Course Designers:

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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.

[l]: 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. $Z1 = 3 + 4i$, $Z2 = 4 - 7i$

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

$Z1 = 3 + 4i$, $Z2 = 4 - 7i$, then find $Z1 + Z2$, $Z1 - Z2$, $Z1 * Z2$ and $Z1 / Z2$

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., $\oint \mathrm{Sin} z\, d$, 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 $x = y^2 + 1$; $-2 \le y \le 2$.

(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 $0 \le y \le 2\pi$.

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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