

(Syllabus under NEP, w.e.f. 2023-24)
B.A./B.Sc.(Mathematics)
H. N.B. Garhwal University, Srinagar (Garhwal) Uttarakhand

Students enrolled in the **B.Sc.** Programme under NEP-2020 offered by the Department under the School of Sciences will have the opportunity to learn and master the following components in addition to attain important essential skills and abilities :

PO-No.	Outcomes
PO-1	Capable of delivering basic disciplinary knowledge gained during the programme.
PO-2	Capable of describing advanced knowledge gained during the programme.
PO-3	Capable of analyzing the results critically and applying acquired knowledge to solve the problems.
PO-4	Capable to identify, formulate, investigate and analyze the scientific problems and innovating to design and create products and solutions to real life problems.
PO-5	Ability to develop a research aptitude and apply knowledge to find the solution of burning research problems in the concerned and associated fields at global level.
PO-6	Ability to gain knowledge with the holistic and multidisciplinary approach across the fields.
PO-7	Learn specific sets of disciplinary or multidisciplinary skills and advanced techniques and apply them for betterment of mankind.
PO-8	Ability to learn and work in a group and capable of leading a team.

Programme Specific Outcomes (PSOs):

On completion of Integrated B.Sc.-M.Sc. (Mathematics) Programme a student:

Number	Programme Specific Outcomes
PSO-1	Will have a strong foundation in both pure and applied mathematics.
PSO-2	Will be able to apply mathematical skills for solving problems and for preparing various competitive exams.
PSO-3	Will be able to communicate mathematical knowledge effectively, in writing as well as orally.
PSO-4	Will identify applications of mathematics in other disciplines, leading to enhancement of career prospects in different fields and research areas.
PSO-5	Will have basic knowledge of programming and computational techniques as required for employment.
PSO-6	Should have the knowledge of the fundamental axioms in mathematics and capability of developing ideas based on them and inculcate mathematical reasoning.
PSO-7	Will be able to locate and analyse the different mathematical texts with appropriate theoretical framework.
PSO-8	Should be able to develop analytical skills, critical thinking, creativity, communication and presentation skills through assignments, seminar and project work.

Semester	Core Subject-1	Additional/ Interdisciplinary/ Multidisciplinary course	Skill/ Vocational Course-I
I	Differential Calculus (Theory-Credits-06)	Basic Calculus	Integral Calculus*(Either in I or III Semester)
II	Differential Equations (Theory-Credits-06)	Basic Differential Equations	Vector calculus*Either in II or IV Semester)
III	Real Analysis (Credits-06- Theory-05+Tutorial-01)	Elementary Real Analysis	
IV	Abstract Algebra (Credit-06 , Theory-05+Tutorial-01)	Algebra	
V	Linear Algebra (Theory-06 Credits)	Vocational Course(VOC- Either in V or VI Semester)	Choose any one of the following: (a)-Elementary Cryptography, (b)-Combinatorics and Graph Theory.
VI	Complex Analysis(Theory-06 Credits)		

Semester-I

CS-1: Differential Calculus

(Theory- 06-Credits)

Unit-I: Limit and Continuity (ϵ and δ definition), Types of Discontinuities, Differentiability of functions, Rolle's theorem, Lagrange's Mean Value theorem, Cauchy Mean Value Theorem.

Unit-II: Successive differentiation, Leibnitz's theorem, Taylor's theorem with Lagrange's and Cauchy's forms of remainder, Taylor's series, Maclaurin's series of $\sin x$, $\cos x$, e^x , $\log(1+x)$, $(1+x)^m$

Unit-III: Indeterminate forms, Partial Differentiation, Euler's Theorem for Homogeneous functions, Maxima & Minima of function of one and two variables

Unit-IV: Tangents and normal, Curvature. Asymptotes, Singular Points.

Books Recommended:

1. H. Anton, I. Bivens and S. Davis, Calculus, John Wiley and Sons, Inc., 2011.
2. G.B. Thomas and R.L. Finney, Calculus, Pearson Education, 2007.

Additional Course-Part 1

Basic Calculus (04- Credits)

Unit-I: Limit, Continuity and Differentiability

Unit-II: Rolle's Theorem, Lagrange's Mean Value theorems, Cauchy Mean Value Theorem. Expansion of functions, Taylor's and Maclaurin's Series of Functions.

Unit-III: Indeterminate Forms. Partial Differentiation, Euler's Theorem for Homogeneous Function,

Unit-IV: Curvature, Tangents and Normal.

Books Recommended

1. H. Anton, I. Bivens and S. Davis, *Calculus*, John Wiley and Sons, Inc., 2011.
2. G.B. Thomas and R.L. Finney, *Calculus*, Pearson Education, 2007.
3. Tom M. Apostol, *Calculus Vol. I*, John Wiley & Sons, Inc. 2007.

Course Outcome (Differential Calculus)

- CO1** Determine the points of continuity and discontinuity using the definition of limit.
- CO2** Understand the consequences of the Mean value theorem for continuous functions.
- CO3** Use the Euler's theorem for homogenous function.
- CO4** Trace the curves in Cartesian and polar form using the concepts of maxima and minima, asymptotes, tangent and normal, singular points of functions of single and two variables.

Skill Course-I

Integral Calculus (02-Credits)

Unit-I: Integration of rational and irrational functions, Properties of definite integrals.

Reduction formulae for integrals of rational and trigonometric functions,

Unit-II: Gamma and Beta functions. Areas and lengths of curves in the plane, Volumes and surfaces of solids of revolution. Double and triple integrals.

Books Recommended

1. G.B. Thomas and R.L. Finney, *Calculus*, 9th Ed., Pearson Education, Delhi, 2005.
2. H. Anton, I. Bivens and S. Davis, *Calculus*, John Wiley and Sons (Asia) P. Ltd., 2002.

Course Outcome (Integral Calculus)

- CO1** About different techniques of integration of rational, irrational and trigonometric functions.
- CO2** How to use gamma and beta functions to evaluate the integrals.
- CO3** How to compute double and triple integrals.
- CO4** Compute the areas and lengths of the curves in the plane and volume and surfaces of solids of revolution.

Semester-II

Core Subject 1: Differential Equations (Theory-06 Credits)

Unit-I: Classification of differential equations: their origin and applications, initial value problems, boundary value problems, existence of solution. Separable equation and reducible to this form.

Unit-II: Exact differential equation, integrating factors, special integrating factor and transformations. linear differential equation and Bernoulli equations, first order higher degree equations solvable for x, y, p.

Unit-III: Higher-order differential equations with constant coefficients, basic theory of linear differential equations, The Cauchy-Euler equation, Simultaneous differential equations. Wronskian and its properties Second order linear differential equations with variable coefficients, Inspection Method, Reducible to normal form, Change of Independent Variable, Variation of Parameters. Total differential equations.

Unit-IV: Order and degree of partial differential equations, Concept of linear and non-linear partial differential equations, Formation of first order partial differential equations, Linear partial differential equation of first order, Lagrange's method, Charpit's method.

Books Recommended

1. Shepley L. Ross, *Differential Equations*, 3rd Ed., John Wiley and Sons, 1984.
2. I. Sneddon, *Elements of Partial Differential Equations*, McGraw-Hill, International Edition, 1967.

Course Outcome (Differential Equations)

- CO1** Formulate and solve differential equations arising from changes in physical world.
- CO2** Solve the first order exact differential equation by different methods.
- CO3** Solve the linear homogeneous equations with constant coefficients, linear non-homogeneous equations.
- CO4** Formulate the first order partial differential equation. Using Lagrange and Charpit's method for finding the solution of partial differential equation.

Additional course-Part-2 Basic Differential Equations (04 credits)

Unit-I: Classifications of Differential equations, their origin and applications, initial value problems.

Unit-II: Exact differential equations of first order, Integrating factors, special integrating factor and transformations, Linear differential equations and Bernoulli equation.

Unit-III: First order higher degree equations solvable for x, y, p . Higher order differential equations with constant coefficients.

Unit-IV: Order and degree of partial differential equations, Concept of linear and non-linear p.d.e., formulation of first order partial differential equations.

Books Recommended:

1. Shepley L. Ross, *Differential Equations*, 3rd Ed., John Wiley and Sons, 1984.
2. I. Sneddon, *Elements of Partial Differential Equations*, McGraw-Hill, International Edition, 1967.

Skill Course-II Vector Calculus (02 Credits)

Unit-I: Scalar and vector products of three and four vectors, Reciprocal systems of vectors, Applications of vectors to three dimensional geometry. Differentiation of vectors, partial differentiation of vectors, Velocity and acceleration, Integration of vectors.

Unit-II: Differential operators, Gradient of a scalar point function, Directional Derivative, divergence and curl of vectors. Line integrals, Surface integrals, Applications of Gauss's, Green's and Stokes theorems.

Books Recommended

1. G.B. Thomas and R.L. Finney, *Calculus*, 9th Ed., Pearson Education, Delhi, 2005.
2. H. Anton, I. Bivens and S. Davis, *Calculus*, John Wiley and Sons (Asia) P. Ltd. 2002.
3. P.C. Matthews, *Vector Calculus*, Springer Verlag London Limited, 1998.

Course Outcome (Vector Calculus)

- CO1** Find multiple products of three and more vectors.
- CO2** Find differentiation and partial differentiation of vector functions.
- CO3** Understand the notions of gradient, divergence and curl.
- CO4** Verify Green's theorem, Gauss's and Stoke's theorem.

Semester-III
Major Paper-III (CS-1)
Real Analysis (Theory- 06 credits)

Unit I: Finite and infinite sets, Examples of countable and uncountable sets, Real line, Bounded sets, Supremum and infimum, Completeness property of \mathbb{R} , Archimedean property of \mathbb{R} , intervals, Concept of limit points, closed sets, statement of Bolzano-Weierstrass theorem.

Unit II: Real Sequence, Bounded sequence, Cauchy convergence criterion for sequences, Cauchy's theorem on limits, order preservation and squeeze theorem, monotone sequences and their convergence, monotone convergence theorem.

Unit III: Infinite series. Cauchy convergence criterion for series, Positive term series, Geometric series, Comparison test, p-test, Root test, Ratio test, Alternating series, Leibnitz's test, Cauchy Condensation test, absolute and conditional convergence.

Unit IV: Riemann integral : Definition and examples, Properties of Riemann integrals, Necessary and sufficient conditions for integrability, Fundamental theorem of Calculus.

Books Recommended

1. T. M. Apostol, *Calculus* (Vol. I), John Wiley and Sons (Asia) P. Ltd., 2002.
2. R.G. Bartle and D. R Sherbert, *Introduction to Real Analysis*, John Wiley and Sons (Asia) P. Ltd., 2000.
3. K.A. Ross, *Elementary Analysis- The Theory of Calculus Series- Undergraduate Text in Mathematics*, Springer Verlag, 2003.

Course Outcome (Real Analysis)

- CO1** Define and recognize the basic properties of field of real numbers.
CO2 Understand the concept of limit point and Bolzano-Weierstrass theorem.
CO3 Define and recognize the series and sequence of real numbers and their convergence.
CO4 Understand the concept of Riemann integral and its properties.

Additional Course

Part-3

Elementary Real Analysis (Theory- 04 credits)

Unit I: Supremum and infimum of a set, Completeness property of \mathbb{R} , Archimedean property of \mathbb{R} , Concept of limit points and statement of Bolzano-Weierstrass theorem.

Unit II: Real Sequence, Bounded sequence, Cauchy convergence criterion for sequences, Cauchy's theorem on limits, monotone sequences and their convergence, monotone convergence theorem.

Unit III: Infinite series. Cauchy convergence criterion for series, Geometric series, Comparison test, p-test, Root test, Ratio test, Alternating series, Leibnitz's test, absolute and conditional convergence.

Unit IV: Riemann integral: Definition and examples, Properties of Riemann integrals, Necessary and sufficient conditions for integrability.

Books Recommended

1. T. M. Apostol, *Calculus* (Vol. I), John Wiley and Sons (Asia) P. Ltd., 2002.
2. R.G. Bartle and D. R Sherbert, *Introduction to Real Analysis*, John Wiley and Sons (Asia) P. Ltd., 2000.
3. K.A. Ross, *Elementary Analysis- The Theory of Calculus Series- Undergraduate Texts in Mathematics*, Springer Verlag, 2003.

Course Outcome (Elementary Real Analysis)

- CO1** Understand the concept of limit point and Bolzano-Weierstrass theorem.
- CO2** Define and recognize the series and sequence of real numbers and their convergence.
- CO3** Understand the concept of Riemann integral and its properties.
- CO4** Understand the concept of Riemann integral and its properties.

Skill Course-I Integral calculus (02-Credits) (If not opted in Semester I)

Major Paper-IV (CS-1) Abstract Algebra (Theory- 06 Credits)

Unit I: Definition and examples of groups, Abelian groups, the groups of integers under addition and multiplication modulo n , Subgroups, Necessary and sufficient condition, Examples of subgroups including the center of a group, Groups of complex roots of unity.

Unit II: The general linear group $GL_n(n, R)$, Groups of symmetries of (i) an isosceles triangle, (ii) an equilateral triangle, (iii) a rectangle, and (iv) a square, Permutation groups, Even and odd permutations, Group of quaternions.

Unit III: Homomorphism and isomorphism of groups, Order of an element, Cyclic groups and its properties, Cosets, Index of subgroup, Lagrange's theorem., Cayley's theorem.

Unit IV: Normal subgroups: Definition and examples. Definition and examples of rings, Examples of commutative and non-commutative rings, the ring of integers modulo n , Ring of matrices, Subrings and ideals, Integral domains and fields with examples.

Books Recommended

1. John B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.
2. M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.
3. Joseph A Gallian, Contemporary Abstract Algebra, 4th Ed., Narosa, 1999.

Course Outcome (Abstract Algebra)

- CO1** Understand the basic properties of groups, identify abelian and non-abelian groups.
- CO2** Discuss the Lagrange's theorem and its consequences.
- CO3** Characterize the cyclic groups, normal subgroups, simple groups.
- CO4** Extend group structures to ring, integral domain and field.

Additional Course Algebra (Theory- 04 Credits)

Unit I: Definition and examples of groups, Abelian groups, the groups of integers under addition and multiplication modulo n , Subgroups, Necessary and sufficient condition, Examples of subgroups including the center of a group, Groups of complex roots of unity.

Unit II: The general linear group $GL_n(n, R)$, Groups of symmetries of (i) an isosceles triangle, (ii) an equilateral triangle, (iii) a rectangle, and (iv) a square, Permutation groups, Even and odd permutations, Group of quaternions.

Unit III: Homomorphism and isomorphism of groups, Order of an element, Cyclic groups and its properties, Cosets, Index of subgroup, Lagrange's theorem.

Unit IV: Normal subgroups: Definition and examples. Definition and examples of rings, Examples of commutative and non-commutative rings, the ring of integers modulo n , Ring of matrices, Subrings and ideals.

Books Recommended :

1. John B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.
2. M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.
3. Joseph A Gallian, Contemporary Abstract Algebra, 4th Ed., Narosa, 1999.

Course Outcome (Algebra)

- CO1** Understand the basic properties of groups, identify abelian and non-abelian groups.
CO2 Discuss the Lagrange's theorem and its consequences.
CO3 Characterize the cyclic groups, normal subgroups, simple groups.
CO4 Extend group structures to ring, integral domain and field.

Skill Course-II**Vector Calculus (02-Credits)**

(If not opted in Semester II)

Semester-V**Major Paper-V (CS-1)****Linear Algebra (Theory- 06 credits)**

Unit I: Vector spaces, Subspaces, Algebra of subspaces, Quotient spaces, Linear combination of Vectors, Linear span, Linear independence/dependence, Basis and dimension, Dimension of subspaces.

Unit II: Linear transformations, Null space, Range, Rank and nullity of a linear transformation, rank-nullity theorem, Isomorphism, Isomorphism theorems, Inevitability and isomorphism's.

Unit III: Matrix representation of a linear transformation, Algebra of linear transformations, Dual space, Dual basis, Double dual, Annihilator.

Unit IV: Eigen value and eigen-vectors of Linear Transformation, Characteristics polynomial, algebraic and geometric multiplicities of eigen-value, Applications of eigen-value and eigen-vectors in finding the power of Matrix A , $\exp(A)$, $\sin(A)$, $\cos(A)$, and $p(A)$, similar Matrices, diagonalization of matrix.

Books Recommended

1. Stephen H. Friedberg, Arnold J. Insel, Lawrence E. Spence, Linear Algebra, 4th Ed., Prentice- Hall of India Pvt. Ltd., New Delhi, 2004.
2. David C. Lay, Linear Algebra and its Applications, 3rd Ed., Pearson Education Asia, Indian Reprint, 2007.
3. S. Lang, Introduction to Linear Algebra, 2nd Ed., Springer, 2005.

Course Outcomes (Linear Algebra)

- CO1** The concepts of vector spaces, quotient spaces, basis and dimension.
CO2 How to find rank and nullity of a linear transformation, matrix representation of a linear transformation.
CO3 How to find characteristic equation of a matrix and eigen values and eigen vectors.
CO4 About dual basis, isomorphism theorem and invertibility.

Vocational Course(VOC)-Semester V/VI
Choose any one of the following((a) or (b))
(a)-Elementary Cryptography (04 credits)

Unit I: The Shift Cipher, The Substitution Cipher, The Affine Cipher, The Vigenere Cipher, The Hill Cipher, The Permutation Cipher, Stream & Block ciphers.

Unit II: Shannon's Theory of Perfect Secrecy, Vernam One Time Pad, Random Numbers, Mode of operations in block cipher, the Data Encryption Standard (DES), Feistel Ciphers, the Advanced Encryption Standard(AES), Prime Number Generation, Fermat Test, Miller Rabin Test.

Unit III: Public Key Cryptography, RSA Cryptosystem, Factoring problem, Rabin Cryptosystem, Quadratic Residue Problem, Diffie-Hellman (DH) Key Exchange Protocol, Discrete Logarithm Problem (DLP), ElGamal Cryptosystem, Elliptic Curve, Elliptic Curve Cryptosystem (ECC)

Unit IV: Hash and Compression Functions, Security of Hash Functions, Iterated Hash Functions, SHA-1, MD-5, Message Authentication Codes.

Books recommended:

1. J Buchmann, Introduction to Cryptography, Springer (India) 2004
2. D R Stinson, Cryptography: Theory and Practice. CRC Press, 2000.
3. B Forouzan, Cryptography and Network security, Tata McGraw Hill, 2011
4. Wenbo Mao, Modern Cryptography: Theory and Practice. Pearsion Education, 2004

Course Outcomes

CO1 Students will understand a solid understanding of both classical and modern cryptographic techniques, including their theoretical foundations and practical applications techniques.

CO2 They will be able to analyze and implement various cryptographic algorithms, understand the mathematical foundations of cryptography, and evaluate the security of different cryptographic methods.

CO3 This knowledge will be crucial for students pursuing careers in cybersecurity, computer science, and related fields.

(b)-Combinatorics and Graph Theory(04 credits)

Unit-I: Pigeonhole principle : Simple form, Strong form, Permutations and Combinations of multisets.

Unit-II: The inclusion-exclusion principle, Combinations with repetitions, Derangements, Permutation with forbidden positions.

Unit-III: Introduction to graph theory, Basic properties, Eulerian and Hamilton graphs, Bipartite multigraphs.

Unit-IV: Trees, Spanning trees, Diagraphs and networks, Directed cycle.

Books recommended:

1. Introductory Combinatorics - Fifth Edition, by Richard A. Brualdi, 2019, Pearson India Education Services Pvt. Ltd.
2. Graph Theory by Narsingh Deo, PHI
3. A Text Book of Graph Theory by R. Balakrishnan, K. Rangnathan, Springer.
4. Foundations of Combinatorics with Applications by Edwared A. Bender, S. Gill Williamson, Dover Books on Mathematics.

Course Outcomes

CO1 Understand the concepts of pigeonhole principles.

CO2 About the inclusion-exclusion principles.

CO3 The concepts of graph theory, diagraphs and networks.

Semester-VI
DSE-Paper (CS-1)
Complex Analysis
(Theory- 06 Credits)

Unit I: Properties of complex numbers, Regions in the complex plane, Functions of complex variable, Limits, Continuity, differentiability of complex functions, Exponential function, Logarithmic function, Trigonometric function.

Unit II: Differentiability and Analyticity, Cauchy-Riemann Equations, Sufficient conditions for analyticity, Harmonic Functions, Harmonic conjugate function, Applications, Examples of analytic functions.

Unit III: Contours, Contour integrals and its examples, Upper bounds for moduli of contour integral, Cauchy- Goursat theorem, Cauchy integral formula. Cauchy inequality, Liouville's theorem, Morera's theorem.

Unit IV: Sequences and Series, Taylor Series, Laurent Series, Singularities, Classification of singularities, Residues and Residue theorem.

Books Recommended

1. James Ward Brown and Ruel V. Churchill, Complex Variables and Applications, 8th Ed., McGraw-Hill International Edition, 2009.
2. Joseph Bak and Donald J. Newman, Complex analysis, 2nd Ed., Undergraduate Texts in Mathematics, Springer-Verlag New York, Inc., New York, 1997.
3. Dennis G. Zill and Patrick D. Shanahan , A First Course in with Applications Complex Analysis, Jones and Bartlett Publishers.

Course Outcomes (Complex Analysis)

CO1 Understand the concept of complex numbers, complex functions and their properties.

CO2 Discuss properties to analytic functions and Cauchy-Riemann equations.

CO3 Prove Cauchy-Goursat theorem, Cauchy integral formula and Liouville's theorem.

CO4 Give examples based on Taylor's and Laurent's series.

Vocational Course(VOC)-Semester V/VI

Choose any one of the following((a) or (b))

(a)-Elementary Cryptography (04 credits)/(b)- Combinatorics and Graph Theory