: Calculus (UG CBCS)
Course Level: 100-199
No. of Contact classes: 60
No. of Non-Contact classes: 0
Prerequisites: Class XII Level Mathematics

Course Objectives: Calculus is referred as 'Mathematics of change' and is concerned with describing the precise way in which changes in one variable relate to the changes in another. Through this course, students can understand the quantitative change in the behaviour of the variables and apply them on the problems related to the environment.

Course Learning Outcomes: The students who take this course will be able to:

- Understand continuity and differentiability in terms of limits.
- Describe asymptotic behavior in terms of limits involving infinity.
- Understand the importance of mean value theorems.

Unit 1: Limits and continuity of a function including different approaches, Properties of continuous functions including Intermediate value theorem.

[1] Chapter 1

(No. of classes: 15, Marks: 20)

Unit 2: (a) Differentiability, Successive differentiation, Leibnitz theorem, Recursion formulae for higher derivatives.

(b) Reduction formulae, derivations and illustrations of reduction formulae of the type $\int \sin^n x\, dx$, $\int \cos^n x\, dx$, $\int \tan^n x\, dx$, $\int \sec^n x\, dx$, $\int (\log x)^n\, dx$, $\int \sin^n x \cos^m x\, dx$.

[2] Chapter 5(for part (a))

[3] Chapter 4 (4.1-4.6) (only for part (b))

(No. of classes: 15, Marks: 20)

Unit 3: Rolle's theorem, Lagrange's mean value theorem with geometrical interpretations and simple applications, Maclaurin and Taylor polynomials and their sigma notations. Taylor's formula with remainder, Introduction to Maclaurin and Taylor series.

[1] Chapter 9 (Sections 9.8 and 9.9 (without 'convergence' part))

[2] Chapter 6

(No. of classes: 15, Marks: 20)

Unit 4: Functions of two or more variables, Partial differentiation up to second order, Euler's theorem on homogeneous functions

[1] Chapter 13 (Sections 13.1 and 13.3)

[2] Chapter 10(10.81)

(No. of classes: 15, Marks: 20)

Text books:

[1] Anton, Howard, Bivens, Irl, & Davis, Stephen (2013). Calculus (10th ed.). John Wiley & Sons Singapore Pte. Ltd. Reprint (2016) by Wiley India Pvt. Ltd. Delhi

[2] Shanti Narayan and P.K. Mittal, Differential Calculus, S. Chand, 2005

[3] Shanti Narayan and P.K. Mittal, Integral Calculus, S. Chand, 2007.

Reference book:

[1] Thomas, Jr. George B., Weir, Maurice D., & Hass, Joel (2014). Thomas' Calculus (13^{th} ed). Pearson Education, Delhi. Indian Reprint 2017.

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SEMESTER-III

Ordinary Differential Equations

Total Marks: 100 (Theory 80, Internal Assessment 20)

No. of Credits: 4

Each unit carries equal credit

Base syllabus: MAT-HG-3016/MAT-RC-3016: Differential Equations (UG CBCS)

Course Level: 200-299

No. of Contact classes: 60

No. of Non-Contact classes: 0

Prerequisites: Class XII Mathematics

Course Objectives: The main objective of this course is to introduce the students to the exciting world of differential equations and their solutions methods.

Course Learning Outcomes: The course will enable the students to:

- Learn basics of 1^{st} order ordinary differential equations and 2^{nd} order linear differential equations
- Learn different techniques for solving the differential equations

Unit 1: **First Order Ordinary Differential Equations**

Classification of differential equations; their origin and application. Solutions. First order exact differential equation. Integrating factors, Rules to find an integrating factor.

[1] Chapter 1(Sections 1.1and 1.2) Chapter 2 (Sections 2.1, 2.2 and 2.4)

Linear equations and Bernoulli equations. Basic theory of higher order linear differential equations. Solving differential equation by reducing its order. Wronskian and its properties.

[1] Chapter 2 (Section 2.3), Chapter 4 (Sections 4.1 and 4.6)

(No. of classes: 30, Marks: 40)

Unit 2: Second Order Linear Differential Equations

Linear homogenous equations with constant coefficients. Linear non- homogenous equations; the method of undetermined coefficients, the method of Variation of Parameters. The Cauchy-Euler equations.

[1] Chapter 4 (Sections 4.2, 4.3, 4.4 and 4.5)

(No. of classes: 30, Marks: 40)

Text Book:

[1] Ross, Shepley L. (1984). Differential Equations (3^{rd} Ed.), John Wiley & Sons,Inc.

Reference Book:

1.Kreyszig, Erwin (2011). Advanced Engineering Mathematics(10^{th} ed.).John Wiley & Sons, Inc. Wiley India Edition 2015.

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SEMESTER-IV

Paper-I

Real analysis

Total Marks: 100 (Theory 80, Internal Assessment 20)

No. of Credits: 4

Base syllabus: MAT-HG-4016/ MAT-RC-4016: Real Analysis (UG CBCS)

Course Level: 200-299

No. of Contact classes: 60

No. of Non-Contact classes: 0

Prerequisites: Class XII level Mathematics

Course Objective: The course will develop a deep and rigorous understanding of real line R andof defining terms to prove the results about convergence and divergence of sequences and series of real numbers. These concepts have wide range of applications in real life scenario.

Course Learning Out comes: This course will enable the students to:

- Understand many properties of the real line *R*, including completeness and Archimedean properties.
- Learn to define sequences in terms of functions from *N* to a subset of *R*.
- Recognize bounded, convergent, divergent, Cauchy and monotonic sequences and to calculate their limit superior, limit inferior, and the limit of a bounded sequence.
- Apply limit comparison tests for convergence, the ratio, root, Raabe's, integral tests for convergence of an infinite series of real numbers.
- Alternating series and absolute convergence of an infinite series of real numbers.

UNIT 1: Algebraic and order properties of R, absolute value and real line, bounded sets, supremum and infimum, completeness property of R, the Archimedean property, the density theorem, intervals, nested interval theorem, uncountability of R.

[1] Chapter 2

(No of classes: 10, Marks: 15)

UNIT 2: Real sequences, limit of a sequence, convergent sequence, bounded sequence, limit theorems, monotone sequences, monotone convergence theorem, subsequences, monotone subsequence theorem, Bolzano Weierstrass theorem for sequences, Cauchy sequences, Cauchy's convergence criterion, properties of divergence sequences.

[1] Chapter 3

(No of classes: 25, Marks: 30)

UNIT 3: Infinite series, convergence and divergence of infinite series, Cauchy criterion, Tests for convergence: comparison test, limit comparison test, ratio test, root test, integral test, Raabes's test, Absolute convergence, rearrangement theorem, alternating series, Leibniz test, conditional (non-absolute) convergence.

[1] Chapter 3: Section: 3.7, Chapter 9: Sections: 9.1-9.3.

(No of classes: 25, Marks: 35)

Text Book:

1. R.G. Bartle and D.R. Sherbert, *Introduction to Real Analysis*, 3rd Ed., John Wiley and Sons, 2002.

Reference Books:

1. Gerald G. Bilodeau, Paul R. Thie, G.E. Keough, *An Introduction to Analysis,* Jones &Bartlett, Second Edition, 2010.
2. A. Kumar and S. Kumaresan, *Basic Course in Real Analysis*, CRC Press, 2014.
3. K.A. Ross, *Elementary Analysis*: *The Theory of Calculus*, Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.

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SEMESTER-IV

Paper-II

Complex Analysis (with practical)

Total Marks: 100

(Theory: 60, Practical 20, Internal Assessment: 20)

No. of Credits: 4 (Theory 3, Practical 1)

Base syllabus: MAT-HC-5016: Complex Analysis (including practical)

Course Level: 200-299

No. of Contact classes: 75 (15×3+30×1)

No. of Non-Contact classes: 0

Prerequisites: Knowledge on

- complex number system as the extension of real number system
- Algebra of complex numbers.
- Properties of complex number.
- Modulus, argument and geometrical representation of complex numbers

Course Objectives: The main objective of this course is to develop a deep understanding of the complex plane together with various related concepts. These concepts have wide applicability in different aspects.

Course Learning Outcomes: The completion of the course will enable the students to:

- Learn the significance of differentiability of complex functions leading to the understanding of Cauchy−Riemannequations.
- Learn some elementary functions and valuate the contour integrals.
- Understand the role of Cauchy−Goursat theorem and the Cauchy integral formula

UNIT 1: Functions of complex variable, mappings, limits, theorems on limits, limits involving point at infinity, continuity. Derivatives, rules for differentiation, Cauchy-Riemann equations, sufficient conditions for differentiability, polar co-ordinates.

[1]: Chapter 2 (Section 13, 14, 15, 16, 17, 18, 19, 20, 21, 22,23,24)

(No. of classes: 10, Marks: 15)

UNIT 2: Analytic functions, examples of analytic functions, harmonic function. The exponential function, Logarithmic function, examples, branches and derivatives of logarithms,some identities involving logarithms, the power function. trigonometric function, zeros and singularities of trigonometric functions derivatives of functions, definite integrals of functions.

[1]: Chapter 2 (Sections 25, 26,27), Chapter 3 (Sections 30, 31,32,33,34, 35,36,37,38), Chapter 4 (Section 41,42)

(No. of classes: 15, Marks: 15)

UNIT 3: Contours, Contour integrals and its examples, upper bounds for moduli of contour integrals, antiderivatives, proof of antiderivative theorem.

[1]: Chapter 4 (Section 43, 44, 45,47, 48, 49)

(No. of classes: 10, Marks: 15)

UNIT 4: Cauchy-Goursat theorem, simply connected domains, multiply connected domains, Cauchy integral formula, extension of Cauchy integral formula, Liouville's theorem and the fundamental theorem of algebra.

[1]: Chapter 4 (Sections 50, 52, 53,54, 55, 58)

(No. of classes: 10, Marks: 15)

LAB WORK TO BE PERFORMED ON A COMPUTER

(MODELING OF THE FOLLOWING PROBLEMS USING MATLAB/ MATHEMATICA/ MAPLE etc.)

1. Declaring a complex number and graphical representation. e.g. $Z_1 = 3 + 4i$, $Z_2 = 4 - 7i$

2. Program to discuss the algebra of complex numbers, e.g.,

$Z_1 = 3 + 4i$, $Z_2 = 4 - 7i$, then find $Z_1 + Z_2$, $Z_1 - Z_2$, $Z_1 * Z_2$ and Z_1 / Z_2

3. To find conjugate, modulus and phase angle of an array of complex numbers.

e.g. $Z = [2+ 3i, 4-2i, 6+11i, 2-5i]$

4. To compute the integral over a straight line path between the two specified end points.

e. g., $\oint \mathrm{Sin} z \, dz$, along the contour C which is a straight line path from -1+ i to 2 - i.

5. To perform contour integration., e.g.,

(i) $\oint (z^2 - 2z + 1) dz$ along the Contour C given by $x = y^2 + 1; -2 \leq y \leq 2$.

(ii) $\oint (z^3 + 2z^2 + 1) dz$ along the contour C given by $x^2 + y^2 = 1$, which can be parameterized by $x = \cos(t), y = \sin(t)$ for $0 \leq y \leq 2\pi$.

6. To plot the complex functions and analyze the graph. e.g.,

$f(z) = z, iz, z^2, z^3, e^z$ and $(z^4-1)^{1/4}$, etc

(No. of practical classes: 30, Marks: 20)

Text Book:

1. James Ward Brown and Ruel V. Churchill, Complex Variables and Applications (Ninth Edition), McGraw-Hill Indian Edition, 2021.

Reference Book:

1. Joseph Bak and Donald J. Newman, *Complex analysis* (2nd Edition), Undergraduate Texts in Mathematics,Springer-Verlag New York, Inc., New York, 1997.

2. M.R. Spiegel, *Complex Variables*. Schaum's Outlines series, McGraw Hill Education, 2017

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SEMESTER-IV

Paper-III

Analytical Geometry

Total Marks: 100 (Theory 80, Internal Assessment 20)

No. of Credits: 4 (Each unit carries equal credit)

Base syllabus: MAT-HG-1026: Analytical Geometry (UG CBCS)

Course Level: 200-299

No. of Contact classes: 60

No. of Non-Contact classes: 0

Prerequisites: Class XII Mathematics

Course Objectives: The primary objective of this course is to introduce some basic tools of two-dimensional and three-dimensional coordinate systems and also to familiarise the use of Vector Algebra in Coordinate Geometry.

Course Learning Outcomes: This course will enable the students to:

- transform coordinate systems
- learn about pair of straight lines
- have a clear understanding of the conic sections and related properties
- recognise three dimensional surfaces represented by equations of the second degree
- learn two different systems of coordinates which are very useful to define the position of a point in space
- acquire basic concepts of Vector Algebra and understand the use of geometric view of vectors in Coordinate Geometry.

UNIT 1: Transformation of coordinates, invariants under orthogonal transformations, pair of straight lines.

[1] Chapter 1 (Section 1.3), Chapter 2, Chapter 3

(No. of classes: 15, Marks: 20)

UNIT 2: Parabola, parametric coordinates, tangent and normal, ellipse and its conjugate diameters with properties, hyperbola and its asymptotes, General conics: tangent, condition of tangency, pole and polar, centre of a conic, equation of pair of tangents, reduction to standard forms, central conics, equation of the axes, and length of the axes, polar equation of a conic, tangent and normal, and properties.

[1] Chapters 4, 5, 6, 7, 9 (upto Section 9.43)

(No. of classes: 15, Marks: 20)

UNIT 3: Quadric surfaces: Sphere, Cylinder and Cone. Cylindrical and spherical polar coordinates.

[1] Chapter 6 (Section 6.1 – 6.3), Chapter 12

(No. of classes: 15, Marks: 20)

UNIT 4: Rectangular coordinates in 3-space, Vector viewed geometrically, Vectors in coordinates system, Vectors determined by length and angle, Dot product, Cross product and their geometrical properties, Triple product, Parametric equations of lines in 2-space and 3-space.

[2] Chapter 11 (Section 11.1 - 11.5)

(No. of classes: 15, Marks: 20)

Text Books:

1. R.M. Khan, Analytical Geometry of two and three dimensions and Vector Analysis. New Central Book Agency, 2012.

2. Anton, Howard, Bivens, Irl, & Davis, Stephen (2013), Calculus (10^{th} ed.). John Wiley & Sons, Singapore Reprint (2016) by Wiley India Pvt. Ltd., Delhi.

Reference Book:

1. R.J.T. Bell, Coordinate Solid Geometry, Macmillan, 1983.

2. E.H. Askwith, The Analytical Geometry of the Conic Sections, Nabu Press (27 February 2012)

3. B. Das, Analytical Geometry and Vector Analysis, Orient Book Company, Kolkata -700007

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SEMESTER-IV

Paper-IV

Number Theory

Total Marks: 100 (Theory 80, Internal Assessment 20)

No. of Credits: 4

Base syllabus: MAT-HE-5016: Number Theory (UG CBCS)

Course Level: 200-299

No. of Contact classes: 60

No. of Non-Contact classes: 0

Prerequisites: Mathematics in senior secondary school or equivalent standard.

Course Objectives:

The primary objective of this course is to develop students' understanding of integers, with a focus on their properties and representations, as well as their understanding of number theoretic analysis.

Course Learning Outcomes: On successful completion of the course students will be able to:

- Explain division algorithm, Euclid's algorithms and greatest common divisor.
- Explain the concepts of congruences, linear congruences .
- Explore the Chinese Remainder theorem to solve simultaneous linear congruences.
- Explain Fermat's theorem and Wilson's theorem.
- Solve a range of problems in number theory
- Apply mathematical ideas and concepts within the context of number theory.
- Communicate number theoretic techniques to a mathematical audience.

Unit 1: Well-Ordering Principle of integers, Archimedian property, First principle of finite induction, Second principle of finite induction, The division algorithm of integers, The greatest common divisor, The Euclidean algorithm, The Diophantine equation $ax + by = c$, Fundamental Theorem of Arithmetic, The sieve of Eratosthenes, The Goldbach Conjecture.

[1] Chapter 1 (Sections 1.1), Chapter2 (sections 2.2 -- 2.5), Chapter3.

(No of classes:20, Marks:25)

Unit 2: Congruence modulo of a fixed positive integer, Basic properties of congruences, Binary and decimal representation of integers, Linear congruences, Chinese Remainder Theorem, Fermat's Little Theorem, pseudoprimes, Wilson's Theorem.

[1] Chapter 4 (Sections 4.2-4.4) Chapter5 (Sections: 5.2, 5.3).

(No of classes: 20, Marks: 25)

Unit 3: Number Theoretic Functions: The sum and number of divisors of a positive integer, Multiplicative functions, Mobius function, The Mobius inversion Formula, The greatest integer function, Euler's Phi-Function, Euler's Theorem, Properties of Euler's Phi function.

[1] Chapter 6 (Sections 6.1-6.3), Chapter 7 (Sections 7..2 to 7.4) .

(No of classes:20, Marks:30)

Text Books:

1. David M. Burton, *Elementary Number Theory*, 7th Edition, McGraw Hill Education (India) private limited. 2012.

Reference Books:

1. G.A. Jones and J. Mary Jones, *Elementary Number Theory*. Undergraduate Mathematics Series (SUMS) , 2005.

2. Neville Robinns, *Beginning Number Theory*. 2nd Ed., Narosa Publishing House Pvt. Ltd. Delhi-2007

3. K.C. Chowdhury, *A First Course in Number Theory*, Asian Books Publications- 2012.

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SEMESTER-V

Paper-I

Abstract Algebra

Total Marks: 100 (Theory 80, Internal Assessment 20)

No. of Credits: 4

Each unit carries equal credit

Base syllabus: MAT-HC-3026: Group Theory-I (UG CBCS)

Course Level: 300-399

No. of Contact classes: 60

No. of Non-Contact classes: 0

Prerequisites: Mathematics in senior secondary school or equivalent standard.

Course Objectives: The primary objective of this course is to introduce abstract mathematical objects, viz. groups, rings and fields and study their properties. It is also focussed to study the consequences of these mathematical structures.

Course Learning Outcomes: On successful completion of the course students will be able to:

- Recognize the mathematical objects called group, ring and fields.
- Link the fundamental concepts of groups and symmetries of geometrical objects.
- Explain the significance of the notion of Permutation groups, cosets, cyclic groups, normal subgroups, factor groups.
- Analyse consequences of Lagrange's theorem and Fermat's Little theorem.
- Describe structure preserving mappings between groups and their consequences.
- Describe the fundamental concepts in ring theory such as of the subrings, integral domains, ideals, factor rings and fields.

Unit 1: Definition and examples of groups, Elementary properties of groups, Symmetries of a square, Dihedral groups, order of a group, Order of an element in a group, Subgroups, Subgroup Tests, Subgroup generated by an element of a group, Centre of a group, Centralizer of an element in a group, Cyclic groups, Properties of cyclic groups, Fundamental theorem of cyclic groups.

[1] Chapter 1 to Chapter 4.

(No. of classes: 15, Marks: 20)

Unit 2: Permutations, Permutation group, Properties of permutations, Even and odd permutations, Alternating groups, Cosets, Properties of cosets, Lagrange's Theorem, Fermat's Little Theorem, Normal subgroups, Factor groups.

[1] Chapter 5 (up to theorem 5.7), Chapter 7 (up to theorem 7.2), Chapter 9 (up to theorem 9.2)

(No. of classes: 15, Marks: 20)

Unit 3: Isomorphism of groups, Cayley's Theorem, Properties of isomorphism, Group homomorphism, Kernal of a group homomorphism, Properties of group homomorphism, First isomorphism Theorem of groups.

[1] Chapter 6 (up to theorem 6.3), Chapter 10 (up to theorem 10.4).

(No. of classes: 15, Marks: 20)

Unit 4: Rings, Examples of rings, Properties of rings, Subrings, Zero-Divisors in a ring, Integral domains, Fields, Characteristic of a ring, Ideals, Ideal Test, Factor rings, Prime ideals and maximal ideals of a ring.

[1] Chapter 12 to Chapter 14.

(No. of classes: 15, Marks: 20)

Text Books:

1. Gallian Joseph A., *Contemporary Abstract Algebra* (8th Edition) , Cengage Learning India Private limited, Delhi, Fourth impression, 2015.

Online link: https://ict.iitk.ac.in/wp-content/uploads/CS203-Mathematics-for-Computer-Science-III-Gallian.pdf

Reference Books:

1. David S. Dummit and Richard M. Foote, *Abstract Algebra* (2nd Edition) , John Wiley and Sons (Asia) Pvt. Ltd. , Singapore, 2003.

2. John B. Fraleigh, *A First course in Abstract Algebra*, 7th Edition, Pearson, 2002.

3. G. Santhanam. *Algebra,* Narosa Publishing House, 2017.

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SEMESTER-V

Paper-II

Multivariate Calculus

Total Marks: 100 (Theory 80, Internal Assessment 20)

No. of Credits: 4

(Each unit carries equal credits)

(Use of Scientific calculator is allowed)

Base syllabus: MAT-HC-4016: Multivariate Calculus (UG CBCS)

Course Level: 300-399

No. of Contact classes: 60

No. of Non-Contact classes: 0

Prerequisites: Knowledge on the following topics:

- Functions of single variable, limit, continuity, differentiability and extrema of single variable functions.
- Knowledge of Integration
- Vector valued functions, dot and cross product of vectors.

Course Objectives: To understand the extension of the studies of single variable differential and integral calculus to functions of two or more independent variables. Also, the emphasis will be on the use of Computer Algebra Systems by which these concepts may be analyzed and visualized to have a better understanding. This course will facilitate to becomeaware of applications of multivariable calculus tools in physics, economics, optimization, and understanding the architecture of curves and surfaces in plane and space etc.

Course Learning Outcomes: This course will enable the students to:

- Learn the conceptual variations when advancing in calculus from one variable to multivariable discussion.
- Understand the maximization and minimization of multivariable functions subject to the given constraints on variables.
- Learn about inter-relationship amongst the line integral, double and triple integral formulations.
- Familiarize with Green's, Stokes' and Gauss divergence theorems

UNIT 1: Functions of several variables, Level curves and surfaces, Limits and continuity, Partial differentiation, Higher order partial derivative, Chain rule, Directional derivatives, The gradient, Maximal property of the gradient.

[1] Chapter 11 [(Sections 11.1, 11.2, 11.3, 11.5, Section 11.6 (upto page 592)]

(No. of classes: 15, Marks: 20)

UNIT 2: Extrema of functions of two variables, Method of Lagrange multipliers, Constrained optimization problems; Definition of vector field, Divergence and curl.
[1] Chapter 11 [Section 11.7 (up to page 605), Section 11.8 (pages 610-614)], Chapter13 (Section 13.1)
(No. of classes: 15, Marks: 20)

UNIT 3: Double integration over rectangular and nonrectangular regions, Double integrals in polar coordinates, Triple integral over a parallelepiped and solid regions, Volume by triple integrals.
[1] Chapter 12 (Sections 12.1-12.4)
(No. of classes: 15, Marks: 20)

UNIT 4: Line integrals, Applications of line integrals**:** Mass and Work, Fundamental theorem for line integrals, Conservative vector fields, Green's theorem, Area as a line integral; Surface integrals, Stokes' theorem, The Gauss divergence theorem.
[1] Chapter 13 [(Sections 13.2, 13.3), Section 13.4 (pages 712 to 716), Section 13.5 (pages 723 to 726) Section 13.6 (pages 733 to 737), Section 13.7 (pages 742 to 745)]
(No. of classes: 15, Marks: 20)

Text book:

[1] Strauss, Monty J.,Bradley, Gerald L.,& Smith, Karl J.(2007). *Calculus* (3rd ed.).Dorling Kindersley (India) Pvt. Ltd. (Pearson Education). Delhi. Indian Reprint 2011

Reference Books:

1. Marsden, J.E., Tromba, A., & Weinstein,A.(2004).*Basic Multivariable Calculus*.Springer (SIE). First Indian Reprint.
2. G.B. Thomas and R.L. Finney, Calculus, 9th Ed., Pearson Education, Delhi, 2005.
3. James Stewart, Multivariable Calculus, Concepts and Contexts, 2nd Ed., Brooks /Cole, Thomson Learning, USA,2001.

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SEMESTER-V

Paper-III

Theory of Real Functions

Total Marks: 100 (Theory 80, Internal Assessment 20)

No. of Credits: 4

Base syllabus: MAT-HC-3016: Theory of Real Functions (UG CBCS)

Course Level: 300-399

No. of Contact classes: 60

No. of Non-Contact classes: 0

Prerequisites: Class XII level Mathematics

Course Objective: The primary objective of this course is to study limit point of set and limit of a function. The discussion on continuous functions and differentiability with some related theorems will also be focused in this course.

Course Learning Outcomes: This course will enable the students to:

- Have a rigorous understanding of the concept of limit of a function.
- Learn about continuity and uniform continuity of functions defined on intervals.
- Understand geometrical properties of continuous functions on closed and bounded intervals.
- Learn extensively about the concept of differentiability using limits, leading to a better understanding for applications.
- Know about applications of mean value theorems and Taylor's theorem

UNIT 1: Cluster point or limit point of a set, limits of a function (ε-δ approach), sequential criterion for limits, divergence criteria, limit theorems, one sided limits, infinite limits and limits at infinity.

[1] Chapter 4

(No. of classes: 15, Marks: 20)

UNIT 2: Continuous functions, sequential criterion for continuity and discontinuity, algebra of continuous functions, continuous functions on intervals, maximum-minimum theorem, intermediate value theorem, location of roots theorem, preservation of intervals theorem, uniform continuity, uniform continuity theorem, monotone and inverse functions.

[1] Chapter 5 (5.1 to 5.6)

(No. of classes: 15, Marks: 30)

UNIT 3: Differentiability of a function at a point and in an interval, Caratheodory's theorem, chain rule, derivative of inverse function, Rolle's theorem, mean value theorem, Darboux's theorem, Cauchy mean value theorem, Taylor's theorem and applications to inequalities, Taylor's series expansions of exponential and trigonometric functions, ln(1+x), 1/(ax+b) and $(1+x)^n$.

[1] Chapter 6, and Taylor series as in Section 6.4.

(No. of classes: 30, Marks: 30)

Text Book:

1. R.G. Bartle and D.R. Sherbert, *Introduction to Real Analysis*, 3rd Ed., John Wiley and Sons, 2002.

Reference Books:

1. Ajit Kumar and S. Kumaresan, *A Basic Course in Real Analysis*, CRC Press, Indian Ed. 2014.
2. K.A. Ross, *Elementary Analysis: The Theory of Calculus*, Springer, 2004.
3. Mattuck, *Introduction to Analysis*, Prentice Hall, 1999.
4. S.R.Ghorpade and B.V.Limaye, *A Course in Calculus and Real Analysis*, Springer, 2006.

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SEMESTER-V

Paper-IV

Numerical Analysis (with practical)

Total Marks: 100

(Theory: 60, Practical 20, Internal Assessment: 20)

No. of Credits: 4 (Theory 3, Practical 1)

(Use of Scientific calculator is allowed)

Base syllabus: MAT-HG-4026: Numerical Analysis (UG CBCS)

Course Level: 300-399

No. of Contact classes: 75 (15×3+30×1)

No. of Non-Contact classes: 0

Prerequisites: Class XII level Mathematics, Knowledge on computer software and programming

Course Objectives: To comprehend various computational techniques to find approximate value for possible root(s) of non-algebraic equations, to find the approximate solutions of system of linear equations and Quadratic equations.

Course Learning Outcomes: The course will enable the students to:

- Learn some numerical methods to find the zeroes of nonlinear functions of a single variable and solution of asystem of linear equations, up to a certain given level of precision.
- Know about iterative and non-iterative methods to solve system of linear equations
- Know interpolation techniques to compute the values for a tabulated function at points not in the table.
- Integrate a definite integral that cannot be done analytically
- Find numerical differentiation of functional values
- Solve differential equations that cannot be solved by analytical methods

Unit 1: Gaussian elimination method (with row pivoting), Gauss-Jordan method; Iterative methods**:** Jacobi method, Gauss-Seidel method; Interpolation**:** Lagrange form, Newton form, Finite difference operators, Gregory-Newton forward and backward difference interpolations, Piecewise polynomial interpolation (Linear and Quadratic).

[1] Chapter 3(Sections 3.1, and3.2),Chapter 6(Sections 6.1,and 6.2) Chapter 8(Section8.1, Section8.3 (8.3.1, and8.3.2)

[2] Chapter 3(Sections 3.2, and 3.4) Chapter 4(Section 4.2) Chapter 4(Sections 4.3,and 4.4)

[1]Chapter 18 (Sections18.1to18.3)

(No. of classes: 20, Marks: 30)

Unit 2: Numerical differentiation**:** First and second order derivatives; Numerical integration**:** Trapezoid rule, Simpson's rule; Extrapolation methods**:** Richardson extrapolation, Romberg integration; Ordinary differential equation**:** Euler's method, Modified Euler's methods **(**Heun and Mid-point).

[2] Chapter 11 [Sections 11.1(11.1.1,11.1.2,11.1.4), and11.2(11.2.1,11.2.2,11.2.4)]

[1] Chapter 22 (Sections22.1, and 22.2,22.3)

(No. of classes: 25, Marks: 30)

***Practical / Lab work to be performed on a computer*:**

Use of computer aided software (CAS), for example *Matlab/Mathematica/Maple* etc., for developing the following numerical programs:

(i) Lagrange's interpolation method

(ii) Newton's interpolation method

(iii) To calculate forward and backward differences

(iv) Trapezoidal rule

(v) Simpson's rule

Note: For any of the CAS *Matlab/Mathematica/Maple* etc., Data types-simple data types, floating data types, character data types, arithmetic operators and operator precedence, variables and constant declarations, expressions, input/output, relational operators, logical operators and logical expressions, control statements and loop statements, arrays should be introduced to the students.

(No. of practical classes: 30, Marks: 20)

Text Books:

[1] Chapra, Steven C.(2018).*Applied Numerical Methods with* MATLAB *for Engineers and* Scientists (4^{th} ed.) Mc Graw-Hill Education.

[2] Fausett, Laurene V. (2009). *Applied Numerical Analysis Using* MATLAB. Pearson. India

[3] Jain, M.K., Iyengar, S.R.K., & Jain R.K.(2012). *Numerical Methods for Scientific and Engineering Computation* (6^{th} ed.). New Age International Publishers. Delhi.

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SEMESTER-VI

Paper-I

Linear Algebra

Total Marks: 100 (Theory 80, Internal Assessment 20)

No. of Credits: 4

Each unit carries equal credit

Base syllabus: MAT-HC-5026: Linear Algebra (UG CBCS)

Course Level: 300-399

No. of Contact classes: 60

No. of Non-Contact classes: 0

Prerequisites for the paper: Senior Secondary School Mathematics or equivalent

Course Objectives: The objective of this course is to introduce the students with the fundamental theory of linear spaces and also emphasizes the application of techniques using the adjoint of linear operator and minimal solutions to systems of linear equations.

Course Learning Outcomes: This course will enable the students to:

- Learn about linear spaces and their general properties, linear dependence and linear independence of vectors, bases and dimensions of vector spaces
- Basic concepts of linear transformations, dimension theorem, matrix representations of linear transformations, and the change of coordinate matrix.
- Compute the characteristic polynomial, eigenvalues, eigenvectors and eigenspaces, as well as the geometric and the algebraic multiplicities of an eigenvalue and apply the basic diagonalization result.
- Compute inner products and determine orthogonality on vector spaces including Gram-Schmidt orthogonalization to obtain orthonormal basis.

Unit 1: Definition and examples of vector spaces, general properties of vector spaces, Definition and examples of subspaces, subspace criterions and algebra of subspaces, null space and column space of a matrix, Linear transformations, Kernel and range of a linear transformation.

[1]: Chapter 4 (Sections 4.1-4.2), [2] : Chapter 4

(No. of classes: 15, Marks: 20)

Unit 2:, Linear combinations of vectors, linearly dependent and independent sets, bases of vector spaces, coordinate systems, dimension of a vector space, ranks, change of basis.

[1]: Chapter 4 (Sections 4.3-4.7), [2] : Chapter 5

(No. of classes: 15, Marks: 20)

Unit 3: Eigenvectors and eigenvalues of a matrix, The Characteristic equation, Diagonalization, eigenvector of a linear transformation, Complex eigenvalues. Invariant subspaces and Cayley-Hamilton Theorem.

[1]: Chapter 5 (Sections 5.1-5.5), [2]: Chapter 9, [3]: Chapter 5 (Sections 5.4)

(No. of classes: 15, Marks: 20)

Unit 4: Inner products, Length and orthogonality, orthogonal sets, orthogonal projections, The Gram-Schmidt process, Inner product spaces.

[1]: Chapter 6 (Sections 6.1-6.4, 6.7), [2]: Chapter 12

(No. of classes: 15, Marks: 20)

Text Books:

1. David C. Lay, *Linear Algebra and its Applications*, 3rd Edition, Pearson Education, Asia, Indian Reprint, 2007
2. Seymour Lipschutz, *Theory and Problems of Linear Algebra*, Schaum's Outline Series, McGraw-Hill Book Company, Singapore
3. Stephen H. Friedberg, Arnold J. Insel, Lawrence E. Spence, *Linear Algebra*, 4th Edition, Prentice Hall of India Pvt. Ltd., New Delhi, 2004.

Reference Books:

1. S. Kumaresan, *Linear Algebra- A Geometric Approach*, Prentice Hall of India, 2017
2. Gilbert Strang, Linear Algebra and its Applications, Thomson, 2007
3. G. Schay, Introduction to Linear Algebra, Narosa, 1997

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SEMESTER-VI

Paper-II

Partial Differential Equations (with practical)

Total Marks: 100

(Theory: 60, Practical 20, Internal Assessment: 20)

No. of Credits: 4 (Theory 3, Practical 1)

Base syllabus: MAT-HC-6026: Partial Differential Equations (including practical) (UG CBCS)

Course Level: 300-399

No. of Contact classes: 75 (15×3+30×1)

No. of Non-Contact classes: 0

Prerequisites: Class XII level Mathematics, Knowledge on computer software

Course Objectives: The main objectives of this course are to teach students to form and solve partial differential equations and use them in solving some physical problems.

Course Learning Outcomes: The course will enable the students to:

- Formulate, classify and transform first order PDEs into canonical form.
- Learn about method of characteristics and separation of variables to solve first order PDE's.
- Classify and solve second order linear PDEs.
- Learn about Cauchy problem for second order PDE and homogeneous and non-homogeneous wave equations.
- Apply the method of separation of variables for solving many well-known second-order PDEs.

Unit 1: Introduction, Classification, Construction of first order partial differential equations (PDE). Cauchy's problem for first order equations, linear equations of the first order, Integral surfaces passing through a given curve, Nonlinear partial differential equations of the first order, Cauchy's method of characteristics, Charpit's method. Solutions satisfying given conditions, Jacobi's method.
[1] Chapter 2 (Sections 2.1 to 2.3), [2] Chapter 2 (Section 3, 4,5, 7,8,10,12, 13)
(No. of classes: 15, Marks: 20)

Unit 2: Canonical form of first order PDE, Method of separation of variables for first order PDE.
[1] Chapter 2 (Sections 2.6 and 2.7)
(No. of classes: 15, Marks: 20)

Unit 3: Reduction to canonical forms, Equations with constant coefficients, General solution.
[1] Chapter 4 (Sections 4.1 to 4.5), [2] Chapter 3 (Sections 4, 5)
(No. of classes: 15, Marks: 20)

Practical /Lab work to be performed in a Computer Lab:
Modelling of the following similar problems using Mathematica /MATLAB/ Maple/ Maxima/ Scilab etc.

1. Solution of Cauchy problem for first order PDE.
2. Plotting the characteristics for the first order PDE.
3. Plot the integral surfaces of a given first order PDE with initial data.

4. Solution of wave equation $\frac{\partial^2 u}{\partial t^2} = c^2 \frac{\partial^2 u}{\partial x^2}$ for any two of the following associated conditions:

(a) $u(x,0) = \phi(x);\ u(x,0) = \psi(x), x \in R; t > 0$

(b) $u(x,0) = \phi(x);\ u_t(x,0) = \psi(x);\ \ u(0,t) = 0, x > 0; t > 0$

(c) $u(x,0) = \phi(x);\ u_t(x,0) = \psi(x);\ \ u_x(0,t) = 0, x > 0; t > 0$

(d) $u(x,0) = \phi(x);\ u_t(x,0) = \psi(x);\ \ u(0,t) = 0, u(l,t) = 0; x > 0; t > 0$

5. Solving systems of ordinary differential equations.

6. Solution of one-Dimensional heat equation $u_t = k\, u_{xx}$, for a homogeneous rod of length l.

That is - solve the IBVP:

$$u_t = k\, u_{xx}, \qquad 0 < x < l, \qquad t > 0$$
$$u(0,t) = 0, \qquad u(l,t) = 0, \qquad t \geq 0$$
$$u(0,t) = f(x), \ \ 0 \leq x \leq l$$

(No. of practical classes: 30, Marks: 20)

Text Book:

1. Tyn Myint-U and Lokenath Debnath**,** *Linear Partial Differential Equation for Scientists and Engineers*, Springer, Indian reprint, 2006.
2. Sneddon, I. N. (2006). *Elements of Partial Differential Equations*, Dover Publications. Indian Reprint.

Reference Book:

1. Stavroulakis, Ioannis P &Tersian, Stepan A. (2004). *Partial Differential Equations*: *An Introduction with Mathematica and* MAPLE (2nd ed.). World Scientific.
2. M. D. Raisinghania, Advanced Differential Equations, S. Chand & Company LTD.

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SEMESTER-VI

Paper-III

Metric Spaces

Total Marks: 100 (Theory 80, Internal Assessment 20)

No. of Credits: 4

Base syllabus: MAT-HC-6016: Riemann Integration and Metric Spaces (UG CBCS)

Course Level: 300-399

No. of Contact classes: 60

No. of Non-Contact classes: 0

Prerequisites for the paper: Senior Secondary School Mathematics or equivalent

Course Objectives: Up to this stage, students do study the concepts of analysis which evidently rely on the notion of distance. In this course, the objective is to develop the usual idea of distance into an abstract form on any set of objects, maintaining its inherent characteristics, and the resulting consequences.

Course Learning Outcomes: The course will enable the students to:

- Learn various natural and abstract formulations of distance on the sets of usual or unusual entities. Become aware one such formulations leading to metric spaces.
- Analyse how a theory advances from a particular frame to a general frame.
- Appreciate the mathematical understanding of various geometrical concepts, viz. Balls or connected sets etc. in an abstract setting.
- Learn about the two important topological properties of metric spaces, namely connectedness and compactness.

UNIT 1: Definition and examples of Metric spaces, sequences in metric spaces, Cauchy sequences, complete metric spaces. Open and closed balls, neighbourhood, open set, interior of a set. Limit point of a set, closed set, diameter of a set, Cantor's theorem. Subspaces, dense sets, separable spaces.

[1] Chapter 1, Sections: 1.1-1.4, Chapter 2, Sections: 2.1, 2.2, 2.3.12 - 2.3.16

(No. of classes: 15, Marks: 20)

UNIT 2: Continuity: Continuous mappings, sequential criterion and other characterizations of continuity. Uniform continuity. Homeomorphism, Equivalent metrics, Isometry. Contraction mappings.

[1] Chapter 3, Sections 3.1, 3.4, 3.5, 3.7 (upto 3.7.2)

(No. of classes: 15, Marks: 20)

UNIT 3: Connected metric spaces: Connectedness, connected subsets of real numbers, connectedness and continuous mappings, components. Compact metric spaces: bounded sets and compactness, other characterisations of compactness, continuous functions on compact spaces.

[1] Chapter 4, Sections 4.1, Chapter 5, Sections 5.1, 5.2, 5.3

(No. of classes: 30, Marks: 40)

Text Book:

1. Satish Shirali & Harikishan L. Vasudeva, Metric Spaces, Springer Verlag London (2006) (First Indian Reprint2009)

Reference Books:

1. S. Kumaresan, Topology of Metric Spaces, 2nd Ed., Narosa Publishing House, 2011.
2. G.F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, 2004.
3. Micheal O. Searcoid, Metric Spaces, Springer Publication, 2007

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SEMESTER-VI

Paper-IV

Mechanics

Total Marks: 100

(Theory: 80, Internal Assessment: 20)

No. of Credits: 4

Each unit carries equal credit

Base syllabus: MAT-HE-5026: Mechanics (UG CBCS)

Course Level: 300-399

No. of Contact classes: 60

No. of Non-Contact classes: 0

Prerequisites: Class XII level Mathematics

Course Objectives: The course aims at understanding the various concepts of physical quantities and the related motion of bodies under the action of forces.

Course Learning Outcomes: The course will enable the students to:

- Know about the concepts in statics such as moments, couples, equilibrium in both two and three dimensions.
- Understand the theory behind friction and center of gravity.
- Know about conservation of mechanical energy and work-energy equations.

- Learn about translational and rotational motion of rigid bodies.

UNIT1: Composition and resolution of forces, Parallelogram of forces, Triangle of forces, Converse of triangle of forces, Lami's Theorem, Parallel forces, Moment of a force about a point and an axis. Couple, Resultant of a system of forces. Equilibrium of coplanar forces. Friction, C.G of an arc, plane area, surface of revolution, solid of revolution.
[3] Chapter I-X
(No. of classes: 30, Marks: 40)

UNIT 2: Velocities and acceleration along radial and transverse directions and along tangential and normal directions, motion in a straight line under variable acceleration, simple harmonic motion and elastic string. Newton's law of motion. Work, Energy and momentum, Conservative forces-Potential energy, Impulsive forces, Motion in resisting medium.

[1] Chapter I Sections 1.1, 1.2,1.3, Chapter –2 Sections 2.1,2.2, Chapter 3 Sections 3.1.3.2, Chapter 4 Sections 4.1, Chapter 5Sections5.1,5.3,Chapter 6Sections6.1,6.3.
[2] Chapter 3(Sections:3.1,3.2,3.3,3.4).
(No. of classes: 30, Marks: 40)

Text Books:

1. S.L. Loney, An elementary treatise on the dynamics of a particle and of rigid bodies, Surjeet publications
2. F.Chorlton,TextbookofDynamics,CBS,Publications2nd Edition,1985
3. B.C. Das & B. N. Mukherjee, Statics, U. N. Dhur & Sons Pvt. Ltd.

Reference books:

1. M.R.Spiegel, Theoretical Mechanics, Schaum Series 2010.

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