Vision, Mission, PEO, PO, PSO & CO of

DEPARTMENT OF MATHEMATICS, KUMAUN UNIVERSITY, SOBAN SINGH JEENA CAMPUS, ALMORA

About the Department

- The department of Mathematics, Kumaun University, Nainital was established in 1951 at DSB Campus Nainital and the department of Mathematics at S. S. J. Campus , Almora come into existence in the year 1962. It is the biggest department in terms of strength of the students. The department is running undergraduate, post graduate and Ph. D. programs ever 1962. The department offers opportunities for the education and research in a wide spectrum of areas in Mathematics, such as Differential Geometry, Riemannian Geometry, Special functions, Operation Research, Mathematical statistics, Relativity & Astrophysics etc. Department is recognized as Centre of Excellence in Mathematical Science(CEMS) by Uttarakhand Science and Research Centre (USERC) in 2011.The department have dedicated, experienced & sincere faculty members and non – teaching members. Department has an MOU with National Defence Academy, Khadakwasla, Pune for Ph.D. degree. One assistant professor of National Defence Academy is doing his research work under the supervision of HOD Prof. Jaya Upreti. The department organized Madhava Mathematics Competition for undergraduate students with the collaboration of NBHM every year in winter.

Vision:

- Imparting of quality of Mathematics education and inculcating education of the spirit of research through innovative teaching and research methodologies.
- The centre stage Mathematical knowledge in the curriculum, install analytical and logical thinking among students and promote Mathematical reasoning as an important area of human thought.
- To achieve high standards of excellence in generating and propagating knowledge in Mathematics.
- Department is committed for providing an education that combines rigorous academics with joy of discovery.
- To provide an environment where student can learn, become competent users of Mathematics and understand the use of Mathematics in other disciplines.

Mission:

- To nurture mathematically inclined students & provide them a supportive environment that fosters intellectual growth.
- To create an environment that supports outstanding research.
- To pursue collaborate programmes with highly reputed national & international institute.
- To prepare our undergraduate students to develop the attitude and ability to apply Mathematical methods and ideas in a wide variety of careers.
- To produce post graduate students with strong foundation to join research or to serve industry.
- To provide the best possible facilities for our students, particularly in the area of computer facilities, library facilities and administrative support.

Programme Educational Objectives (PEOs)

The Program Educational Objectives (PEOs) for Mathematics describe accomplishments that students are expected to attain within three to five years after graduation and post graduation.

PEO – 1 : To provide students knowledge and insight in Mathematics so that they are able to work as mathematical professional.

PEO – 2 : To prepare them to pursue higher studies and conduct research.

PEO – 3 : To provide students with knowledge and capability in formulating & analysis of mathematical models in real life application.

PEO – 4 : To introduce the fundamentals of mathematics to students and strength the student's logical and analytical ability.

PEO – 5 : To develop teaching skills, subject knowledge in the course of their study which will help them to shine in various field including Education, IT etc.

Programme Outcomes (POs)

The UG and PG graduates of Mathematics will be able to:

PO – 1 : **Knowledge domain:** Demonstrate an understanding of the basic concepts in mathematics, statistics, operations research and their importance in the solution of some real- world problems.

PO – 2 : **Problem analysis:** Analyze and solve the well-defined problems in mathematics statistics, and operations research. Utilize the principles of scientific enquiry, thinking analytically, clearly and critically, while solving problems and making decision. Find, analyze, evaluate and apply information systematically and shall make defensible decisions.

PO – 3 : **Presentation and Interpretation of Data:** Demonstrate the ability to manipulate and visualize data and to compute standard statistical summaries.

PO – 4 : **Modern tool usage**: Learn, select, and apply appropriate methods and procedures, resources and computing tool such as Excel, MATLAB, MATHEMATICA, SPSS etc with an understanding of the limitations.

PO – 5 : **Ethics:** Analyze relevant academic, professional and research ethical problems and commit to professional ethics and responsibilities with applicable norms of the data analysis and research practices.

PO – 6 : **Communication:** Effectively communicate about their field of expertise on their activities, with their peer and society at large. Such as, being able to comprehend and write effective reports and design documentation, make effective presentations.

PO – 7 : **Project Management:** Apply Knowledge and understanding of principles of mathematics and statistics effectively as an individual, and as a member or leader in diverse teams to manage projects in multidisciplinary environment.

PO – 8 : **Research Proposal:** Define, design and deliver a significant piece of research work that is clear and concise. Demonstrate the necessary skills and knowledge of deeper understanding of their chosen research area. Understand the philosophy of research in mathematical sciences and appreciate the value of its development.

PO –9 : **Thrust area:**

Riemannian Geometry studies smooth manifolds using a Riemannian metric. There are many applications of Riemannian geometry to other branches of mathematics and to the sciences. Einstein used it and its generalization, Finsler geometry to formulate general relativity theory. It impacted group theory, representation theory analysis, algebraic and differential topology. Relativity is one of the most famous scientific theories of the 20th century. Formulated by Albert Einstein in 1905, the theory of Relativity is the notion that the laws of physics are the same everywhere. The theory explains the behavior of objects in space and time, and it can be used to predict everything from the existence of black hole, to light bending due to gravity, to the behavior of the planet Mercury in its orbit.

Operations Research (OR) is relatively a new discipline. The first formal activities of OR were initiated in England during the Second World War, when a team of British scientists set out to make decisions regarding the best utilization of war material. OR begins when some mathematical and quantitative technique is used to verify the decision being taken. OR provides a quantitative technique or a scientific approach to the executives for making better decisions for operations under their control.

Statistics is about the mathematical modeling of observable phenomena, using stochastic models, and about analyzing data: estimating parameters of the model and testing hypotheses. In these notes, we study various estimation and testing procedures. We consider their theoretical properties and we investigate various notions of optimality.

Programme Specific Outcome (PSOs)

After the successful completion of UG and PG programs in Mathematics the students will be able to:

PSO – 1 : Understand the mathematical concepts and application in the field of algebra / analysis, statistic, manifolds, relativity & astrophysics.

PSO – 2 : For (B.Sc) -: Get jobs in public / private sectors and pursuing higher studies at national and international level.

PSO – 3 : To apply knowledge of Mathematics in all the fields of learning including higher research and extensions.

PSO – 4 : To provide a systematic understanding of the concepts and theories of mathematics and analyze the situations.

Course Outcomes (COs)

List of COs for UG and PG Courses of Mathematics

A. List of Undergraduate Courses

B. Sc. Three Year Degree Course
Department of Mathematics:

Semester	Paper	Title
Semester – I	I	Elementary Algebra and Trigonometry
	II	Differential Calculus
Semester – II	I	Geometry and vector analysis
	II	Integral Calculus
Semester –III	I	Advanced Algebra
	II	Differential Equations
	III	Mechanics
Semester– IV	I	Vector spaces and Matrices
	II	Real Analysis
	III	Mathematical Methods
Semester -V	I	Linear Algebra
	II	Complex Analysis
	III	Functions of several variables and Partial Differential Equations
Semester– VI	I	Numerical Methods
	II	Mathematical Statistics
	III	Operation Research

Semester – I

Paper I - Elementary Algebra and Trigonometry

S.No. Topics

1. **Numbers:** Natural numbers, Integers, Rational and Irrational Numbers, Real numbers, Complex numbers, Mappings, Equivalence relation and partitions, Congruence modulo n.

2. **Roots of Equations:** Fundamental Theorem of Algebra, Relation between Roots and Coefficients, Transformation of Equations, Descartes rule of signs, Algebraic Solution of Cubic equations (Carden method), Bi-quadratic Equation.

3. **Elementary matrices:** Symmetric, Skew-symmetric, Hermitian and skew-Hermitian matrices, Elementary operations and matrices, ad joint and inverse of matrix.

4. **Trigonometry:** De-movire's Theorem and its applications, Exponential, Logarithmic, Circular and Hyperbolic function together with their inverses, Gregory's series and Summations of Trigonometric series.

Paper II – Differential Calculus

S.No.	Topics:
1.	**Limit, Continuity and Differentiability:** Functions of one variable, Limit of a function (ε-δ Definition), Continuity of a function, Properties of continuous functions, Intermediate value theorem, Classification of Discontinuities, Differentiability of a function, Rolle's Theorem, Mean value theorems and their geometrical interpretations, Applications of mean value theorems.
2.	**Successive Differentiation, Expansions of functions and Indeterminate forms:** Successive Differentiation, n^{th} Differential coefficient of functions, Leibnitz Theorem; Taylor's Theorem, Maclaurin's Theorem, Taylor's and Maclaurin's series expansions.
3.	**Tangents and Normals:** Geometrical meaning of $\frac{dy}{dx}$, Definition and equation of Tangent, Tangent at origin, Angle of intersection of two curves, Definition and equation of Normal, Cartesian subtangent and subnormal, Tangents and Normals of polar curves, Angle between radius vector and tangent, Perpendicular from pole to tangent, Pedal equation of curve, Polar subtangent and polar subnormal, Derivatives of arc (Cartesian and polar formula).
4.	**Curvature and Asymptotes:** Curvature, Radius of curvature; Cartesian, Polar and pedal formula for radius of curvature, Tangential polar form, Centre of curvature, Asymptotes of algebraic curves, Methods of finding asymptotes, Parallel asymptotes.
6.	**Singular Points and Curve Tracing:** Regular points and Singular Points of a curve, Point of inflection Double Points, Cusp, Node and conjugate points, Curve tracing.

II Semester

Paper I – Geometry and vector analysis

S.No.	Topics:
1.	**Polar Equation of conics**: Polar coordinate system, Distance between two points, Polar equation of a Straight line, Polar equation of a circle, Polar equation of a conic, Chords, Tangent and Normal to a conic, Chord of contact, Polar of a point.
2.	**Vector Algebra and its Applications to geometry (Plane and Straight Line):** Triple product, Reciprocal vectors, Product of four vectors. General equation of a Plane, Normal and Intercept forms, Two sides of a plane, Length of perpendicular from a point to a plane, Angle between two planes, System of planes. Direction Cosines and Direction ratios of a line, Projection on a straight line, Equation of a line, Symmetrical and unsymmetrical forms, Angle between a line and a plane, Coplanar lines, Lines of shortest distance, Length of perpendicular from a point to a line, Intersection of three planes, Transformation of coordinates.
3.	**Vector Differentiation**: Ordinary differentiation of vectors, Applications to mechanics, Velocity and Acceleration, Differential operator-Del, Gradient, Divergence and Curl.
4.	**Vector Integration**: Line, Surface and volume integrals, Simple applications of Gauss divergence theorem, Green's theorem and Stokes theorem (without proof).

Paper II –Integral Calculus

S.No.	Topics
1.	**Definite Integrals:** Integral as a limit of sum, Properties of Definite integrals, Fundamental theorem of integral calculus, Summation of series by integration, Infinite integrals, Differentiation and integration under the integral sign.
2.	**Functions Defined by Infinite Integrals:** Beta function, Properties and various forms, Gamma function, Recurrence formula and other relations, Relation between Beta and Gamma function, Evaluation of integrals using Beta and Gamma functions.
3.	**Multiple Integrals:** Double integrals, Repeated integrals, Evaluation of Double integrals, Double integral in polar coordinates, Change of variables and Introduction to Jacobians, Change of order of integration in Double integrals, Triple integrals, Evaluation of Triple integrals, Drichlet's theorem and its Liovelle's extension.
4.	**Geometrical Applications of Definite Integrals:** Area bounded by curves (quadrature), Rectification(length of curves), Volumes and Surfaces of Solids of revolution.

III Semester

Paper I – Advanced Algebra

S.No.	Topics
1.	**Rings**: Rings, Various types of rings, Rings with unity, Rings without zero divisors, Properties of rings, Sub rings.
2.	**Ideals:** Ideals, Quotient rings, Principal ideals, Maximal ideals, Prime ideals, Principal ideal domains, Characteristic of a ring.
3.	**Integral domains and Fields**: Integral domain, Field, Skew field etc., Field of quotients of an integral domain, Embedding of an integral domain in a field, Factorization in an integral domain, Divisibility, Units, Associates, Prime and irreducible elements, Unique Factorization Domain, Euclidean rings.
4.	**Polynomial rings**: Polynomials over a ring, Degree of a polynomial, Zero, Constant and monic polynomials, Equality of polynomials, Addition and multiplication of polynomials, Polynomial rings, Embedding of a ring R into R[x], Division algorithm, Euclidean algorithm, Units and associates in polynomials, Irreducible polynomials.

Paper II – Differential Equations

S.No. Topics

1. **Differential equations:** Introduction of Differential equations, Order and Degree of Differential Equations Complete primitive (general solution, particular solution and singular solutions), Existence and uniqueness of the solution $\frac{dy}{dx} = f(x, y)$.

2. **First Order Differential Equations:** Differential equations of first order and first degree, Separation of variables, Homogeneous Equations, Exact Equations, Integrating Factor, Linear Equation, Equation of First order but not of first degree, Various methods of solution, Clairaut's form, Singular solutions, Trajectory, Orthogonal Trajectory, Self-Orthogonal family of Curves.

3. **Linear Differential Equations:** Linear equations with constant coefficients, Complementary function, Particular integral, Working rule for finding solution, Homogeneous linear equations.

4. **Miscellaneous Equations:** Simultaneous differential equations, Differential equations of the form $\frac{dx}{P} = \frac{dy}{Q} = \frac{dz}{R}$ where P, Q, R are functions of x, y, z. Exact differential equations, Total differential equations, Series solutions of differential equations, Linear differential equations of second order with variable coefficients.

5. **Applications:** Initial and boundary value problems, Simple applications of differential equations of first order.

Paper III – Mechanics

S.No. Topics

1. **Rectilinear motion:** Newton's Laws of Motion, velocity and acceleration, motion under constant acceleration, motion under inverse square law, rectilinear motion with variable acceleration, Simple Harmonic Motion.

2. **Kinematics in two dimension:** Angular velocity and angular acceleration, Components of velocity and acceleration along coordinate axes, Radial and transverse components of velocity and acceleration, tangential and normal components of velocity and acceleration.

3. **Motion in resisting medium, constrained motion and Central orbits:** Terminal Velocity, Motion in resisting medium in a straight line, Motion on vertical circle, Cycloidal motion, Central Force, Central orbit, intrinsic equation, Pedal form, apse and apsidal distance.

4. **Statics:** Coplanar Forces, Equilibrium of forces in three dimensions, Common catenary, Catenary of uniform strength, Virtual work.

IV Semester

Paper I – Vector Space and Matrices

S.No.	Topics
1.	**Vector spaces:** Vector space, sub spaces, Linear combinations, linear spans, Sums and direct sums.
2.	**Bases and Dimensions:** Linear dependence and independence, Bases and dimensions, Dimensions and subspaces, Coordinates and change of bases.
3.	**Matrices:** Idempotent, nilpotent, involuntary, orthogonal and unitary matrices, singular and nonsingular matrices, negative integral powers of a nonsingular matrix; Trace of a matrix.
4.	**Rank of a matrix:** Rank of a matrix, linear dependence of rows and columns of a matrix, row rank, column rank, equivalence of row rank and column rank, elementary transformations of a matrix and invariance of rank through elementary transformations, normal form of a matrix, elementary matrices, rank of the sum and product of two matrices, inverse of a non-singular matrix through elementary row transformations; equivalence of matrices.
5.	**Applications of Matrices:** Solutions of a system of linear homogeneous equations, condition of consistency and nature of the general solution of a system of linear non-homogeneous equations, matrices of rotation and reflection.

Paper II – Real Analysis

S.No.	Topics
1.	**Continuity and Differentiability of functions:** Continuity of functions, Uniform continuity, Differentiability, Taylor's theorem with various forms of remainders.
2.	**Integration:** Riemann integral-definition and properties, integrability of continuous and monotonic functions, Fundamental theorem of integral calculus, Mean value theorems of integral calculus.
3.	**Improper Integrals:** Improper integrals and their convergence, Comparison test, Dritchlet's test, Absolute and uniform convergence, Weierstrass M-Test, Infinite integral depending on a parameter.
4.	**Sequence and Series:** Sequences, theorems on limit of sequences, Cauchy's convergence criterion, infinite series, series of non-negative terms, Absolute convergence, tests for convergence, comparison test, Cauchy's root Test, ratio Test, Rabbe's, Logarithmic test, De Morgan's Test, Alternating series, Leibnitz's theorem.
5.	**Uniform Convergence:** Point wise convergence, Uniform convergence, Test of uniform convergence, Weierstrass M-Test, Abel's and Dritchlet's test, Convergence and uniform convergence of sequences and series of functions.

Paper III – Mathematical Methods

S.No.	Topics
1.	**Integral Transforms**: Definition, Kernel.
2.	**Laplace Transforms**: Definition, Existence theorem, Linearity property, Laplace transforms of elementary functions, Heaviside Step and Dirac Delta Functions, First Shifting Theorem, Second Shifting Theorem, Initial-Value Theorem, Final-Value Theorem, The Laplace Transform of derivatives, integrals and Periodic functions.
3.	**Inverse Laplace transforms**: Inverse Laplace transforms of simple functions, Inverse Laplace transforms using partial fractions, Convolution, Solutions of differential and integro-differential equations using Laplace transforms. Dirichlet's condition.
4.	**Fourier Transforms**: Fourier Complex Transforms, Fourier sine and cosine transforms, Properties of Fourier Transforms, Inverse Fourier transforms.

V Semester

Paper I – Linear Algebra

S.No.	Topics
1.	**Linear Transformations:** Linear transformations, rank and nullity, Linear operators, Algebra of linear transformations, Invertible linear transformations, isomorphism; Matrix of a linear transformation, Matrix of the sum and product of linear transformations, Change of basis, similarity of matrices.
2.	**Linear Functionals:** Linear functional, Dual space and dual basis, Double dual space, Annihilators, hyperspace; Transpose of a linear transformation.
3.	**Eigen vectors and Eigen values:** Eigen vectors and Eigen values of a matrix, product of characteristic roots of a matrix and basic results on characteristic roots, nature of the characteristic roots of Hermitian, skew-Hermitian, unitary and orthogonal matrices, characteristic equation of a matrix, Cayley-Hamilton theorem and its use in finding inverse of a matrix.
4.	**Bilinear forms:** Bilinear forms, symmetric and skew-symmetric bilinear forms, quadratic form associated with a bilinear form.

Paper II - Complex Analysis

S.No.	Topics
1.	**Complex Variables:** Functions of a complex variable; Limit, continuity and differentiability.
2.	**Analytic functions:** Analytic functions, Cauchy and Riemann equations, Harmonic functions.
3.	**Complex Integration:** Complex integrals, Cauchy's theorem, Cauchy's integral formula, Morera's Theorem, Liouville's Theorem, Taylor's series, Laurent's series, Poles and singularities.
4.	**Residues:** Residues, the Residue theorem, the principle part of a function, Evaluation of Improper real integrals.

Paper III – Functions of Severable Variables and Partial Differentiable Equations

S.No.	Topics
1.	**Functions of several variables**: Limit, continuity and differentiability of functions of several variables.
2.	**Partial Derivatives**: Partial derivatives and their geometrical interpretation, differentials, derivatives of composite and implicit functions, Jacobians, Chain rule, Euler's theorem on homogeneous functions, harmonic functions, Taylor's expansion of functions of several variables.
3.	**Partial differential equations**: Partial differential equations of first order, Charpit's method, Linear partial differential equations with constant coefficients. First-order linear, quasi-linear PDE's using the method of characteristics.
4.	**Partial differential equations of 2nd-order:** Classification of 2nd-order linear equations in two independent variables: hyperbolic, parabolic and elliptic types (with examples).

VI Semester

Paper I – Numerical Methods

S.No.	Topics
1.	**Errors in numerical Calculations**: Absolute, Relative and Percentage errors, General Error, Error in series approximation.
2.	**Solutions of Algebraic and Transcendental Equations:** Bisection method, False position method, Newton-Raphson Method, Picard's iteration method.
3.	**Linear systems of equations:** Consistency of Linear System of equations, Solutions of Linear Systems by direct method: Guassian elimination and computation of inverse of a matrix, Method of Factorization,. Solutions of linear systems by iterative methods: Jacobi method, Gauss-Siedel method.
4.	**Interpolation and curve fitting:** Errors in Polynomial interpolation, Finite differences, Differences of a polynomial, Newton's forward and backward interpolation, Central differences, Gauss, Stirling, Bessel's and Everett's Formulae, Lagrange's Interpolation formula.
5.	**Numerical differentiation and integration**: Numerical differentiation, Newton-Cotes Integration formula, Numerical integration by Trapezoidal rule, Simpson'1/3, Simpson's 3/8, and Romberg Integration.

Paper II- Mathematical Statistics

S.No. Topics

1. **Descriptive Statistics and Exploratory Data Analysis:** Frequency distribution, Graphical representation of a frequency distribution, Measures of central tendency, Measures of dispersion, Moments, skewness and kurtosis.

2. **Correlation and regression:** Scatter diagram, Karl Pearson's coefficient of correlation and its calculation, Regression and equations of lines of regression, Rank correlation coefficient, Concept of Partial and Multiple correlations in case of distribution of three variables.

3. **Probability:** Notion of Probability, Random experiment, sample space, Mathematical and statistical definitions of Probability of an event, Axiom of probability, elementary properties of probability; equally likely, mutually exclusive, independent and compound events, Conditional probability, Additive law of probability and Multiplicative law of probability, Mathematical expectation, Inverse probability, Baye's Theorem, Concept of random variable.

Paper III- Operation Research

S.No Topics

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1. **Basics of OR and LPP**: Development of OR, Definition, characteristics, scope, objectives and limitations of OR, convex sets, Basic feasible solutions, Formulation of LPP, Graphical Method to solve LPP, General LPP, Canonical and Standard forms, Properties of Solutions and Theory of Simplex method, Big M Method and Two phase simplex method, Degeneracy in LPP. Duality in LPP, Duality and simplex method, Dual simplex method.

2. **Transportation and assignment Models**: Formulation of TP, Transportation Table, Finding initial basic feasible solution, Test of optimality, Degeneracy, MODI method, Stepping Stone method, Solutions of Assignment problems, Hungarian method.

B.A. /B. Sc. Mathematics
Course Structure (Semester System)
Undergraduate level onward 2019.

I Semester	II Semester	III Semester	IV Semester	V Semester	VI Semester
Elementary Algebra and Trigonometry	Geometry and vector analysis	Analytical Geometry	Differential Equation	Real Analysis	Complex Analysis
Differential Calculus	Integral Calculus	Group Theory	Ring Theory	Functions of several variables and Partial Differential Equations	Linear Algebra

B. List of Postgraduate Courses

M. Sc. MATHEMATICS SEMESTER CURRICULUM

Semester	Paper	Title	Credits
Semester I	I	Real Analysis	6
	II	Topology	6
	III	Differential Geometry and Tensor Calculus	6
Semester II	I	Complex Analysis	6
	II	Abstract Algebra	6
	III	Differential Equations	6
Semester III	I	Linear Algebra	6
	II	Measure Theory	6
	III	Numerical Solutions of ODE and PDE	6
Semester IV	I	Dynamics of Rigid Bodies	6
	II	Functional Analysis	6
	III	Calculus of variation and Integral Equations	6
• Electives for Semester I & III (Out of six papers only one paper will be opted)			
		Mathematical Statistics	6
		Number Theory	6
		Fluid Mechanics	6
		Discrete Mathematics	6
		Computer Programming and Mathematical Computations	6
		Special Functions	6
• Electives for Semester II & IV (Out of six papers only one paper will be opted)			
		Relativity	6
		Riemannian Geometry	6
		Advanced Abstract Algebra	6
		Operation Research	6
		Statistical Analysis	6
		Dynamical System	6

SEMESTER I

Paper I

Real Analysis

Course No.: 5311 Credit Hours: Per week

I. Course Outline

A. Lectures

S.No.	Topics	No. of Lectures
1.	Metric spaces with various examples, Open sets, Interior of a set, Structure of open subsets of the real line, Limit points, Closed sets, closure of a set, Subspaces.	6
2.	Cauchy sequences, Complete metric spaces and completion of a metric space, Continuity and Uniform continuity, Sequential notion of continuity and Uniform limit theorem, Compactness.	6
3.	Functions of several variables: Concept of functions of two variables, Simultaneous and iterated limits in functions of two variables.	6
4.	Partial derivatives: Definition, Existence and continuity, Interchange of order of differentiation, Directional derivatives.	6
5.	Composite functions, Continuity and differentiability of functions of two variables, Taylor"s theorem.	6

Paper – II

TOPOLOGY

Course No.: 5312 Credit Hours: Per week

I Course Outline

A. Lectures

S.No.	Topics	No. of Lectures
1.	Topological spaces with examples, Topologies on the real number system, Open sets, Neighbourhood of a point/set.	6
2.	Local Base, Base and sub-base of a topology, closed sets, interior, boundary, closure, limit point, Derived sets.	6

3.	Continuous functions, Homeomorphisms, Topological property and topological embedding, Rules for constructing continuous functions in topological spaces.	**6**
4.	Compact spaces, Limit point compact and Sequentially compact spaces, Locally compact spaces, Connected spaces, Path connected spaces, Components, Locally connected spaces.	**6**
5.	First and Second Countable spaces, Separable and Lindelof spaces, Separation axioms: T1, T2, T3 (Regular), T4 (Normal) spaces.	**6**

Paper –III

DIFFERENTIAL GEOMETRY AND TENSOR CALCULUS

Course No.: 5313 Credit Hours: Per week

I. Course Outline

A. Lectures

S.No.	Topics	No. of Lectures
1.	Curves in space, parameterized curves, regular curves, helices, arc length, reparametrization (by arc length), tangent, principal normal, binormal, osculating plane, normal plane, rectifying plane, curvature and torsion of smooth curves, Frenet-Serret formulae, Frenet approximation of a space curve.	**6**
2.	Order of contact, Osculating circle, osculating sphere, spherical indicatrices, involutes and evolutes, Bertrand Curves, intrinsic equations of space curves, isometries of $R3$, fundamental theorem of space curves, surfaces in $R,3$ regular surfaces, co-ordinate neighborhoods, parameterized surfaces, change of parameters, level sets of smooth functions on $R3$, surfaces of revolution, tangent vectors, tangent plane. first and second fundamental forms, classification of points on a surface.	**6**
3.	Curvature of curves on surfaces, normal curvature, principal curvatures, geometric interpretation of principal curvatures, Euler theorem, mean curvature, lines of curvature, Rodrigue's formula, umbilical points, minimal surfaces, definition and examples, Gaussian curvature, intrinsic formulae for the Gaussian curvature, isometries of surfaces.	**6**

4.	Christoffel symbols, curvature tensor, geodesics, geodesics on a surface of revolution, geodesic curvature of a curve.	**6**
5.	*n*-dimensional real vector space, contravariant vectors, dual vector space, Covariant vectors, tensor product, second order tensors, tensors of type (*r*, *s*), symmetry and skew symmetry of tensors, fundamental algebraic operations: Addition, multiplication, contraction and inner product. Quotient law of tensors.	**6**

SEMESTER II

Paper - I

COMPLEX ANALYSIS

Course No.: 5321 Credit Hours: Per week

I. Course Outline

A. Lectures

S.No.	**Topics**	**No. of Lectures**
1.	Conformal mappings, Power series representation of analytic functions, Analytic functions as mappings, Riemann sphere, Linear transformations, Mobius transformation, Cross ratios, Mobius transformation on circles.	**6**
2.	Derivative of an analytic function, Higher order derivatives, Cauchy's theorem integral formula. Morera's theorem, Cauchy inequality and Liouville's theorem. .	**6**
3.	Counting zeros, The open mapping theorem, Maximum modulus principle,Schwarz lemma, The fundamental theorem of algebra.	**6**
4.	Harmonic functions, Mean value property, Poisson formula.	**6**
5.	Entire functions, Jensen's formula, Meromorphic functions.	**6**

Paper – II

ABSTRACT ALGEBRA

Course No.: 5322 Credit Hours: Per week

I. Course Outline

A. Lectures

S.No.	Topics	No. of Lectures
1.	Normal and subnormal series, Zassenhaus's lemma, Schreiers' refinement theorem, composition series, Jordan Holder theorem, chain conditions, examples. Internal and external direct products and their relationship.	**6**
2.	Sylow subgroups. Sylow's I, II and III theorems, p – groups, examples andapplications, Groups of order p q, Direct and inverse images of Sylow subgroups.	**6**
3.	Commutators. Solvable groups, solvability of subgroups and factor groups. Nilpotent groups and their equivalent characterizations.	**6**
4.	Rings, ideals, prime and maximal ideals ,quotient rings. Factorisation theory in commutative domains. Prime and irreducible elements, G.C.D. Euclidean Domains. Principal Ideal Domain. Divisor chain condition. Unique Factorisation Domains, examples and counter examples. Polynomial rings over domains. Eisenstein's irreducibility criterion .Unique factorisation in polynomial rings over U.F.D.s.	**6**
5.	Fields, finite fields, field extensions, Galois extensions.	**6**

Paper – III

DIFFERENTIAL EQUATIONS

Course No.: 5323 Credit Hours: Per week

I. Course Outline

A. Lectures

S.No.	Topics	No. of Lectures
1.	Existence and uniqueness of solutions of initial value problems for first order ordinary differential equations, singular solutions of first order ODEs, system of first order ODEs., Sturm-Liouville boundary value problem, Green's function.	**6**
2.	Formation of P.D.E.'s. First order P.D.E.'s, Classification of first order, P.D.E.'s, Complete, general and singular integrals, Lagrange's or quasi - linear equations, Integral surfaces through a given curve. Orthogonal surfaces to a given system of surfaces, Characteristic curves.	**6**
3.	Charpit's method, Jacobi's Method. Cauchy problem for first order PDEs.	**6**
4.	Linear equations with constant coefficients, Reduction to canonical forms, Classification of second order P.D.E.s.General solution of higher order PDEs with constant coefficients.	**6**
5.	Method of separation of variables: Laplace, Heat and Wave equations in Cartesian, cylindrical and spherical polar coordinates.	**6**

SEMESTER III

Paper – I

LINEAR ALGEBRA

Course No.: 5331 Credit Hours: Per week

I. Course Outline

A. Lectures

S.No.	Topics	No. of Lectures
1.	A brief review of vector space, Inner products, Orthogonality, Best approximations, Projections, Cauchy-Schwartz inequality.	**6**
2.	Adjoint of a linear transformation, Self adjoint transformations, Unitary operators.	6

3.	Normal operators: Definition and properties.	6
4.	Spectral theory for normal operator, Polar decomposition of a linear operator, Roots of a family of normal operators, Self adjoint algebra generated by a family of linear operators.	6
5.	Eigen vectors and eigen values of a linear operator, Minimal polynomial of a linear operator and its relations to characteristic polynomial, Caley-Hamilton theorem.	6

Paper – II

MEASURE THEORY AND INTEGRATION

Course No.: 5332 Credit Hours: Per week

I. Course Outline

A. Lectures

S.No.	Topics	No. of Lectures
1.	Countable sets, uncountable sets, relation between the cardinality of a nonempty set and the cardinality of its power set; Boolean ring, σ-ring, Boolean algebra and σ-algebra of sets, Set function.	**6**
2.	**Lebesgue Measure**: Introduction, Outer measure, Measurable sets and Lebesgue measure, Example of nonmeasurable sets, Measurable functions.	**6**
3.	**The Lebesgue Integral:** The Riemann integral, The Lebesgue integral of a bounded function over a set of finite measure, The integral of nonnegative functions. The general Lebesgue integral, Convergence in measure.	**6**
4.	Containerized nursery- Type and size of container including root trainers, potting media.	**6**
5.	**Differentiation and Integration:** Differentiation of monotone functions, Functions of bounded variation, Differentiation of an integral, Absolute continuity, Convex functions.	**6**
6.	**General Measure and Integration Theory:** Measure spaces, Measurable functions, Integration, General convergence theorems, The Lp spaces, Measure and Outer Measure, Outer measure and measurability, The extension theorem, Inner measure, Caratheodory outer measure.	**6**

Paper –III

NUMERICAL SOLUTIONS OF ODE AND PDE

Course No.: 5333 Credit Hours: Per week

I. Course Outline

A. Lectures

S.No.	Topics	No. of Lectures
1.	**Numerical Solution of ordinary Differential equations**: Numerical solution of ODE by Picard's, Euler's, Modified Euler's and Runge-Kutta methods, Boundary value problems: Finite difference method, Shooting method.	6
2.	**Numerical Solution of Partial Differential equations:** Classification of second order general PDE, Difference method.	6
3.	**Difference methods for Parabolic PDE.** Heat conduction equation and its numerical solutions with finite difference methods (Two and three level difference methods).	6
4.	**Difference methods for Hyperbolic PDE.** Wave equation and its numerical solutions with finite difference methods (First order only).	6
5.	**Difference methods for Elliptical PDE.** Dirichlet problem for Laplace equation and its numerical solutions with finite difference methods.	6

SEMESTER IV

PAPER - I

DYNAMICS OF RIGID BODIES

Course No.: 5341 Credit Hours: Per week

I. Course Outline

A. Lectures

S.No.	Topics	No. of Lectures
1.	D'Alembert's principle, Motion about a fixed axis (Finite and Impulsive forces).	**6**
2.	Motion in two dimensions under Finite and Impulsive forces.	6
3.	Principle of conservation of momentum and energy.	6
4.	Lagrange's equations in generalized co-ordinates.	6
5.	Hamilton's principle, principle of least action, Euler's geometrical and dynamical equations.	6

PAPER - II

FUNCTIONAL ANALYSIS

Course No.: 5342 Credit Hours: Per week

I. Course Outline

A. Lectures

S.No.	Topics	No. of Lectures
1.	Inequalities (Auxiliary, Cauchy Schwarz, Holder and Minkowski), Example of metric spaces (especially $R^n, C^n, l^n C[a,b], s, B(A),\ l^p$).	**6**
2.	Normed and Banach Spaces, Completion of a normed space, Finite dimensional normed spaces; Compactness and finite dimension, linear operators, Bounded and continuous linear operators; Linear functional; linear operators and functional on finite dimensional spaces, Dual space.	**6**
3.	Inner product space; Hilbert space; Properties of Inner product spaces, Orthogonal complements and direct sums, Orthonormal sets and sequences; Hilbert adjoint operators, Self-Adjoint, Unitary and normal operators.	**6**

4.	Zorn's Lemma, Hahn Banach Theorem for real vector, Open mapping theorem, Closed graph theorem.	**6**
5.	Banach Contraction Principle (BCP), Some applications of BCP.	**6**

PAPER - III

CALCULUS OF VARIATIONS AND INTEGRAL EQUATIONS

Course No.: 5343 Credit Hours: Per week

II. Course Outline

B. Lectures

S.No.	**Topics**	**No. of Lectures**
1.	Functionals and extremals, Necessary and sufficient conditions for extrema, Variation and its properties.	**6**
2.	Euler equations, Cases of several dependent and independent variables, Variational methods for boundary value problems in ordinary and partial differential equations, Functionals dependent on higher derivatives, Parametric forms, Simple applications.	**6**
3.	Classification of linear integral equations, Relation between differential and integral equations.	**6**
4.	Fredholm equations of second kind with separable kernels, Fredholm alternative theorem, Eigen values and eigen functions.	**6**
5.	Method of successive approximation for Fredholm and Volterra equations, Resolvent kernel.	**6**

Electives for Semester I & III (Out of six papers only one paper will be opted)

ELECTIVES (SEMESTER I & III)

MATHEMATICAL STATISTICS

Course No.: 5351 Credit Hours: Per week

II. Course Outline

A. Lectures

S.No.	Topics	No. of Lectures
1.	Descriptive Statistics: Measures of central tendency, dispersion skewness and kurtosis Elements of probability: Sample space, discrete probability, independent events, Baye's theorem, random variables and distribution functions (univariate, bivariate, and genereralization to multivariate).	**6**
2.	Mathematical expectation and moments: Moment generating function, Characteristic function and cumulants. Probabilistic inequalities (Tchebychev, Markov and Jensen). Modes of convergence: weak and strong laws of large numbers. Central limit theorem (i.i.d. case). Markov chains with finite and countable state space, Poisson and birth- and- death processes.	**6**
3.	Some standard discrete and continuous univariate distributions (Binomial, Poisson, Normal, Gamma and Beta).	**6**
4.	Correlation, Rank correlation. Regression lines. Multiple and partial correlation of three variables only.	**6**
5.	Concept of sampling and statistics: simple random sampling Stratified sampling and systematic sampling, Probability proportional to size sampling, Ratio and regression methods.	**6**

THEORY OF NUMBERS

Course No.: 5352 Credit Hours: Per week

I. Course Outline

A. Lectures

S.No.	Topics	No. of Lectures
1.	Divisibilty theory in integers, Prime Numbers, Unique Factorization theorem.	**6**
2.	Theory of congruences, Fermet's theorem, Wilson's theorem.	6
3.	Number-theoretic functions: $d(n), \sigma(n), \mu(n), \varphi(n)$ and $\varphi(n)$ including elementary results.	6
4.	Primitive roots, Residues, Quadratic Reciprocity Law, Perfect numbers.	6
5.	Fibonacci numbers, Continued fractions, Irrational numbers, Representation of numbers by two or four squares.	6

FLUID DYNAMICS

Course No.: 5353 Credit Hours: Per week

I. Course Outline:

A. Lectures

S.No.	Topics:	No. of Lectures
1.	Lagrangian and Eulerian methods, Equation of continuity, Boundary surface, Stream lines, Velocity potential, Euler's equation of motions, Bernoulli's theorem, Helmholtz equations, Cauchy's integral, Equation of motion under impulsive forces, Principal of energy.	**6**
2.	Motion in two dimensions, Velocity potential and current functions, Sources and sinks, Doublet and images, Circle theorem, Motion of circular and elliptic cylinder in two dimensions, Joukowski transformation, Motion in three dimensions, Three dimensional sources, Sinks and doublets, Image of source in front of sphere, Motion of spheres, Stroke's stream function.	**6**
3.	General theory of irrotational motion, Permanence of irrotational motion circulation, Stroke's theorem, Kelvin's circulation theorem, Green's theorem, Kelvin's minimum energy theorem, Conformal Representation, Kutta and Joukowski transformation.	**6**

4.	Vortex motion: Rectilinear vortices, Rectilinear vortex with a circular section, An infinite row of parallel rectilinear vortices, Karman stream, Use of conformal transformation, Vortex pairs.	**6**
5.	General theory of stress strain, Navier-Stroke's equations.	**6**

DISCRETE MATHEMATICS

Course No.: 5354 Credit Hours: Per week

I. Course Outline:

A. Lectures

S.No.	**Topics**	**No. of Lectures**
1.	Principle of mathematical induction, Partially ordered sets, Lattices: Lattices as partially ordered sets, Their Properties, Lattices and algebraic systems. Principle of duality, Sub lattices, Complete, Complemented and Distributive lattices.	**6**
2.	Boolean algebra, Boolean functions, Boolean expressions, Applications to switching circuits.	**6**
3.	Elements of graph theory: Basic terminology, Paths and circuits, Eulerian and Hamiltonian graphs, Planar graphs, Directed graphs.	**6**
4.	Trees: Rooted trees, path lengths, spanning trees, minimum spanning trees.	**6**
5.	Permutations and Combinations, the rules of sums and products, Properties of binary relations, Equivalence relations and partitions, Functions and Pigeonhole principle, Principle of inclusion and exclusion.	**6**

COMPUTER PROGRAMMING AND MATHEMATICAL COMPUTATION

Course No.: 5355 Credit Hours: Per week

I. Course Outline

A. Lectures

S.No.	Topics	No. of Lectures
1.	Introduction to Programming in C: Introduction to Algorithms & Flowcharts Variables, constant, Keywords, signed and unsigned modifiers.	6
2.	Expression and operators: Arithmetic, logical and relational operators, bitwise operators, incremental operators, assignment operators. Functioning of these operators. Control flow: If-else, switch, while, do-white, for loops, continue, break statements, Nesting of control statements and loops.	6
3.	Working with functions: Variable and functions, Argument passing to functions, type of functions, storage classes, scope rule, C preprocessor and standard libraries.	6
4.	Pointers, arrays and File handling: Pointers, addresses, arrays, multidimensional arrays, String, Input/ Output, Standard input and output, basic file handling.	6
5.	User Defined Data-types: Structure, Union, enumeration.	6

SPECIAL FUNCTIONS

Course No.: 5356 Credit Hours: Per week

I. Course Outline

A. Lectures

S.No.	Topics	No. of Lectures
1.	Preliminaries, Gamma function and related functions, Gauss multiplication theorem, the hypergeometric differential equation, Gauss hypergeometric function.	5
2.	Preliminaries, Gamma function and related functions, Gauss multiplication theorem, the hypergeometric differential equation, Gauss hypergeometric function.	8

3.	Bessel's equation, solution of Bessel's equation, Bessel's functions $J_n(x)$, Recurrence Formulae, Equations reducible to Bessel's equation, orthogonality of Bessel's Functions, A generating function for $J_n(x)$, Basic properties.	**5**
4.	Legendre's equation, Legendre's polynomial $P_n(x)$, Legendre's function of the second kind $Q_n(x)$, General solution of Legendre's equation, Rodrigue's formula.	**8**
5.	Legendre polynomials, A generating function of Legendre's polynomial, Orthogonality of Legendre polynomials, Recurrence formulae for $P_n(x)$.	**5**

Electives for Semester II & IV (Out of five papers only one paper will be opted)

RELATIVITY

Course No.: 5371 Credit Hours: Per week

II. Course Outline

B. Lectures

S.No.	**Topics**	**No. of Lectures**
1.	Special Relativity: Inertial Frames of reference, Michelson-Morley experiment, Doppler effect, Stellar aberration, Simultaneity, Postulates of special relativity, Lorentz transformation, Length contraction, Time dilation, Clock paradox, Addition of velocities and accelerations, Four-dimensional space time, Light cone, Mass variation, Velocity four vector, Momentum and force, Mass-Energy relationship.	**6**
2.	General Relativity: Geodesics, Geodesic coordinates, Curvature tensor and its algebraic properties, Bianchi's identities, Contracted curvature tensor, Conditions for a flat space time, Displacement of space-time, Killing equations, Groups of motion, Space –time of constant curvature.	6
3.	Principal of covariance, Non-inertial frames of reference, Principal of equivalence, Weak field approximation of geodesic equations, Law of gravitation in empty space-time, Canonical coordinates, Schwarzschild solutions.	6

4.	Experimental tests of general relativity, Schwarzschild metric in isotropic coordinates, Brikhoff's theorem, Law of gravitation in non-empty space time.	6
5.	Energy-Momentum tensor for a perfect fluid, Poisson's equation as the weak field approximation, Schwarzschild interior solution, Gravitational collapse of a ball. Einstein-Maxwell equations of electromagnetism, Gravitational field of a point charge.	6

RIEMANNIAN GEOMETRY

Course No.: 5372 Credit Hours: Per week

III. Course Outline

C. Lectures

S.No.	**Topics**	**No. of Lectures**
1.	Dual vector Spaces: N-dimensional real vector space, Covariant vectors, Dual space, Contravariant vectors, tensor product, Other tensors of second order, Tensors of type (r,s). Algebraic Operations on tensors: Symmetric and skew symmetric properties, Fundamental algebraic operations, Inner product of vectors, Euclidean vector space.	**6**
2.	Tensor Calculus: Differentiable manifold, Lie-bracket, Tangent space, Connexions, Covariant derivatives, Curvature tensor, Parallelism. Lie derivative, Exterior derivative, Cartan's structural equations.	**6**
3.	Riemannian geometry : Riemannian metric, Christoffel symbols, Curvature tensor with respect to Christoffel symbols, Differential operators, Geodesics, Geodesic coordinates, Riemannian curvature, Conformal curvature tensor, Frenet's formulae.	**6**
4.	Ricci's Coefficients of Rotation: Orthonormal basis, Curl of a congruence, Canonical congruences, Gaussian and Ricci curvature.	**6**
5.	Sub-manifolds and Hypersurfaces: Normals, Gauss's formulae, Weingarten equations, Coordinate viewpoint, Lines of curvature, Generalized Gauss and Mainardi-Codazzi equations.	**6**

ADVANCED ABSTRACT ALGEBRA

Course No.: 5373 Credit Hours: Per week

II. Course Outline

B. Lectures

S.No.	Topics	No. of Lectures
1.	Modules over a ring, Endomorphism ring of an abelian group, R-Module structure on an abelian group M as a ring homomorphism from R to Endz {M}, Submodules, Direct summands, Annihilators, Faithful modules, Homomorphism, Factor modules, Correspondence theorem, Isomorphism theorems.	**6**
2.	$Hom_R[M,N]$ as an abelion group and $Hom_R[M,N]$ as a ring, Exact sequences, Five lemma, Products, coproducts and their universal property, External and internal direct sums.	**6**
3.	Free modules. Homomorphism extension property, Equivalent characterization as a direct sum of copies of the underlying ring, Split exact sequences and their characterizations, Projective modules, Injective modules, Divisible groups, Examples of injective modules, Boolean Algebra.	**6**
4.	Factorization of polynomials in extension fields, Splitting fields and their uniqueness, Separable field extensions, Perfect fields, Seperability over fields of prime characteristic, Transitivity and seperability, Automorphism of fields, Dedekind's theorem, Fixed fields, Normal extensions, Splitting fields and normality, Normal closures.	**6**
5.	Galois extensions, Fundamental theorem of Galois theory, Computation of Galois groups of polynomials.	**6**

OPERATION RESEARCH

Course No.:5374 Credit Hours: Per week

I. Course Outline:

B. Lectures

S.No.	Topics	No.of Lectures
1.	**Basics of OR and LPP**: Development of OR, Definition, characteristics, scope, objectives and limitations of OR, Formulation of LPP, Graphical Method to solve LPP, General LPP, Canonical and Standard forms, Properties of Solutions and Theory of Simplex method, Big M Method and Two phase simplex method, Degeneracy in LPP. Duality in LPP, Duality and simplex method, Dual simplex method, Revised simplex method and bounded variable problems.	6
2.	**Transportation and assignment Models**: Lp Formulation of TP, Transportation Table, Finding initial basic feasible solution, Test of optimality, Degeneracy, MODI method, Stepping Stone method, Solutions of Assignment problems, Hungerian method, Duality in assignment problem.	6
3.	**Sensitivity Analysis**: Changes in Objective Function Coefficient, Changes in constants, Changes in coefficients of decision variables in constraints, Structural changes.	6
4.	**Integer and Dynamic Programming**: Pure and Mixed integer programming, Gomory all IPP method, Fractional cut method, Branch and bound method, Dynamic programming: Recursive equation approach, dynamic programming algorithm.	6
5.	**Network Analysis and Nonlinear Programming**: Network flow problem, minimal spanning tree problem, shortest rout problem, maximal flow problem, minimum cost flow problems, critical path analysis, PERT and CPM, Formulation of NLPP, general NLPP, constrained optimization with equality and unequality constraints.	6

STATISTICAL ANALYSIS

Course No.: 5375 Credit Hours: Per week

I. Course Outline

A. Lectures

S.No.	Topics	No. of Lectures
1.	Statistical Inference: Concept of consistency, efficiency, sufficiency, unbiasedness, and completeness. Existence of best asymptotically, normal estimates under regulatory conditions. Maximum likelihood and other methods of estimation. Properties of maximum likelihood estimates. Minimax and Baye's estimates. Interval estimation: Neyman's Approach. Best confidence intervals.	6
2.	Testing of Hypothesis: Simple and composite hypothesis, critical region, two types of errors, level of significance and power of a test. Most powerful test and uniformly most powerful test.	6
3.	Neyman and Pearson's lemma. Likelihood Ratio tests. Large sample test. Sampling distribution of mean and variates. Exact sampling distributions: t, F and Z distributions and tests of significance based on them. Chi square distribution and its applications. Non parametric tests. Analysis of variance and covariance. Gauss – Markov models. Fixed, random and mixed effect models.	6
4.	Simple and multiple linear regressions. Elementary regression diagnostics. Logistic regression.	6
5.	Hazard function and failure rates. Censoring and life testing series and parallel systems.	6

DYNAMICAL SYSTEM

Course No.: 5376 Credit Hours: Per week

I. Course Outline

A. Lectures

S.No.	Topics	No. of Lectures
1.	**One Dimensional Dynamics**: Examples of dynamical systems, Preliminaries from calculus, elementary definitions, Hyperbolicity, An example from quadratic family, symbolic dynamics.	6
2.	Topological conjugacy, Chaos, structural stability, Sarkovskii's theorem, The Schwrzian derivative, Bifurcation theory.	6

3.	**Complex Analytic Dynamics:** Preliminaries from complex analysis, The Riemann sphere, Steriographic projection, Examples from quadratic maps.	**6**
4.	Equicontinuity and normal families, Montel's Theorem, Julia and Fatou sets, Fixed and periodic points and their classification.	**6**
5.	Critical points, Exceptional points, Properties of Julia sets, Mandelbrot set.	**6**

(Prof. Jaya Upreti)
Head & Convener
Department of Mathematics
Kumaun University
SSJ Campus, Almora