Chhatrapati Shahu Ji Maharaj University, Kanpur

Uttar Pradesh State University (Formerly Kanpur University, Kanpur)

Minutes of the Meeting of Board of Studies (held on 01 July 2025)

A Meeting of the Board of Studies (BOS) for the subject Mathematics was held on 01 July 2025 at 11:00 AM via online ode (Google-meet), with video conferencing at the CSJM University Campus Kanpur. The agenda was to discuss and approve the course structure and syllabus of the B.Sc. (Hons.) and M.Sc. in Mathematics with AI and Data Science programs.

The detailed course structure and syllabus for both the programs had already been shared with all BOS members. During the meeting, a presentation on the course structure and syllabus was delivered. After thorough discussion on each aspect of the syllabus, the following suggestions and recommendations were made by the BOS members:

1. Few corrections related to practicals were incorporated as per the members' suggestions.
2. All other minor recommendations were incorporated into the syllabus as advised by the Board members. The members unanimously approve the final syllabus.

The Meeting was attended by the Following BOS Members:

Convener

Prof. Pushpendra Kumar Tripathi, DAV P. G. College, Kanpur

External Members

1. Prof. A. K. Mishra, BHU Varanasi
2. Prof. Sahadeo Padhye, MNNIT Prayagraj
3. Prof. M. K. Dutta, Pro-VC, Amity University, Noida
4. Prof. Vineet Kansal, Director, IET Lucknow

Internal Members

1. Dr. Namita Tiwari, CSJM University Campus, Kanpur
2. Dr. P.N. Pathak, CSJM University Campus, Kanpur
3. Dr Arpit Dwivedi, CSJM University Campus, Kanpur

Invited Members

4. Dr. Deepak Kr Verma, Department of Computer Science, UIET, CSJMU, Kanpur.
5. Dr. Varsha Gupta, CSJM University Campus, Kanpur
6. Dr. D K Singh, CSJM University Campus, Kanpur.
7. Dr. Izhar Ali Khan, CSJM University Campus, Kanpur.

Invited Members

4. Dr. Deepak Verma, Department of Computer Science, UIET, CSJMU, Kanpur.
5. Dr. Varsha Gupta, CSJM University Campus, Kanpur.
6. Dr. D K Singh, CSJM University Campus, Kanpur.
7. Dr. Izhar Ali Khan, CSJM University Campus, Kanpur.

CONVENER
MATHEMATICS
C.S.J.M. UNIVERSITY, KANPUR

Prof. Pushpendra Kumar Tripathi	Prof. A. K. Mishra	Prof. Sahadeo Padhye	Prof. M. K. Dutta
Prof. Vineet Kansal	Dr. Namita Tiwari	Dr. P.N. Pathak	Dr Arpit Dwivedi
Dr. Deepak Verma	Dr. Varsha Gupta	Dr. D K Singh	Dr. Izhar Ali Khan

To,

The Dean Academics

Chhatrapati Shahu Ji Maharaj University Kanpur

Date: - -07-2025

Subject: - Report of online meeting conducted by the Board of Studies-Mathematics, CSJMU.

Respected Dean Academics,

Following the guidelines received from the U.P. government regarding three years B.Sc. (Honours) Course in Mathematics and the post graduate course, the Board of Studies-Mathematics conducted an online meeting (Google-meet), with video conferencing at the CSJM University Campus, Kanpur on 1st July, 2025 at 11:00 AM. The course structure and syllabus for three years B.Sc. (Honours) Course in Mathematics and a new course M.Sc. in Mathematics with AI and Data Science was passed and approved by the BOS unanimously after some discussion and minor changes. The following members of the BOS and some special invited members joined the meeting: -

Convener

Prof. Pushpendra Kumar Tripathi, DAV P. G. College, Kanpur

External Members

1. Prof. A. K. Mishra, BHU Varanasi
2. Prof. Sahadeo Padhye, MNNIT Prayagraj
3. Prof. M. K. Dutta, Pro-VC, Amity University, Noida
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Internal Members

1. Dr. Namita Tiwari, CSJM University Campus, Kanpur
2. Dr. P.N. Pathak, CSJM University Campus, Kanpur
3. Dr Arpit Dwivedi, CSJM University Campus, Kanpur

CHHATRAPATI SHAHU JI MAHARAJ UNIVERSITY, KANPUR

STRUCTURE OF SYLLABUS FOR THE

PROGRAM: B.Sc.(Hons.) SUBJECT: Mathematics

CURRICULUM AND CREDIT FRAMEWORK FOR B.Sc. HONOURS MATHEMATICS (3YEARS)

Semester I			
COURSE CODE	**TYPE**	**COURSE TITLE**	**CREDITS**
BH030101T	CORE	Calculus	4
BH030102T	CORE	Algebra And Trigonometry	4
BH030103T	CORE	Real Analysis I	4
VOCxxx	Skill enhancement course	Vocational Skill Enhancement course I	3
Z011101	Co-curricular Course	First Aid and Basic Health	2
	TOTAL		17

Semester II			
COURSE CODE	**TYPE**	**COURSE TITLE**	**CREDITS**
BH030201T	CORE	Multivariable Calculus	4
BH030202T	CORE	Ordinary Differential Equations	4
BH030203T	CORE	Geometry	4
BH030204TM	Minor	Differential & Integral Calculus	6
VOCxxx	Skill enhancement course	Vocational Skill Enhancement course I	3
Z021201	Co-curricular Course	Human Values and Environment Studies	2
	TOTAL		23
	Total credits after completion of 1st year		40

NOTE: 1. Total credits after completion of 1 year=40

2. Student is entitled for certificate in Faculty after successful completion of first two semesters.

CHHATRAPATI SHAHU JI MAHARAJ UNIVERSITY, KANPUR

STRUCTURE OF SYLLABUS FOR THE

PROGRAM: B.Sc.(Hons.) SUBJECT: Mathematics

Semester III

COURSE CODE	TYPE	COURSE TITLE	CREDITS
BH030301T	CORE	Real Analysis II	4
BH030302T	CORE	Algebra I	4
BH030303T	CORE	Probability and Statistics	4
VOCxxx	Skill Enhancement course (SEC)	Vocational Skill Enhancement course	3
Z031301	Co-curricular Course	Physical Education and Yoga	2
	TOTAL		17

Semester IV

COURSE CODE	TYPE	COURSE TITLE	CREDITS
BH030401T	CORE	Linear Algebra	4
BH030402T	CORE	Partial Differential Equations	4
BH030403T	CORE	Operations Research	4
BH030404TM	Minor	Integral Transform	6
BH030404R	Project	Research Project/Internship/Field Work	3
Z041401/ Z041402	Co-curricular Course	Social Responsibility and Community Engagement/Indian Language	2
	TOTAL		23
	Total credits after completion of 2nd year		40+40=80

NOTE: 3. Total credits after completion of 2nd year=80

4. Student is entitled for Diploma in Faculty after successful completion of four semesters.

CHHATRAPATI SHAHU JI MAHARAJ UNIVERSITY, KANPUR

STRUCTURE OF SYLLABUS FOR THE

PROGRAM: B.Sc.(Hons.) SUBJECT: Mathematics

Semester V

COURSE CODE	TYPE	COURSE TITLE	CREDITS
BH030501T	CORE	Complex Analysis	4
BH030502T	CORE	Algebra II	4
BH030503T BH030504T BH030505T BH030506T BH030507T	Elective I and II	Any two from 1. Mathematical Logic 2. Number Theory 3. Information Theory and Coding 4. Discrete Mathematics 5. Special Theory and Relativity	4
BH020508P	Practical - I	An Introduction to Maple/MATLAB -I	4
BH030509R	Research Project	Research Project on topics which are Inter/Intra faculty	5
	TOTAL		25

Semester VI

COURSE CODE	TYPE	COURSE TITLE	CREDITS
BH030601T	CORE	Metric Spaces	4
BH030602T	CORE	Numerical Analysis	4
BH030603T BH030604T BH030605T BH030606T BH030607T BH030608T	Elective I and II	Any two from 1. Integral Transforms and Fourier Analysis 2. Mechanics 3. Cryptography 4. Graph Theory 5. C++ Programming for Mathematics 6. Mathematical Finance	4
BH030609P	Practical - II	An Introduction to Maple/MATLAB -II	4
BH030610R	Research Project	Research Project on topics which are Inter/Intra faculty	5
	TOTAL		25
GRAND TOTAL			**130**

CHHATRAPATI SHAHU JI MAHARAJ UNIVERSITY, KANPUR

STRUCTURE OF SYLLABUS FOR THE

PROGRAM: B.Sc.(Hons.) SUBJECT: Mathematics

NOTE: 5. Total credits after completion of 3rd year=130
6. Student is entitled for 3 years B.Sc. (Honours) Mathematics UG degree after successful completion of six semesters.

NOTE:

1. **Do not mark any Code/Information in Column-A, it will be endorsed by the University.**
2. **CIA** in Column-E stands for **'Continuous Internal Assessment'** and depicts the maximum internal marks. Respective examination will be conducted by subject teacher. **ESE** in Column F stands for **'End Sem Examination/Evaluation'** and depicts the maximum external marks. Respective examination will be conducted by the University.
3. Column-B defines the nature of course/paper. The word **CORE** herein stands for **Compulsory Subject Paper**.
4. Column-D depicts the credits assigned for the corresponding course/paper.
5. **Elective:** It will be a Subject Elective. Students may accordingly select one or more subject papers under this category.
6. **Amongst the electives, one or two electives may be declared as Open (Generic) electives that shall be open as Minor Elective to students of other faculty in 1st or 2nd semester of a PG program.**
7. In both years of PG program, there will be a Research Project or equivalently a research-oriented Dissertation as per guidelines issued earlier.
8. Research project can be done in form of Internship/Survey/Field work/Research project/ Industrial training, for which report/dissertation shall have to be submitted. The evaluation for the same shall be done at the end of each year in form of seminar/presentation and viva voce.
9. The student straight away will be awarded 05 credits if he publishes a research paper on the topic of Research Project or Dissertation.

CHHATRAPATI SHAHU JI MAHARAJ UNIVERSITY, KANPUR

STRUCTURE OF SYLLABUS FOR THE

PROGRAM: B.Sc.(Hons.) SUBJECT: Mathematics

Semester I

Course Code- BH030101T

Course Name- Calculus (Credits: 04)

Course Objectives:

CO1: Understand the fundamental concepts of real-valued functions, their properties, and graphical representations.
CO2: Analyze the behavior of functions using limits, continuity, and differentiation, including advanced techniques such as Taylor series and maxima/minima.
CO3: Apply knowledge of coordinate systems and geometric tools to analyze curves and their characteristics.
CO4: Evaluate definite and improper integrals and apply integration to solve problems in geometry and analysis.

Unit I:

Relations and functions, Real valued function, Inverse of a function, Some elementary real functions such as: linear, quadratic, power, polynomial, rational, absolute value, signum and greatest integer functions with their graphs, domains and ranges; Properties of trigonometric, hyperbolic, logarithmic and exponential functions, Even and odd functions, Periodic functions, Composition of real functions. Limit and Continuity by ε-δ approach.

Unit II:

Indeterminate forms, L'Hospital Rule, Differentiability, Successive Differentiation, Leibnitz's Theorem, Rolle's Theorem, Mean Value Theorem, Expansion of functions (Taylor and Maclaurin Expansion) with remainder.

Unit III:

Polar coordinates system Tangents and normal (Cartesian and Polar curves) Maxima and minima, Concavity & Convexity and point of inflexion, Asymptotes.

Unit IV:

Radius of curvature, Envelopes and Evolute, Tracing of curves (Cartesian and Polar curves), Beta and Gamma functions.

Unit V:

Rectification, Quadrature and Volume of solid of revolution (Cartesian form, Parametric form and Polar form). Proper and Improper Integrals, Convergence of improper integrals of first kind and second kind.

Reference Books:

- Gorakh Prasad- Differential calculus, Pothishala Pvt. Ltd. Allahabad 2000
- Gorakh Prasad- Integral calculus, Pothishala Pvt. Ltd. Allahabad 2000
- G.B. Thomas and R.L.Finney, Calculus , Pearson's Education 2005
- G.B. Thomas and J Has, M.D. Weir, Calculus, Pearson's Publication 12th Edition
- S. C. Malik and S. Arora: Mathematical Analysis, New Academic Science Ltd, 5th Ed, 2017.

- K. Ahmad and P. Sharma- Text Book of Calculus, New Age International Publishers, 2022.

Course Code- BH030102T
Course Name- Algebra and Trigonometry (Credits: 04)
Course Objectives:

CO1: Understand the foundational concepts of set theory including cardinality, order, and the structure of partially ordered sets.
CO2: Apply matrix operations to solve linear systems and understand the properties of different classes of matrices.
CO3: Analyze linear transformations using eigenvalues and eigenvectors; use the Cayley–Hamilton theorem and matrix diagonalization techniques.
CO4: Analyze complex-valued functions and their transformations, including exponential, trigonometric, and logarithmic functions.
CO5: Evaluate mathematical series using Gregory's series and trigonometric identities, including summation through complex methods.

Unit I:

Theory of Sets, Cardinality of sets, Countable and uncountable sets, Schröder-Bernstein theorem, Cantor's set, Cantor's theorem, Order relation in cardinal numbers, Arithmetic of cardinal numbers, partially ordered set.

Unit II:

Hermitian and Skew-Hermitian Matrices, Elementary operations on Matrices. Inverse of a Matrix. Rank of a Matrix. Reduction into Normal and Echelon forms. Consistency and Solution of the system of linear equations.

Unit III:

Linear independence, The characteristic equation Eigenvalues and eigenvectors, Cayley–Hamilton theorem. Diagonalization and Quadratic form.

Unit IV:

Review of Complex numbers, Properties of Modulus and Argument, Applications of De Moivre's Theorem, Complex functions (Exponential, direct and inverse trigonometric and hyperbolic functions, Logarithmic function) and separation into real and imaginary parts.

Unit V:

Gregory's series, Generalization of Gregory's series, Evaluation of π, Summation of Series (C+ iS method only)

Reference Books:

- P. B. Bhattacharya, S. K. Jain and S. R. Nagpal, First Course in Linear Algebra, Wiley Eastern Ltd., New Delhi, 1983.
- S.L. Loney, Plane Trigonometry part-II, Deepa & Company, Nai Sarak, Delhi.

Course Code- BH030103T
Course Name- Real Analysis I (Credits: 04)
Course Objectives:

CO1: Demonstrate a rigorous understanding of the real number system, including properties of order, bounds, supremum/infimum, and completeness.
CO2: Understand and apply concepts from the topology of the real line, such as open/closed sets, accumulation points, and compactness.
CO3: Analyze sequences of real numbers for convergence or divergence using formal definitions and standard theorems (like Monotone Convergence Theorem).
CO4: Investigate infinite series, determine convergence via various tests (comparison, ratio, root, etc.), and understand absolute vs. conditional convergence.
CO5: Apply rigorous ε–δ definitions of limits and continuity, and understand their consequences in terms of function behavior and topological properties.

Unit I:

Algebraic and Order Properties of R, Countabilty in R, Bounded Sets, Unbounded sets, Supremum and Infimum of sets, The Completeness Property of R, The Archimedean Property, Density of Rational (and Irrational) numbers in R, Intervals. neighborhood of a point in R.

Unit II:

Interior point, Exterior point, Boundary points & boundary, Open set, Limit points, Accumulation points, Isolated points, closed set, Closure of a set, Perfect set, Compact set, Heine- Boral theorem, Denseness and theorem based on their properties and Bolzano-Weierstrass theorem for sets.

Unit III:

Sequences, Bounded sequence, Monotone Sequences, Cauchy sequence, Convergent sequence, Limit of a sequence. sequential criterion for limits, divergence criteria, limit theorems, Monotone Convergence Theorem. Subsequences, Divergence Criteria, Monotone Subsequence Theorem (statement only), Bolzano Weierstrass Theorem for Sequences., Cauchy's Convergence Criterion.

Unit IV:

Infinite series, nature of infinite series, Cauchy Criterion, Tests for convergence: Comparison test, Limit Comparison test, Ratio Test, Cauchy's nth root test, Integral test, Alternating series, Leibniz test, Absolute and Conditional convergence.

Unit V:

Continuous functions, sequential criterion for continuity & discontinuity, algebra of continuous functions. Continuous functions on an interval, intermediate value theorem, location of roots theorem, preservation of intervals theorem. Uniform continuity, non-uniform continuity criteria, uniform continuity theorem.

Reference Books:

- R.G. Bartle and D. R. Sherbert, Introduction to Real Analysis (3rd Edition), John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.
- Gerald G. Bilodeau, Paul R. Thie, G.E. Keough, An Introduction to Analysis, Jones & Bartlett, Second Edition, 2010.
- Brian S. Thomson, Andrew. M. Bruckner, and Judith B. Bruckner, Elementary Real Analysis, Prentice Hall, 2001.

Suggestive Readings:

- Mattuck, Introduction to Analysis, Prentice Hall (1999). 2. S. R. Ghorpade & B. V. Limaye, A Course in Calculus and Real Analysis – Springer (2006).
- S. C. Malik, Savita Arora, Mathematical analysis, second edition, New age international Limited, Publishers.

VOCxxx- Vocational Skill Enhancement course I (Credits: 03)

Z011101-First Aid and Basic Health (Credits: 02)

CHHATRAPATI SHAHU JI MAHARAJ UNIVERSITY, KANPUR

STRUCTURE OF SYLLABUS FOR THE

PROGRAM: B.Sc.(Hons.) SUBJECT: Mathematics

Semester II

Course Code- BH030201T

Course Name- Multivariable Calculus (Credits: 04)

Course Objectives:

CO1: Understand and analyze functions of several variables, including level curves, limits, continuity, partial differentiation, total differentiation, and their applications such as tangent planes and normal lines.
CO2: Apply techniques of multivariable calculus for function expansion, compute Jacobians, estimate approximation errors, and solve optimization problems using methods including Lagrange multipliers.
CO3: Evaluate double and triple integrals in different coordinate systems to compute area, mass, volume, and apply transformations including change of variables and order of integration.
CO4: Understand scalar and vector point functions and perform vector calculus operations such as gradient, divergence, curl, and directional derivatives, including the use of vector identities.
CO5: Apply the concepts of line, surface, and volume integrals in evaluating physical quantities like mass and work, and utilize the fundamental theorems of vector calculus including Green's, Stokes', and Gauss' divergence theorems.

Unit I:

Functions of several variables, Level curves and surfaces, Limits and continuity of functions of two variables, Necessary and sufficient condition for differentiability of functions two variables, Partial differentiation, Euler's theorem for homogeneous functions, Total differentiation, Change of variables, Tangent planes and normal lines.

Unit II:

Expansion of functions of several variables Jacobians, Approximations of Errors, Extrema of functions of two and more variables, Method of Lagrange multipliers, Constrained optimization problems.

Unit III:

Double integration in Cartesian and polar coordinates, Area, Mass and Volume by double integral, Change of order and change of variables, Triple integration (Cartesian, Spherical and Cylindrical coordinates), Volume by triple integrals, Dirichlet integral and Liouville's integral.

Unit IV:

Scalar and vector point functions, Vector field, Vector differentiation and integration, gradient, Divergence, Directional derivatives, curl, Scalar potential and vector identities.

Unit V:

Line integrals, Applications of line integrals: Mass and Work, Fundamental theorem for line integrals, Area as a line integral Conservative vector fields, Surface integrals, Volume integrals Green's theorem, Stokes' theorem, Gauss divergence theorem.

Reference Books:

- Jerrold Marsden, Anthony J. Tromba & Alan Weinstein (2009). Basic Multivariable Calculus, Springer India Pvt. Limited.
- James Stewart (2012). Multivariable Calculus (7th edition). Brooks/Cole. Cengage.
- Monty J. Strauss, Gerald L. Bradley & Karl J. Smith (2011). Calculus (3rd edition). Pearson Education. Dorling Kindersley (India) Pvt. Ltd.
- George B. Thomas Jr., Joel Hass, Christopher Heil & Maurice D. Weir (2018).

Course Code- BH030202T
Course Name- Ordinary Differential Equations (Credits: 04)
Course Objectives:

CO1: Solve and classify first-order differential equations.
CO2: Develop general solutions of second-order linear ODEs.
CO3: Construct series solutions around ordinary and singular points.
CO4: Apply ODE techniques to real-world and theoretical problems.
CO5: Apply the existence and uniqueness theorems.

Unit I:

Order and degree of a differential equation, Basic concepts and genesis of ordinary differential equations, Solutions of differential equations of first order and first degree. First order higher degree equations solvable for x, y and p. Clairaut's form and singular solutions.

Unit II:

Linear differential equations with constant coefficients, Solutions of homogeneous linear differential equations, Euler-Cauchy equation, Solutions of simultaneous differential equations.

Unit III:

The statement and geometrical interpretation of Picard's theorem for the existence and uniqueness of the solutions of the first order differential equations and its applications. Solution of linear differential equations of second order with variable coefficients (By inspection, By reducing into Normal form, by changing the dependent/independent variable), Wronskian and its properties, Method of variation of parameters and method of undetermined coefficients, General theory of linear differential equations of second order with variable coefficients,

Unit IV:

Series Solutions of Differential Equations, Ordinary points and Singular points of differential equations, Power series method, Frobenius method.

Unit V:

Legendre's equation, Legendre polynomials, Rodrigue's formula, Orthogonality of Legendre polynomials, Bessel's equation, Bessel functions and their properties, Recurrence relations.

Reference Books:

- Belinda Barnes & Glenn Robert Fulford (2015). Mathematical Modelling with Case Studies: A Differential Equation Approach Using Maple and MATLAB (2nd edition). Chapman & Hall/CRC Press, Taylor & Francis.
- H. I. Freedman (1980). Deterministic Mathematical Models in Population Ecology. Marcel Dekker Inc.
- Erwin Kreyszig (2011). Advanced Engineering Mathematics (10th edition). Wiley.
- Martin Braun (1993). Differential Equations and Their Applications (4th edition). Springer.

Course Code- BH030203T
Course Name- Geometry (Credits: 04)
Course Objectives:

CO1: Understand and apply polar equations of conic sections and related properties like tangents, normals, and auxiliary circles.
CO2: Analyze planes using different forms of equations and solve related geometric problems.
CO3: Solve problems involving lines, planes, distances, projections, and volumes in 3D space.
CO4: Understand and apply properties of spheres, including tangents, intersections, and radical planes.
CO5: Study cones and cylinders, and analyze their intersections, tangents, and reciprocal forms.

Unit I:

General equation of second degree, Polar equation of Conics (parabola, ellipse and hyperbola when focus in taken as pole), Polar equations of the chord joining two points, tangent, normal, polar (chord of contact)

Unit II:

Direction ratios & direction cosine of a St. line. plane passing through one point, Normal form, intercept form and general equation of a plane, plane passing through three points, angle between two planes, two sides of a plane, Length of perpendicular from a point to a plane, Bisectors of angles between two planes, Planes passing through the line of intersection of two planes.

Unit III:

Symmetrical and non-symmetrical form of equations of a line, transformation of non-symmetrical form to symmetrical form, Planes passing through a line, coplanar lines, , Length of perpendicular from a point to a line, Orthogonal projection of a point and a line on a plane,

The shortest distance between two lines, intersection of two lines, intersection of three planes, volume of a tetrahedron, pair of planes.

Unit IV:

Equation of a sphere. Plane section of a sphere and intersection of two spheres, spheres passing through a circle, tangent plane, plane of contact, polar lines, angle of intersection of two spheres, power of a point, radical plane, line, centre of spheres, coaxial system of spheres, Orthogonal systems of spheres

Unit V:

Cones and cylinders with given base, intersection of a cone and a plane passing through the vertex of the cone, tangent lines and planes, reciprocal cones, normal plane passing through a generator of the cone, right circular cones and cylinders.

Reference Books:

- M. M. Tripathi, Coordinate geometry.
- Mata Ambar Tiwari and R. S. Sengar. A course in Vector Analysis and its Applications.
- N. Saran and R. S. Gupta: Analytical Geometry of Three Dimensions.

Minor Course

Course Code- BH030204TM
Course Name- Differential & Integral Calculus (Credits: 06)
Course Objectives:

CO1 Explain the relationship between the derivative of a function as a function and the notion of
the derivative as the slope of the tangent line to a function at a point.
CO2 Compare and contrast the ideas of continuity and differentiability.
CO3 To find maxima and minima, critical points and inflection points of functions and to determine the concarity of curves
CO4 Double integral and application
CO5 Triple integral and their applications

Unit I: Differential Calculus: Differentiability and differentials. Successive differentiation and Leibnitz Theorem. Statement of Rolle's Theorem. Mean Value Theorem, Taylor and Maclaurin's Theorems, indeterminate forms. Limits and continuity of functions of two variables.

Unit-II: Partial Differentiation: Definition of Partial derivatives. Euler’s Theorem on homogeneous functions, total derivative of composite & implicit functions, Errors and

approximations.

Unit-III: Applications: Asymptotes. Curvature, Concavity, Convexity and points of inflection.Extreme Points, Envelopes. Curve tracing, Tracing of Cartesian, Polar Curves,

Unit-IV: Integral Calculus: Integration, Beta and Gamma Functions,Application of Integral Calculus: Quadrature, Area, length of arc, Arc length as a parameter. Multiple Integrals: Definitions, Double integrals, Triple Integral.

Text and Reference Books:

1. Shanti Nayaran, Differential Calculus, ShyamLal Charitable Trust, Delhi, 2002.
2. Shanti Nayaran, Integral Calculus, ShyamLal Charitable Trust, Delhi, 2002.
3. N. Piskunov, Differential Calculus & Integral Calculus, Vol. 1 and II, Mir Pub., 1981.
4. C.B. Thomas, Calculus and Analytical Geometry, Narosa Pub., Delhi, 1996.
5. N. Piskunov, Differential Calculus & Integral Calculus, Vol. 1 and II, Mir Pub., 1981.

VOCxxx- Vocational Skill Enhancement course I (Credits: 03)

Z021201-Human Values and Environment Studies (Credits: 02)

CHHATRAPATI SHAHU JI MAHARAJ UNIVERSITY, KANPUR

STRUCTURE OF SYLLABUS FOR THE

PROGRAM: B.Sc.(Hons.) SUBJECT: Mathematics

Semester III

Course Code- BH030301T

Course Name- Real Analysis II (Credits: 04)

Course Objectives:

CO1: Explain and apply the concept of differentiability of real-valued functions, including the Mean Value Theorem and Taylor's Theorem with rigorous proofs.
CO2: Analyze the Riemann integral, including conditions for integrability, properties of integrable functions, and apply the Fundamental Theorem of Calculus.
CO3: Examine improper integrals and evaluate their convergence or divergence using comparison and limit tests.
CO4: Distinguish between pointwise and uniform convergence of sequences and series of functions, and understand their implications on continuity, integrability, and differentiability.
CO5: Develop and manipulate power series representations of functions, including radius of convergence and term-by-term differentiation and integration.

Unit I:

Differentiability of a function at a point & in an interval, Carathéodory's theorem, algebra of differentiable functions, relative extrema, interior extremum theorem. Rolle's theorem, mean value theorem, Cauchy's mean value theorem, intermediate value property of derivatives - Darboux's theorem. Applications of mean value theorem to inequalities & approximation of polynomials, Taylor's theorem with Lagrange's form of remainder and Cauchy's form of remainder.

Unit II:

Riemann integration, upper and lower sums; Riemann conditions of integrability, Riemann sum, Riemann integrability of monotone and continuous functions, Properties of the Riemann integral; definition and integrability of piecewise continuous and monotone functions. Intermediate Value theorem for Integrals, Fundamental theorems of Calculus.

Unit III:

Pointwise and uniform convergence of sequence of functions. Theorems on continuity, derivability and integrability of the limit function of a sequence of functions. M_n -test for convergence of sequences.

Unit IV:

Pointwise and uniform convergence of series of functions. Theorems on the continuity and derivability of the sum function of a series of functions; Cauchy criterion for uniform convergence and Weierstrass M-Test. Abel's test and Dirichlet's test for uniform convergence.

Unit V:

Functions of bounded variations, Power series, radius of convergence, Cauchy Hadamard Theorem, Differentiation and integration of power series; Abel's Theorem, Weierstrass Approximation Theorem.

Reference Books:

- K.A. Ross, Elementary Analysis: The Theory of Calculus, Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.
- R.G. Bartle D.R. Sherbert, Introduction to Real Analysis (3rd edition), John Wiley and Sons (Asia) Pvt. Ltd.., Singapore, 2002.
- Charles G. Denlinger, Elements of Real Analysis, Jones and Bartlett (Student Edition),2011.

Course Code- BH030302T
Course Name- Algebra I (Credits: 04)
Course Objectives:

CO1: Understand the fundamental concepts of groups, subgroups, cyclic groups, and group operations with concrete and abstract examples.
CO2: Analyze and apply group homomorphisms and isomorphisms to establish structural properties of groups.
CO3: Apply Lagrange's theorem, the concept of cosets, and normal subgroups in solving group-theoretic problems.
CO4: Investigate and prove important results involving permutation groups, symmetric groups, and their applications.
CO5: Understand and apply group actions, the class equation, and Sylow theorems in classifying finite groups.

Unit I:

Definition and examples of groups including quaternion groups, General Linear group, Symmetries of a polygon, Dihedral groups, elementary properties of groups, order of group, order of an element, subgroups, theorems on subgroups, centralizer, normalizer, center of a group.

Unit II:

Cyclic groups, properties of cyclic groups, Permutation group, cycle notation for permutations, transpositions, even and odd permutations, alternating group, cosets and their properties, index of a subgroup, Lagrange's theorem and consequences including Fermat's Little theorem, Euler's phi functions, Euler's theorem, normal subgroups, factor groups.

Unit III:

Group homomorphisms, properties of homomorphisms, kernel of homomorphism, Cayley's theorem, isomorphisms, first, Second and Third isomorphism theorems, automorphism, inner automorphism, automorphism groups, Commutator subgroup and its properties.

Unit IV:

External direct product of a finite number of groups, properties of external direct products, the group of units modulo n as an external direct product, internal direct products, fundamental Theorem of finite abelian groups.

Unit V:

Conjugacy, class equation and consequences, Cauchy's theorem for finite abelian groups, Cauchy's theorem, Group actions, Index theorem. Groups acting on themselves by conjugation, conjugacy in Sn, p-groups, Sylow groups, Sylow's theorems and consequences.

Reference Books:

- Joseph A. Gallian, Contemporary Abstract Algebra (9th Edition), Narosa Publishing House, New Delhi, 1999 (2010).
- David S. Dummit and Richard M. Foote, Abstract Algebra (3rd Edition), John Wiley and Sons (Asia) Pvt. Ltd, Singapore (2004).
- I.N. Herstein, Topics in Algebra (2nd edition). Wiley India (2006).

SUGGESTED READING:

- Joseph J. Rotman, An Introduction to the Theory of Groups (4th Edition), Springer Verlag, 1995.

Course Code- BH030303T

Course Name- Probability and Statistics (Credits: 04)

Course Objectives:

CO1: Understand the have the basic knowledge on data collection and various statistical elementary tools.

CO2: Have the critical thinking in the theory of probability and its applications in real life problems.

CO3: Apply the theoretical continuous probability distributions like Normal, Exponential, etc., in the relevant application areas.

CO4: Apply the theoretical discrete probability distributions like binomial, Poisson, etc., in the relevant application areas.

CO5: Find the inter-relation between two or more phenomena with the help of curve fitting and correlation-regression analysis.

Unit I:

Probability-definition and basic notions of probability, mutually exclusive events, addition theorem of probability, dependent and independent events, Conditional probability, multiplication theorem, Baye's theorem.

Unit II:

Random variables - Discrete and continuous, Cumulative distribution function, Probability mass/density functions, Mathematical expectation, Moments, Moment generating function, Characteristic function.

Unit III:

Univariate Discrete distributions: Uniform, Bernoulli, Binomial, Negative binomial, Geometric and Poisson.

Unit IV:

Continuous Distributions: Uniform, Gamma, Exponential, Chi-square, Beta and Normal; Normal approximation to the binomial distribution.

Unit V:

Method of least squares, Covariance, Correlation, Correlation coefficient, rank correlation, Regression, Bivariate normal distribution, Chebyshev's theorem, Central limit theorem, Strong law of large numbers, weak law of large numbers.

Reference Books:

- Robert V. Hogg, Joseph W. McKean & Allen T. Craig (2013). Introduction to Mathematical Statistics (7th edition), Pearson Education.
- Irwin Miller &Marylees Miller (2014). John E. Freund's Mathematical Statistics with Applications (8thedition). Pearson. Dorling Kindersley Pvt. Ltd. India.
- Jim Pitman (1993). Probability, Springer-Verlag.
- Sheldon M. Ross (2014). Introduction to Probability Models (11th edition). Elsevier.
- M. Yaglom and I. M. Yaglom (1983). Probability and Information. D. Reidel Publishing Company. Distributed by Hindustan Publishing Corporation (India) Delhi

VOCxxx: Vocational Skill Enhancement course (Credits: 03)

Z031301: Physical Education and Yoga (Credits: 02)

CHHATRAPATI SHAHU JI MAHARAJ UNIVERSITY, KANPUR

STRUCTURE OF SYLLABUS FOR THE

PROGRAM: B.Sc.(Hons.) SUBJECT: Mathematics

Semester IV

Course Code- BH030401T

Course Name- Linear Algebra (Credits: 04)

Course Objectives:

CO1: Solve systems of linear equations using matrix methods and understand matrix properties.
CO2: Understand vector spaces, subspaces, basis, and dimension.
CO3: Analyze linear transformations and apply the rank-nullity theorem and isomorphism.
CO4: Work with dual spaces, eigenvalues, minimal and characteristic polynomials.
CO5: Understand bilinear and quadratic forms, inner product spaces, and apply orthogonalization.

Unit I:

Fields, Vector spaces, subspaces, examples, algebra of subspaces, quotient spaces, linear combination of vectors, direct sum of two subspaces.

Unit II:

Linear span, linear independence, Basis and dimension, theorems on basis and dimensions. quotient spaces.

Unit III:

Linear transformations, Matrix representation of a linear transformation, Algebra of linear transformations, null space, range, rank and nullity of a linear transformation and rank-nullity theorem, Isomorphism, Isomorphism theorems, Transpose of a linear transformation.

Unit IV:

Linear functional, Dual and second dual of a vector space, Eigen vectors and eigen values of a linear transformation, Characteristic polynomial and Cayley–Hamilton theorem, Minimal polynomial.

Unit V:

Bilinear forms, positive forms, quadratic forms. Inner product spaces and norms, Gram Schmidt orthogonalization process, Diagonalization.

Reference Books:

- K.A. Ross, Elementary Analysis: The Theory of Calculus, Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.
- R.G. Bartle D.R. Sherbert, Introduction to Real Analysis (3rd edition), John Wiley and Sons (Asia) Pvt. Ltd.., Singapore, 2002.

Charles G. Denlinger, Elements of Real Analysis, Jones and Bartlett (Student Edition),2011.

Course Code- BH030402T

Course Name- Partial Differential Equations (Credits: 04)

Course Objectives:

CO1: Formulate and solve first-order PDEs.
CO2 Analyze Cauchy problems via characteristic methods.
CO3: Solve constant-coefficient linear PDEs.
CO4: Transform variable-coefficient second-order PDEs and Classify them.
CO5: Apply separation of variables to physical models.

Unit I:

First Order Partial Differential Equations Order and degree of Partial differential equations (PDE), Concept of linear and non-linear partial differential equations, Partial differential equations of the first order, Lagrange's method.

Unit II:

Cauchy problems and characteristics, compatibility, some special type of equation which can be solved easily by methods other than the general method, Charpit's general method.

Unit III:

Homogeneous and nonhomogeneous partial differential equations with constant coefficients. Second Order Partial Differential Equations with Variable Coefficients reducible to equations with constant coefficient.

Unit IV:

Classification of second order PDEs, Change of variables, Reduction to canonical or normal form.

Unit V:

Solution of heat and wave equations in one and two dimensions by method of separation of variables. Applications to vibrating strings.

Reference Books:

- S. Gupta (2004). Calculus of Variations with Applications. PHI Learning.
- Erwin Kreyszig (2011). Advanced Engineering Mathematics (10th edition). Wiley.
- TynMyint-U & Lokenath Debnath (2013). Linear Partial Differential Equation for Scientists and Engineers (4th edition). Springer India.
- H. T. H. Piaggio (2004). An Elementary Treatise on Differential Equations and Their Applications. CBS Publishers.
- S. B. Rao & H. R. Anuradha (1996). Differential Equations with Applications. University Press.
- Ian N. Sneddon (2006). Elements of Partial Differential Equations. Dover Publications.

Course Code- BH030403T
Course Name- Operations Research (Credits: 04)
Course Objectives:

CO1: Formulate and solve the LPP including those that lead to cycling and degeneracy.
CO2: To develop a deep understanding of convexity and their applications in optimization.

CO3: Solve transportation and assignment problems and their importance.
CO4: Apply the above concepts to real life problems.

Unit I:

Introduction and scope of operational research, Formulation of Linear Programming Problems (LPP), Convex sets and their properties, Convex functions, Extreme points, Solutions, Basic solutions, Feasible solutions and Initial Basic Feasible Solutions, Optimal solution, Graphical method; Reduction of feasible solution to basic feasible solution.

Unit II:

Simplex Method Optimality criterion, Improving a basic feasible solution, Unboundedness, Unique and alternate optimal solutions; Simplex algorithm and its tableau format; Artificial variables, Two-phase simplex method, Big-M method.

Unit III:

Duality Formulation of the dual problem, Duality theorems, Complimentary slackness theorem, Economic interpretation of duality, Use of simplex method in duality, Dual simplex method, Sensitivity Analysis.

Unit IV:

Transportation Problems, Mathematical formulation, Methods of finding initial basic feasible solutions: Northwest-corner rule, Least- cost method, Vogel approximation method, Unbalanced Transportation Problem, Degeneracy in Transportation Problem, Algorithm for obtaining optimal solution.

Unit V:

Assignment Problems, Mathematical formulation and Hungarian method for solving Assignment Problem, Assignment Problems of Maximization, Unbalanced Assignment Problems, Travelling Salesman Problem (TSP).

Reference Books:

- Mokhtar S. Bazaraa, John J. Jarvis & Hanif D. Sherali (2010). Linear Programming and Network Flows (4th edition). John Wiley & Sons.
- G. Hadley (2002). Linear Programming. Narosa Publishing House.
- Frederick S. Hillier & Gerald J. Lieberman (2015). Introduction to Operations Research (10th edition). McGraw-Hill Education.
- Hamdy A. Taha (2017). Operations Research: An Introduction (10th edition). Pearson.
- Paul R. Thie & Gerard E. Keough (2014). An Introduction to Linear Programming and Game Theory (3rd edition). Wiley India Pvt. Ltd.

CHHATRAPATI SHAHU JI MAHARAJ UNIVERSITY, KANPUR

STRUCTURE OF SYLLABUS FOR THE

PROGRAM: B.Sc.(Hons.) SUBJECT: Mathematics

Minor Course

Course Code- BH030404TM
Course Name- Integral Transforms (Credits: 06)

Course Objectives:

CO1 Have understanding regarding different kind of integral transforms.
CO2 Understand Fourier transform and its properties and will be able to solve the examples based on it.
CO3 Have deep understanding of Laplace Transformation and its real life application.
CO4 Solve initial value problem and boundary value problem using Laplace Transform.
CO5 Solve initial value problem and boundary value problem using Laplace Transform.

Unit I: Laplace Transform: Existence of Laplace Transform, Function of exponential order, a function of Class A, Laplace Transform of some elementary function, First and Second translation, change of scale property, Laplace transform of the derivative, Laplace transform of Integral, Multiplication, Division, Periodic function.

Unit-II: Inverse Laplace Transform: Null Function, Lerch's Theorem, first and second Translation, Change of scale, Derivatives, Integrals, Multiplication, Division, Convolution Theorem, Heaviside's expansion, The complex inversion formula.

Unit-III: Applications: Solution of Ordinary Differential equations. Solution of Simultaneous Ordinary differential equation.

Unit-IV: Fourier Transform: Fourier Transform, Convolution, Relation between Fourier and Laplace Transform, Parseval's Identity for Fourier Transform, Fourier Transform of derivative of function, Finite Fourier Transform.

Unit-V: Application of Fourier transform: Solution of Initial and Boundary value problems using Fourier transform and finite Fourier Transform.

Reference Books:

1. Ian N Senddon (1972), The Use of Integral Transform, McGraw Hill.
2. L. Dobanth and D. Bhatta, Integral Transforms and Their Applications, 2nd edition, Taylor and Francis
Group.
3. E. Kreyszig (2011), Advanced Engineering Mathematics, John Wiley & Sons.

BH030404R: Project Research Project/Internship/Field Work (Credit 3)

Z041401/
Z041402: Social Responsibility and Community Engagement/Indian Language (Credit 2)

CHHATRAPATI SHAHU JI MAHARAJ UNIVERSITY, KANPUR

STRUCTURE OF SYLLABUS FOR THE

PROGRAM: B.Sc.(Hons.) SUBJECT: Mathematics

Semester V

Course Code- BH030501T
Course Name- Complex Analysis (Credits: 04)
Course Objectives:

CO1: Represent complex numbers algebraically and geometrically
CO2: Harmonic and entire functions including the fundamental theorem of algebra
CO3: Understand about the singularities and Residues
CO4: Represent functions as Taylor's and Laurent's Series
CO5: Understand the concept of complex mappings and linear transformations.

Unit I: Review of complex numbers, Complex plane, Open set, Domain and region in complex plane, Function of a complex variable, Limit, Continuity and Differentiability of a complex valued functions.

Unit II:

Analytic Functions, necessary and sufficient conditions for Analyticity, Cauchy-Riemann Equations in polar form, Harmonic functions, Construction of an analytic function, Analyticity and zeros of exponential, trigonometric and logarithmic functions.

Unit III:

Power Series, Radius of convergence of Power series, Absolute and uniform convergence of power series, Conformal and Isogonal Transformation, Linear Transformation, Bilinear (or Mobius) Transformation, Fixed Points (or Invariant Points).

Unit IV:

Complex line integral, Path independence, Some elementary properties of Complex Line Integral, Cauchy's Theorem, Cauchy-Goursat theorem, Cauchy integral formula, Cauchy's inequality, Derivative of analytic function, Liouville's theorem.

Unit V:

Zeros of an analytic function, singularity and its classification, Limit points of Zeros and Poles, Taylor series and Laurent series of analytic functions. Residue at pole, Cauchy's Residue theorem.

Reference Books:

- Lars V. Ahlfors (2017). Complex Analysis (3rd edition). McGraw-Hill Education.
- Joseph Bak & Donald J. Newman (2010). Complex Analysis (3rd edition). Springer.
- James Ward Brown & Ruel V. Churchill (2009). Complex Variables and Applications (9th edition). McGraw-Hill Education.
- John B. Conway (1973). Functions of One Complex Variable. Springer-Verlag.
- E.T. Copson (1970). Introduction to Theory of Functions of Complex Variable. Oxford University Press. 6. Theodore W. Gamelin (2001). Complex Analysis.

Springer-Verlag.
- George Polya & Gordon Latta (1974). Complex Variables. Wiley.

Course Code- BH030502T
Course Name- Algebra II (Credits: 04)
Course Objectives:

CO1. Understand and apply the fundamental concepts of rings and fields, including commutative rings, integral domains, division rings, and ideals.
CO2. Analyze and construct ring homomorphism's and isomorphism's, and apply the fundamental theorem of homomorphism to study quotient rings.
CO3. Identify and characterize prime, principal, and maximal ideals, and explain their significance in the structure of rings and fields. Use properties of Euclidean rings and apply Wilson's and Fermat's theorems in abstract algebra.
CO4. Work with polynomial rings, understand the division algorithm, and apply Gauss's Lemma and Eisenstein's Criterion to determine irreducibility. Differentiate between Euclidean domains, principal ideal domains (PID), and unique factorization domains (UFD).
CO5. Understand and apply the theory of field extensions, including algebraic, separable, and normal extensions. Explain the concepts of algebraic and transcendental numbers, splitting fields, and finite field classification.

Unit-I: Rings, Integral domain, and Fields Definition, examples and their elementary properties, Commutative rings, Basic theorems of integral domains and fields, Subring, Subfield, Division rings and fields, Idempotent and Nilpotent elements, Characteristic of a ring, Characteristic of a field.

Unit-II: Ordered integral domain, Order relation in integral domain, Ideal in a ring, Simple ring, Prime, principal and maximal ideals, Principal ideal ring, Radical of ideal and primary ideal.

Unit-III: Ring homomorphism and isomorphism, Theorems on homomorphism's, Quotient ring and fundamental theorem of homomorphism of rings, Euclidean rings and their properties.

Unit-IV: Polynomial Rings, Polynomial rings over commutative ring and their basic properties, The division algorithm; Polynomial rings over rational field, Gauss lemma and Eisenstein's criterion, Euclidean domain, principal ideal domain, and unique factorization domain.

Unit-V: Field Extensions and Finite Fields Extension of a field, Algebraic Extensions, Separable Extensions, Normal Extensions, Algebraic element of a field, Algebraic and transcendental numbers, Splitting Fields, Perfect field, Classification of finite fields.

References: 1. I.N Herstein, Topics in Algebra, John Wiley & Sons. New York

2. Michael Artin (2014). Algebra (2nd edition). Pearson.

3. P. B. Bhattacharya, S. K. Jain & S. R. Nagpaul (2003). Basic Abstract Algebra (2nd edition). Cambridge University Press.

4. David S. Dummit & Richard M. Foote (2008). Abstract Algebra (2nd edition). Wiley.

5. John B. Fraleigh (2007). A First Course in Abstract Algebra (7th edition). Pearson.

6. Joseph A. Gallian (2017). Contemporary Abstract Algebra (9th edition). Cengage.

DSE Courses-I (Any Two)

Course Code- BH030503T **(Credit 04)**

1. Course Name- Mathematical Logic
Course Objectives:

CO1: Understand the syntax of first-order logic and build logical formulas and theories.
CO2: Analyze structures and models in first-order logic.
CO3: Apply propositional logic, including proof techniques and compactness.
CO4: Prove meta-theorems and understand consistency and completeness in logic.
CO5: Use completeness and compactness theorems in model theory and algebra.

Unit I:

Syntax of First-order Logic First-order languages, Terms of language, Formulas of language, First order theory.

Unit II:

Semantics of First-order Languages Structures of first order languages, Truth in a structure, Model of a theory, Embeddings and isomorphism.

Unit III:

Propositional Logics Syntax of propositional logic, Semantics of propositional logic, Compactness theorem for propositional logic, Proof in propositional logic, Meta theorem in propositional logic, Post tautology theorem.

Unit IV:

Proof and Meta Theorems in First-order Logic Proof in first-order logic, Meta theorems in first-order logic, Some meta theorem in arithmetic, Consistency and completeness.

Unit V:

Completeness Theorem and Model Theory Completeness theorem, Interpretation in a theory, Extension by definitions, Compactness theorem and applications, Complete theories, Applications in algebra.

Reference Books:

- Richard E. Hodel (2013). An Introduction to Mathematical Logic. Dover Publications.
- Yu I. Manin (2010). A Course in Mathematical Logic for Mathematicians (2nd edition). Springer.
- Elliott Mendelson (2015). Introduction to Mathematical Logic (6th edition). Chapman & Hall/CRC.
- Shashi Mohan Srivastava (2013). A Course on Mathematical Logic (2nd edition). Springer.

2. Course Code- BH030504T (Credit 04)

Course Name- Number Theory
Course Objectives:

CO1: In this course, students learn the properties of the set of integers in detail.
CO2: Students can find integer solutions to the system of equations which arises in real life problems.
CO3: Learn about number theoretic functions, modular arithmetic and their applications.
CO4: Learn about some important results in the theory of numbers including the prime number theorem, Chinese remainder theorem, Wilson's theorem and their consequences.
CO5: Euler's criterion, the Legendre symbol, Jacobi symbol and their properties, to understand modular arithmetic number-theoretic functions and apply them to cryptography.

Unit I:

Divisibility and properties, The division algorithm, G.C.D. (Greatest Common Divisors), L.C.M (Least Common Multiple), Prime Numbers, Euclidean Algorithm, Fundamental Theorem of Arithmetic, Congruences and Basic Properties, Linear Diophantine equation, Chinese remainder theorem.

Unit II:

Fermat's little theorem and applications, Wilson's theorem and applications, Number theoretic functions, sum and number of divisors, perfect numbers, totally multiplicative functions, the Mobius Inversion formula and related results, the greatest integer function and its properties.

Unit III:

Euler's Phi-function, some properties of Euler's Phi-function, Euler's generalization of Fermat's theorem, reduced set of residues, some properties of Euler's phi-function.

Unit IV:

Order of an integer modulo n, complete and reduced residue system, primitive roots for primes, composite co numbers having primitive roots.

Unit V:

Quadratic residues, Euler's criterion, the Legendre symbol and its properties, quadratic reciprocity, Gauss reciprocity law, quadratic congruences with composite moduli, the equation $x^2 + y^2 = z^2$, Fermat's last theorem.

Reference Books:

- D. M. Burton, Elementary Number Theory, 6th edition, Tata McGraw Hill Edition, Indian reprint, 2007.
- T. M. Apostol, Introduction to Analytic Number Theory, Narosa Publication House, New Delhi, 2013.
- N. Robbins, Beginning Number Theory, 2nd edition, Jones & Bartlett Learning, 2017.
- G. A. Jones and J.M. Jones. Elementary Number Theory, Springer, 1998.
- Thomas Koshy, ElementaryNumber Theory with Applications (2nd Edition), Academic Press, 2007. 6. Neville Robinns, Beginning Number Theory (2ndEdition), Narosa Publishing House Pvt.Limited, Delhi, 2007.

3. Course Code- BH030505T **(Credit 04)**
Course Name- Information Theory and Coding
Course Objectives:

CO1: To understand the fundamental concepts of probability theory.

CO2: To develop knowledge of data compression techniques.

CO3: To study the concept of channel capacity.

CO4: To analyze and implement error-correcting codes.

CO5: To explore foundational cryptographic systems.

Unit I:
Random variables (discrete and continuous), distributions, Expectation, variance, joint and conditional distributions, Bayes' theorem, independence, law of large numbers, Entropy properties of entropy, Joint entropy, conditional entropy.

Unit II:
Data Compression, Prefix codes and Kraft-McMillan inequality, Source Coding Theorem and compression limits, Huffman Coding, Construction and optimality of Huffman codes, Universal Source Coding.

Unit III:
Channel Capacity, Discrete memoryless channels (DMC), Capacity of Binary Symmetric Channel (BSC), Shannon's Channel Coding Theorem, Capacity with constraints.

Unit IV:
Differential Entropy, Linear block codes, encoding and decoding, Generator matrix, parity-

check matrix.

Unit V:
Syndrome decoding, Minimum Distance, Hamming codes, Cyclic redundancy checks (CRC), performance measures, Convolutional Codes.

Reference Books:

- Cover, T. M., & Thomas, J. A. (2006). Elements of Information Theory (2nd ed.). Hoboken, NJ: Wiley-Interscience.
- MacKay, D. J. C. (2003). Information Theory, Inference, and Learning Algorithms. Cambridge: Cambridge University Press.
- Lin, S., & Costello, D. J. (2004). Error Control Coding: Fundamentals and Applications (2nd ed.). Upper Saddle River, NJ: Prentice Hall.
- Gallager, R. G. (1968). Information Theory and Reliable Communication. New York: John Wiley & Sons.
- Proakis, J. G. (2001). Digital Communications (4th ed.). New York: McGraw-Hill.
- Jones, G. A., & Jones, J. M. (2000). Information and Coding Theory. London: Springer-Verlag.
- Capocelli, R. M. (1991). Introduction to Information Theory and Coding. New York: Springer.

4. Course Code- BH030506T **(Credit 04)**
Course Name- Discrete Mathematics
Course Objectives:

CO1: In this course, students understand concept of logic and find principle normal forms.
CO2: Students can construct generating function and study its application to counting and in solving recurrence relations.
CO3: Students can represent relations in various ways, find their closures.
CO4: Students can understand posets, lattices & groups.
CO5: Students can have basic knowledge of some important graphs and binary trees.

Unit I:

Recursive definition, generating functions, solution of difference equations, Relations, types of relation, equivalence relation, composition of relation, representation of relations using matrix and graphs, closure of relations.

Unit II:

Partially Ordered Sets(POSET) – Definitions and examples, Basic properties of posets, Hasse diagrams, Dual of a poset, Duality principle, maximal and minimal elements, least upper bound and greatest upper bound, Order isomorphism, Lattice.

Unit III:

Boolean polynomial functions, basic properties, Minimal forms of Boolean polynomials, Disjunctive and conjunctive normal forms, Boolean Algebras, Boolean homomorphism, Switching circuits and applications.

Unit IV:

Graphs –Definition and examples, basic properties of graphs, Konigsberg bridge problem; Pseudo graphs, Complete graphs, Weighted graph, Bipartite graphs, Subgraphs.

Unit V:

Isomorphism of graphs, Adjacency matrix, Incidence matrix, Paths and circuits, Eulerian graph, Hamiltonian graph, Travelling salesman problem, Dijkstra's algorithm.

Reference Books:

- B. A. Davey & H. A. Priestley (2002). Introduction to Lattices and Order (2nd edition). Cambridge University Press.
- Edgar G. Goodaire & Michael M. Parmenter (2018). Discrete Mathematics with Graph Theory (3rd edition). Pearson Education.
- Rudolf Lidl & Günter Pilz (1998). Applied Abstract Algebra (2nd edition). Springer.
- Kenneth H. Rosen (2012). Discrete Mathematics and its Applications: With Combinatorics and Graph Theory (7th edition). McGraw-Hill.
- C. L. Liu (1985). Elements of Discrete Mathematics (2nd edition). McGraw-Hill.

5. Course Code- BH030507T (Credit 04)
Course Name- Special Theory and Relativity
Course Objectives:

CO1: Understand inertial frames, Galilean relativity, and the need for special relativity.
CO2: Apply Lorentz transformations and understand their properties and geometric meaning.
CO3: Analyze relativistic effects like length contraction, time dilation, and velocity transformations.
CO4: Interpret space-time geometry using Minkowski diagrams, intervals, and four-vectors.
CO5: Understand relativistic mechanics including mass-energy equivalence, four-momentum, and equations of motion.

Unit I:

Newtonian Mechanics Inertial frames, Speed of light and Gallilean relativity, Michelson−Morley experiment, Lorentz−Fitzgerold contraction hypothesis, Relative character of space and time.

Unit II:

Postulates of special theory of relativity, Lorentz transformation equations and its geometrical interpretation, Group properties of Lorentz transformations.

Unit III:

Relativistic Kinematics Composition of parallel velocities, Length contraction, Time dilation, Transformation equations for components of velocity and acceleration of a particle and Lorentz contraction factor.

Unit IV:

Geometrical representation of space-time Four dimensional Minkowskian space-time of special relativity, Time-like, light-like and space-like intervals, Null cone, Proper time, World line of a particle, Four vectors and tensors in Minkowiskian space-time.

Unit V:

Relativistic Mechanics Variation of mass with velocity. Equivalence of mass and energy. Transformation equations for mass momentum and energy. Energy-momentum four vector. Relativistic force and Transformation equations for its components. Relativistic equations of motion of a particle.

Reference Books:

- James L. Anderson (1973). Principles of Relativity Physics. Academic Press.
- Peter Gabriel Bergmann (1976). Introduction to the Theory of Relativity. Dover Publications.
- C. Moller (1972). The Theory of Relativity (2nd edition). Oxford University Press.
- Robert Resnick (2007). Introduction to Special Relativity. Wiley.
- Wolfgang Rindler (1977). Essential Relativity: Special, General, and Cosmological. Springer Verlag.
- V. A. Ugarov (1979). Special Theory of Relativity. Mir Publishers, Moscow.

BH020508P Practical - I An Introduction to Maple/MATLAB-I Credits:04

The following practicals should be performed on Maple/MATLAB software.

1. Basic commands on Maple.
2. Basics of plotting.
3. Plotting of 2D curves.
4. Plotting of 3D curves.
5. Other plot commands on Maple.
6. Creating matrices.
7. Implement matrix multiplication, transpose, inverse.
8. Compute Eigenvalues and Eigenvectors.
9. Solving system of linear equations.
10. Finding rank of matrices.

CHHATRAPATI SHAHU JI MAHARAJ UNIVERSITY, KANPUR

STRUCTURE OF SYLLABUS FOR THE

PROGRAM: B.Sc.(Hons.) SUBJECT: Mathematics

BH030509R Research Project Research Project on topics which are Inter/Intra faculty Credits:05

Semester VI

Course Code- BH030601T

Course Name- Metric Spaces (Credits: 04)

Course Objectives:

CO1: Understand the foundational concepts of metric spaces, including open and closed sets, interiors, closures, boundaries, and subspaces.
CO2: Analyze the behavior of sequences in metric spaces, including concepts of convergence, Cauchy sequences, and completeness, and apply the Cantor Intersection and Completion Theorems.
CO3: Examine and apply advanced topological concepts such as dense sets, separability, compactness, and the Baire Category Theorem.
CO4: Evaluate the relationships between completeness, compactness, and total boundedness using key properties and theorems such as the Bolzano-Weierstrass property and finite intersection property.
CO5: Study and apply continuity concepts in metric spaces, including uniform continuity, homeomorphisms, isometries, equicontinuity, and important results like the Ascoli-Arzelà and Banach Contraction Theorems.

Unit I:

Definition and examples of metric spaces, Bounded and unbounded metric spaces, Distance between sets, Diameter of a set, Open and closed balls, Interior points and interior of a set, Open set, Neighbourhood of a point, Limit point of a set, Closure of a set, Closed set, Boundary points and boundary of a set, Exterior points and exterior of a set, Subspace of a metric space.

Unit II:

Sequences and subsequence in a metric space, Convergent and Cauchy sequences, Complete metric spaces, Relation between completeness and closedness, Cantor Intersection Theorem, Completion Theorem**.**

Unit III:

Dense sets, Separable spaces, Nowhere dense sets, Categories and Baire Category Theorem. Cover of a metric space, Compact metric spaces, Compact sets and their criterion, Properties of compact sets, Relation between compactness.

Unit IV:

Completeness and closedness, Finite Intersection property, Bolzano-Weierstrass property, Sequential compactness, Totally bounded spaces.

Unit V:

Continuous functions between two metric spaces, Characterizations of Continuous functions, Continuous functions on compact spaces, Uniform continuous functions. Homeomorphism and Isometry, Equicontinuity and Ascoli-Arzela Theorem, Fixed points, Banach contraction theorem.

Reference Books:

- Q. H. Ansari: Metric Spaces Including Fixed Point Theory and Set-valued Maps, Narosa Publishing House, New Delhi. 2010.
- E. T. Copson: Metric spaces, Cambridge University Press, 1968.
- M. O. Searcoid: Metric spaces, Springer, 2007.
- S. Kumaresan: Topology of Metric Spaces, Narosa Publishing House, 2nd Ed, 2011.

Course Code- BH030602T
Course Name- Numerical Analysis (Credits: 04)
Course Objectives:

CO1: To learn to apply the various numerical techniques for solving real life problems.
CO2: The problems which cannot be solved by usual formulae and methods can be solved approximately by using numerical techniques.
CO3: Evaluate Newtons interpolation, Central difference interpolation formula Explore Gauss interpolation formulae, Langrage's interpolation formula and Newtons divided Difference formulae.
CO4: Know about the solution of algebraic and transcendental equations.
CO5: Find the solution of simultaneous algebraic equations and to evaluate the solution of Trapezoidal rule, Simpson's 1/3rd and 3/8th rules, Weddle and Boole's formula.

Unit I:

Errors in Numerical calculations: Introduction, Numbers and their accuracy, Absolute, relative and percentage errors. Finite Differences, Various difference operators and relation between them, fundamental theorem of finite differences.

Unit II:

Solution of Algebraic And Transcendental Equations: Bisection method, method of false position, secant method, iteration method, Newton's Raphson method. Order of convergence of the above methods.

Unit III:

Interpolation: Newtons forward and backward interpolation formulae. Central difference interpolation formula. Gauss forward and backward interpolation formulae. Lagrange's interpolation formula, Hermite's interpolation formula and Newtons divided difference formulae.

Unit IV:

Solutions of Simultaneous Algebraic Equations: Gauss Elimination method, Gauss-Jorden method, LU Decomposition, Crout method, Relaxation method, Jacobi's method, Gauss-Seidel method.

Unit V:

Numerical Differentiation and Integration: Formula for derivatives, Newton's forward interpolation formula, Newton's backward difference formula, Newton cotes quadrature, Trapezoidal rule, Simpson's 1/3rd and 3/8th rules. Boole's & Weddle rule, Gauss quadrature formula.

Reference Books:

- B.S. Grewal, Numerical Methods in Engg. & Science, Khanna Publications, 2013.
- S. S. Shastri, Introduction Methods of Numerical Analysis, PHI learning pvt. Limited.
- C.E. Froberg, Introduction to Numerical Analysis, Addison Wesly Publication Company, 1970.
- Brian Bradie, A Friendly Introduction to Numerical Analysis, Pearson Education, 2006.
- C. F. Gerald & P. O. Wheatley, Applied Numerical Analysis, Pearson Education, 2008.
- M.K. Jain, S.R.K. Iyenger and R.K. Jain, Numerical Methods for Scientific and Engg. Computations, Wiley Eastern Ltd.
- R.S. Gupta, Element of Numerical Analysis, Macmillon's India, 2010

DSE Courses-II (Any Two)

1. Course Code- BH030603T **(Credit 04)**

Course Name- Integral Transforms and Fourier Analysis

Course Objectives:

CO1: To understand the Laplace transform and its properties.
CO2: Apply the Laplace transform to solve differential equations.

CO3: Compute Fourier series of given function and interpret its coefficients
CO4: Compute Fourier and inverse Fourier transforms of functions.

Unit I:

Laplace Transforms Laplace transform, Linearity, Existence theorem, Laplace Transform of Elementary Functions, Laplace transforms of derivatives and integrals, Shifting theorems, Change of scale property, Laplace transforms of periodic functions, Unit step function, Dirac's delta function.

Unit II:

Further Properties of Laplace Transforms and Applications Differentiation and integration of transforms, Convolution theorem, Integral equations, Inverse Laplace transform, Lerch's theorem, Linearity property of inverse Laplace transform, Translations theorems of inverse Laplace transform, Inverse transform of derivatives, Applications of Laplace transform in obtaining solutions of ordinary differential equations and integral equations.

Unit III:

Fourier Transforms Fourier and inverse Fourier transforms, Fourier sine and cosine transforms, Inverse Fourier sine and cosine transforms, Linearity property, Change of scale property, Shifting property, Modulation theorem, Relation between Fourier and Laplace transforms.

Unit IV:

Solution of Equations by Fourier Transforms Solution of integral equation by Fourier sine and cosine transforms, Convolution theorem for Fourier transform, Parseval's identity for Fourier transform, Plancherel's theorem, Fourier transform of derivatives, Applications of infinite Fourier transforms to boundary value problems, Finite Fourier transform, Inversion formula for finite Fourier transforms.

Unit V:

Fourier series Fourier cosine and sine series, Fourier series, Differentiation and integration of Fourier series, Absolute and uniform convergence of Fourier series, The complex form of Fourier series.

Reference Books:

- James Ward Brown & Ruel V. Churchill (2011). Fourier series and Boundary Value Problems. McGraw-Hill Education.
- Charles K. Chui (1992). An Introduction to Wavelets. Academic Press.
- Erwin Kreyszig (2011). Advanced Engineering Mathematics (10th edition). Wiley.
- Walter Rudin (2017). Fourier Analysis on Groups. Dover Publications.
- A. Zygmund (2002). Trigonometric Series (3rd edition). Cambridge University Press.

2. Course Code- BH030604T **(Credit 04)**
Course Name- Mechanics
Course Objectives:

CO1: Understand rectilinear motion, SHM, motion under forces like gravity and resistance, and motion with varying mass.
CO2: Analyze motion in a plane using different coordinate systems and study special motions like vertical circles and projectiles.
CO3: Understand central force motion, Kepler's laws, and properties of the common catenary.
CO4: Calculate centers of gravity for curves, areas, volumes, and surfaces, including variable density cases.
CO5: Apply concepts of moments, couples, and virtual work in 2D and 3D force systems.

Unit I:
Rectilinear Motion Simple harmonic motion (SHM) and its geometrical representation, SHM under elastic forces, Motion under inverse square law, Motion in resisting media, Concept of terminal velocity, Motion of varying mass.

Unit II:

Motion in a Plane Kinematics and kinetics of the motion, Expressions for velocity and acceleration in Cartesian, polar and intrinsic coordinates; Motion in a vertical circle, projectiles in a vertical plane and cycloidal motion**.**

Unit III:

Central orbits and Kepler's Laws, Common Catenary, Intrinsic and Cartesian equations of the common catenary, Approximations of the catenary.

Unit IV:

Centres of Gravity, Centres of gravity by integration, Centres of gravity of any arc of a given curve, Centres of gravity of plane area, Centre of gravity of a plane area bounded by a curves, Centre of gravity of a volume of revolution, Centre of gravity of a surface of revolution, Centre of gravity when the density varies.

Unit V:

Moment of a force about a point, Moment of a force about a line, Couples, Moment of a couple, Forces in three dimensions, Central axis, constraint bodies, Null Lines and Planes Principle of virtual work for a system of coplanar forces acting on a particle or at different points of a rigid body, Forces which can be omitted in forming the equations of virtual work.

Reference Books:

- S. L. Loney (2006). An Elementary Treatise on the Dynamics of a Particle and of Rigid Bodies. Read Books.
- P. L. Srivatava (1964). Elementary Dynamics. Ram Narin Lal, Beni Prasad Publishers Allahabad.
- J. L. Synge & B. A. Griffith (1949). Principles of Mechanics. McGraw-Hill.
- A. S. Ramsey (2009). Statics. Cambridge University Press.
- A. S. Ramsey (2009). Dynamics. Cambridge University Press.
- R. S. Varma (1962). A Text Book of Statics. Pothishala Pvt. Ltd.
- Dr Vinod Kumar. Dynamics & Statics. Epsilon Publishing House Pvt. Ltd.

CHHATRAPATI SHAHU JI MAHARAJ UNIVERSITY, KANPUR

STRUCTURE OF SYLLABUS FOR THE

PROGRAM: B.Sc.(Hons.) SUBJECT: Mathematics

3. Course Code- BH030605T **(Credit 04)**

Course Name- Cryptography

Course Objectives:

Unit I:

Prime numbers, Modular arithmetic, Fermat's Little Theorem, Euler's Theorem, Chinese Remainder Theorem, Discrete Logarithms, Factoring, Prime number generation, Random number generation

Unit II:

Introduction to Cryptography, Need and goals of cryptography, Conventional encryption techniques, Classical Stream Ciphers: Caesar Cipher, Mono-alphabetic and Poly-alphabetic Ciphers, Playfair Cipher, Hill Cipher, Vigenere Cipher

Unit III:

Stream and Block Ciphers, Symmetric-Key Cryptography, Feistel Structure, Data Encryption Standard (DES), Triple DES, Advanced Encryption Standard (AES), Design of S-boxes, Pseudo-Random Number Generators: PRNG, Linear Feedback Shift Registers (LFSR), One-Time PAD.

Unit IV:

Cryptographic Hash Functions, One-Way Hash Functions, Security of Hash Functions, Message Authentication Codes, MD5, SHA family-Secure Hash Algorithms, digital signature.

Unit V:

Public-key cryptography, Key management principles, Diffie-Hellman Key Exchange Mechanisms, El-Gamal Encryption, RSA Algorithm, DSA and variants, Elliptic Curve, Elliptic Curve Cryptosystem, Elliptic Curve Discrete Logarithm Problem.

Reference Books:

- Stallings, Cryptography and Network Security: Principles and Practice, Pearson Education Asia. ISBN 981-403-589-0.
- B Schneier, Applied Cryptography, Wiley. ISBN 0-471-11709-9
- D Kahn. The Codebreakers, Sphere books. ISBN 0-7221-51497
- P Wayner, Disappearing Cryptography, Academic Press. ISBN 0-12 738671-8
- Cracking DES, Electronic Frontier Foundation. ISBN 1-56592-520-3
- A.J. Menezes, P.C. van Oorschot and S.A. Vanstone, Applied Cryptography, CRC Press, ISBN 0-8493-8523-7, 1997
- D.R. Stinson, Cryptography - Theory and practice, CRC Press, ISBN 0 8493-8521-0, 1995

4. Course Code- BH030606T **(Credit 04)**

Course Name- Graph Theory

Course Objectives:

CO1: Students will achieve command of the fundamental definitions and concepts of graph theory.
CO2: Students will understand and apply the core theorems and algorithms, generating examples as needed, and asking the next natural question.
CO3: Students will achieve proficiency in writing proofs using basic graph theory.
CO4: Students will work on clearly expressing mathematical arguments, in discussions and in their writing.

Unit I:

Introduction to Graph Theory, Definition and examples of a graph, Types of Graphs, Graph Isomorphisms, Subgraph, Walks, Paths, trails and circuits, Fundamental Circuits; Simple graphs, Wheel graphs, Weighted graphs, Complete graphs, Complementary graph, connected graphs, disconnected graphs.

Unit II:

Euler and Hamiltonian graphs, Algorithm to finding Euler trail, Adjacency matrix and incidence matrix of a graph, Directed graphs and their elementary properties, Bipartite graphs, Distance, Eccentricity, Radius, Diameter and center of Graphs, Dijkstra's algorithm to finding shortest path between two vertices in Weighted graph.

Unit III:

Trees, Definition and properties of trees, Rooted and binary trees, Cayley's theorem on a counting tree, Spanning tree, Minimal spanning trees, Algorithms to finding minimal spanning tree in a connected graph.

Unit IV:

Cut edge (or Bridge), Cut-Sets and Cut-Vertices, Branch, Chord, Fundamental Cut-set of a graph and its properties, Connectivity and separability, Network flows.

Unit V:

Planar and Non-planar Graphs, Regions, Degree of regions, Euler theorem for a planar graph, Various representations of a planar graph, Dual of a planar graph, Detection of planarity, Kuratowski's theorem.

Reference Books:

- R. Balakrishnan & K. Ranganathan (2012). A Textbook of Graph Theory. Springer.
- Narsingh Deo (2016). Graph Theory with Applications to Engineering and Computer Science. Dover Publications.
- Reinhard Diestel (2017). Graph Theory (5th edition). Springer.
- Edgar G. Goodaire & Michael M. Parmenter (2018). Discrete Mathematics with Graph Theory (3rd edition). Pearson.
- Douglas West (2017). Introduction to Graph Theory (2nd edition). Pearson

5. Course Code- BH030607T (Credit 04)

Course Name- C- Programming for Mathematics

Course Objectives:

CO1: Understand C- programming basics, syntax, structure, and IDE usage.
CO2: Develop and debug programs using operators, expressions, and control structures.
CO3: Use arrays, classes, and objects to organize and manipulate structured data.
CO4: Apply programming concepts to solve mathematical problems like factorization and geometry.
CO5: Utilize C templates and containers for advanced applications in algebra, number theory, and data structures.

Unit I:

C Essentials Fundamentals of programming, Organization of logic flow in stored program model of computation, C as a general purpose programming language, Structure of a C program, Common compilers and IDE's, Basic data-types, Variables and literals in C.

Unit II:

Operators, Expressions, Evaluation precedence and type compatibility; Outline of program development in C, Debugging and testing; Applications: Greatest common divisor and random number generation.

Unit III:

Structured Data Structured data-types in C, Arrays and manipulating data in arrays; Objects and classes: Information hiding, modularity, constructors and destructors, methods and polymorphism.

Unit IV:

Applications: Factorization of an integer, Euler's totient, Images in Cartesian geometry using points in two & three dimensions, Pythagorean triples.

Unit V:

Containers and Templates Containers and Template Libraries: Sets, iterators, multisets, vectors, maps, lists, stacks and queues; Applications: Basic set algebra, modulo arithmetic and congruence's, projective plane, permutations, monotone sequences and polynomials.

Reference Books:

- Nell Dale & Chip Weems (2013). Programming and Problem Solving with C++ (6th edition). Jones & Bartlett Learning.
- Peter Gottschling (2016). Discovering Modern C++: An Intensive Course for Scientists, Engineers, and Programmers. Pearson.
- Nicolai M. Josuttis (2012). The C++ Standard Library: A Tutorial and Reference (2nd edition). Addison-Wesley, Pearson.
- Donald E. Knuth (1968). The Art of Computer Programming. Addison-Wesley.

6. Course Code- BH030608T **(Credit 04)**
Course Name- Mathematical Finance
Course Objectives:

CO1: Understand interest theory, annuities, bond pricing, yields, and duration measures.
CO2: Analyze term structure of interest rates, bond derivatives, and financial market instruments.
CO3: Apply no-arbitrage principles and understand option pricing fundamentals, including put-call parity.
CO4: Use stochastic models like binomial trees and the Black-Scholes formula to price financial derivatives.
CO5: Evaluate hedging strategies using Greeks, and understand swaps and their valuation.

Unit I:

Basic Theory of Interest and Fixed-Income Securities Principal and interest: simple, compound and continuous; Present and future value of cash flow streams; Net present value, Internal rates of return and their comparison; Inflation, Annuities; Bonds, Bond prices and yields, Macaulay duration and modified duration.

Unit II:

Term Structure of Interest Rates, Bonds and Derivatives Spot rates, forward rates and explanations of term structure; Running present value, Floatingrate bonds, Immunization, Convexity; Putable and callable bonds; Exchange-traded markets and over-the-counter markets; Derivatives: Forward contracts, Future contracts, Options, Types of traders, Hedging, Speculation, Arbitrage.

Unit III:

Mechanics of Options Markets No-arbitrage principle, Short selling, Forward price for an investment asset; Types of options: Call and put options, Option positions, Underlying assets, Factors affecting option prices, Upper and lower bounds for option prices, Put-call parity, Effect of dividends.

Unit IV:

Stochastic Analysis of Stock Prices and Black−Scholes Model Binomial option pricing model, Risk neutral valuation: European and American options on assets following binomial tree model; Lognormal property of stock prices, Distribution of rate of return, Expected return, Volatility, Estimating volatility from historical data, Extension of risk-neutral valuation to assets following geometric Brownian motion, Black−Scholes formula for European options.

Unit V:

Hedging Parameters, Trading Strategies and Swaps Hedging parameters: Delta, gamma, theta, rho and vega; Trading strategies involving options, Swaps, Mechanics of interest rate swaps, Comparative advantage argument, Valuation of interest rate swaps, Currency swaps, Valuation of currency swaps.

Reference Books:

- John C. Hull & Sankarshan Basu (2018). Options, Futures and Other Derivatives (10th edition). Pearson Education.
- David G. Luenberger (2013). Investment Science (2nd edition). Oxford University Press.
- Sheldon M. Ross (2011). An Elementary Introduction to Mathematical Finance (3rd edition). Cambridge University Press.

BH030609P Practical - II An Introduction to Maple/MATLAB -II Credits:04

The following practicals should be performed on Maple/MATLAB software.

1. Finding roots of equations using Bisection method.
2. Finding roots of equations using Newton-Raphson Method.
3. Solving Linear Systems using Gauss Elimination.
4. LU decomposition.
5. Polynomial Interpolation.
6. Numerical Differentiation.
7. Numerical Integration – Trapezoidal Rule.
8. Numerical Integration – Simpson's Rule
9. Solving differential equations.
10. Difference Equations.

BH030610R Research Project Research Project on topics which are Inter/Intra faculty Credits: 05

CHHATRAPATI SHAHU JI MAHARAJ UNIVERSITY, KANPUR

STRUCTURE OF SYLLABUS FOR THE

PROGRAM: M.Sc. in Mathematics with Artificial Intelligence & Data Science

CURRICULUM AND CREDIT FRAMEWORK FOR **M.SC. IN MATHEMATICS WITH ARTIFICIAL INTELLIGENCE & DATA SCIENCE** (2YEARS)

Semester I			
COURSE CODE	**TYPE**	**COURSE TITLE**	**CREDITS**
B260701T	CORE	**Linear Algebra**	4
B260702T	CORE	**Probability and Statistics**	4
B260703T	CORE	**Artificial Intelligence**	4
B260704T	CORE	**Mathematics for Data Science**	4
B260705P	Practical-1	**Lab based on the courses B260701T to B260704T**	4
	TOTAL		20

Semester II

COURSE CODE	**TYPE**	**COURSE TITLE**	**CREDITS**
B260801T	CORE	**Numerical Analysis**	4
B260802T	CORE	**Discrete Mathematics**	4
B260803T	CORE	**Operation Research**	4
B260804T	CORE	**Data Structure**	4
B260805T B260806T B260807T B260808T	Elective-1	**Any one from DSE Courses-I** 1. Cyber Security 2. Graph Theory 3. Big Data Analytics	4
	TOTAL		20

NOTE: Total credits after completion of 1 year=40

CHHATRAPATI SHAHU JI MAHARAJ UNIVERSITY, KANPUR

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PROGRAM: M.Sc. in Mathematics with Artificial Intelligence & Data Science

Semester III

COURSE CODE	TYPE	COURSE TITLE	CREDITS
B260901T	CORE	**Database Management Systems**	4
B260902T	CORE	**Introduction to Machine Learning**	4
B260903T	CORE	**Design and Analysis of Algorithms**	4
B260904P	Practical-2	**Lab based on the courses B260901T to B260903T**	4
B260905R	Project	**Master's Dissertation**	4
	TOTAL		20

Semester IV

COURSE CODE	TYPE	COURSE TITLE	CREDITS
B261001T	CORE	**Cryptography & Data Privacy**	4
B261002T	CORE	**Deep Learning & Neural Networks**	4
B261003T	CORE	**SWAYAM Course**	4
B261004T B261005T B261006T B261007T	Elective-2	**Any one from DSE Courses-II** 1. Reinforcement Learning (Mathematical Approach) 2. AI in Cybersecurity & Adversarial Machine Learning 3. Natural Language Processing (NLP) & AI Applications 4. Data Mining & Warehousing	4
B261008R	Project	**Master's Dissertation / Research Thesis**	4
	TOTAL		20
	Total credits after completion of 2nd year		40+40=80

CHHATRAPATI SHAHU JI MAHARAJ UNIVERSITY, KANPUR

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PROGRAM: M.Sc. in Mathematics with Artificial Intelligence & Data Science

Discipline Specific Elective Papers (DSE-I): (Credit 04 each) (1 paper to be selected for III semester)

1. Cyber Security (4)
2. Graph Theory (4)
3. Big Data Analytics (4)

Discipline Specific Elective Papers (DSE-II): (Credit 04 each) (1 paper to be selected for IV semester)

5. Reinforcement Learning (Mathematical Approach) (4)
6. AI in Cybersecurity & Adversarial Machine Learning (4)
7. Natural Language Processing (NLP) & AI Applications (4)
8. Data Mining & Warehousing (4)

Semester I

Course Code- B260701T
Course Name- Linear Algebra (Credits: 04)
Course Objectives:

CO1: Find rank, nullity of linear transformation and its row space and column space.
CO2: Understand notion of dual space and dual of dual space.
CO3: Understand concepts of bilinear forms, adjoint operators and spectral theorem.
CO4: Find geometric and algebraic multiplicity of Eigen values and its relation with diagonalization of matrix.
CO5: Apply the above concepts to other disciplines.

Unit I:

Review of matrices and system of equations, Vector spaces, subspaces, linear dependence, basis, dimension, dual space, quotient space.

Unit II:

Algebra of linear Transformation, representation of linear transformations by matrices, eigen values and eigen vectors, invariant subspaces, annihilating polynomials, triangulation and diagonalization.

Unit III:

Primary decomposition theorem, rational and Jordan form, inner product spaces, orthonormal bases, Gram-Schmidt orthogonalization process.

Unit IV:

Linear functionals, adjoint, self adjoint, normal and unitary operators, spectral theorem for normal operators.

Reference Books:

- K. Hoffman and R. Kunze, Linear Algebra, PHI, 1996.
- S. Axler, Linear Algebra Done Right, UTM, Springer 1997.
- G.C. Cullen, Linear Algebra with Applications, Addison Wesley 1997.
- P. R. Halmos, Finite dimensional vector spaces, Springer Verlag, New York, 1987.

Course Code- B260702T

Course Name- Probability and Statistics (Credits: 04)

Course Objectives:

CO1: Find the probability of real life problems.
CO2: Understand notion of random variables.
CO3: Understand concepts of Discrete and Continuous Distributions.
CO4: Find the Correlation, Regression and Calculation of covariance.
CO5: Apply the above concepts to other disciplines.

Unit I:

Probability Functions and Moment Generating Function Basic notions of probability, Conditional probability and independence, Baye's theorem.

Unit II:

Random variables - Discrete and continuous, Cumulative distribution function, Probability mass/density functions; Mathematical expectation, Moments, Moment generating function, Characteristic function.

Unit-III:

Univariate Discrete and Continuous Distributions Discrete distributions: Uniform, Bernoulli, Binomial, Negative binomial, Geometric and Poisson; Continuous distributions: Uniform, Gamma, Exponential, Chi-square, Beta and normal; Normal approximation to the binomial distribution.

Unit-IV:

Correlation, Regression and Central Limit Theorem, Correlation coefficient, Covariance, Calculation of covariance from joint moment generating function, Independent random variables, Linear regression for two variables, method of least squares, Bivariate normal distribution, Chebyshev's theorem, Strong law of large numbers, Central limit theorem and weak law of large numbers.

Reference Books:

- Robert V. Hogg, Joseph W. McKean & Allen T. Craig (2013). Introduction to Mathematical Statistics (7th edition), Pearson Education.
- Irwin Miller & Marylees Miller (2014). John E. Freund's Mathematical Statistics with Applications (8th edition). Pearson. Dorling Kindersley Pvt. Ltd. India.
- Jim Pitman (1993). Probability, Springer-Verlag.
- Sheldon M. Ross (2014). Introduction to Probability Models (11th edition). Elsevier.
- A. M. Yaglom and I. M. Yaglom (1983). Probability and Information. D. Reidel Publishing Company. Distributed by Hindustan Publishing Corporation (India) Delhi.

Course Code- B260703T

Course Name- Artificial Intelligence (Credits: 04)

Course Objectives:

CO1: Learn the differences between optimal reasoning vs human like.

CO2: Understand basic principles of AI towards problem solving, inference perception, knowledge representation and learning.

CO3: Understand the notions of state space representation, heuristic search, time and space complexities.

CO4: Understand the applications of AI namely Intelligent Agents, Game Play, Expert Systems, Machine Learning and NLP.

CO5: Apply the above concepts to other disciplines.

Unit I:

Introduction: What is AI? Foundations of AI, History of AI, Agents and Environments, the nature of the Environment, Problem Solving Agents, Problem Formulation, Search Strategies.

Unit II:

Knowledge and Reasoning: Knowledge-based Agents, Representation, Reasoning and Logic, Prepositional logic, First-order logic, Using First-order Logic, Inference in First-order logic, forward and Backward Chaining.

Unit III:

Learning: Learning from Observations, Forms of Learning, Inductive Learning, Learning Decision Trees, Why Learning Works, Learning in Neural and Belief networks.

Unit IV:

Practical Natural Language Processing: Practical applications, Efficient parsing, scaling up the lexicon, Scaling up the Grammar, Ambiguity, Perception, Image formation, Image processing operations for Early vision, Speech recognition and Speech Synthesis.

Reference Books:

- Stuart Russell, Peter Norvig, ―Artificial Intelligence: A Modern Approach, 2nd Edition, Pearson Education, 2007.
- B. Yagna Narayana, ―Artificial Neural Networks, PHI, 2005.
- 3. E. Rich and K. Knight, ―Artificial Intelligence, 3rd Edition, TMH, 2017.
- Dan W. Patterson, ―Artificial Intelligence and Expert Systems, PHI, 2015.
- Giarrantana, Riley, ―Expert Systems: Principles and Programming, 4th Edition, Course Technology Inc, 2004.
- Ivan Bratka, ―PROLOG Programming for Artificial Intelligence, Pearson Education, 3rd Edition, 2012.

Course Code- B260704T

Course Name- Mathematics for Data Science (Credits: 04)

Course Objectives:

CO1: Understanding of the Mathematical and Logical Basis to many Modern Techniques in the Technology like Data Science, Artificial Intelligence, Machine Learning and Programming Language Design etc.

CO2: Understand the basic concepts of sets, vector space, subspace, basis and dimension.

CO3: Understand important characteristics of Matrices, Eigen Values, Eigen Vectors and Vector Spaces etc.

CO4: Learn how to analyze and solve a linear system of equations.

CO5: Check linear dependency of vectors and identify Eigen values and Eigen Vectors Derivative of Matrix, which will form the basis for Principal Component Analysis.

Unit I:

Set Theory: Binary Operations, Functions and Relations, Recurrence relations and Generating Functions, Permutations and Combinations: Pigeon Hole Principle, Prepositional Calculus, Tautology & Contradiction, Boolean Algebra, Congruence, Euler's phi function.

Unit II:

Differentiation: Logarithmic Differentiation, Partial differentiation, Euler's Theorem for Homogenous Functions, Maxima and Minima. Integration: Double Integration, Change of Order of Integration.

Unit III:

Vectors: Dot Product, Cross Product, Triple product, Scalar and Vector Fields, Vector Differentiation, Gradient, Divergence and Curl, Vector Integration.

Unit IV:

Matrices & Determinants: Matrix, Def., types, Addition, Subtraction, Multiplication of Matrices, Singular and Non-Singular Matrices, Rank of a Matrix, Solution of Simultaneous Equations, Cayley Hamilton Theorem, Eigen Values & Eigen Vectors.

Reference Books:

- Seymour Lipschutz, Marc Lipson, ―Linear Algebra, 6th Edition, Schaum Series, 2018.
- Seymour Lipschutz, Marc Lipson, H. Patil, ―Discrete Mathematics, 3rd Edition, Schaum Series, 2017.
- Elliott Mendelson, Frank Ayres, ―Calculus, 6th Edition, Schaum Series, 2012.
- Philip N. Klein, ―Coding the Matrix: Linear Algebra Through Applications to Computer Science, Newtonian Press, 2013.
- Sheldon Axler ―Linear Algebra Done Right, 3rd Edition, Springer, 2015.

B260705P Practical - 1 Lab based on the courses B260701T to B260704T
Credits:04

Semester II

Course Code- B260801T

Course Name- Numerical Analysis (Credits: 04)

Course Objectives:

CO1: To solve the algebraic and transcendental Equation.
CO2: To solve the linear system of equation using different numerical methods.
CO3: To understand the interpolation techniques.
CO4: To able to integrate the functions using Numerical Methods.
CO5: To solve the various differential equations using Numerical Methods.

Unit I:

Roots of transcendental equations and polynomial equations, Bisection method, Iteration based on first degree equations, Regula-Falsi methods, Rate of convergence, Generalized Newton- Raphson method, Computation of errors.

Unit II:

System of linear equation: Direct method-: Gauss Elimination method, Triangularization method, Iterative methods-: Jacobi's method, Gauss-Seidel method, SOR method,

Givens power method for Eigen value and Eigenvectors.

Unit III:

Interpolation and Approximation Lagrange's and Newton's divided difference, Finite difference operators, Hermite interpolation, piecewise & cubic spline interpolation, Least square approximation.

Unit IV:

Newton Cotes Quadrature formula, trapezoidal rule, Simpson's 1/3 rule, Simpson's 3/8 rule, Weddle's rule, Numerical Methods for ODE: Single step method -Euler's method, Taylor series method, Runge- Kutta method of 2nd and 4th order, Numerical methods for BVP, Multi step method-predictor- corrector method, Adams Bash forth method.

Reference Books:

- Gerald, C. Fand Wheatly, P.O, Applied Numerical Analysis", 6th edition, Wesley, 2002
- Jain, M.K, Iyengar, S.R.K and Jain, R.K, "Numerical methods for Scientific and Engineering computation, New Age Pvt. Pub, New-Delhi, 2000
- Introduction to Numerical Analysis by S.S Sastry, Prentice Hall, Flied
- Krishnamurthy, E.V & Sen, S.K, Applied Numerical analysis, East West Publication

Course Code- B260802T

Course Name- Discrete Mathematics (Credits: 04)

Course Objectives:

CO1: Have the knowledge of Fibonacci sequence, linear recurrence relations with constant coefficients.

CO2: Construct generating function and study its application to counting and in solving recurrence relations

CO3: Simplify logic and Boolean circuits using K-maps.

CO4: Find principle disjunctive & conjunctive normal forms and application of inference theory.

Unit I:

Logic: Introduction to logic, Rules of Inference, Validity of arguments, Normal forms, Direct and Indirect proofs, Proof by contradiction, Recurrence relations with examples of Fibonacci numbers, Difference equation, generating function, solution of recurrence relation using generating functions.

Unit II:

Definition and types of relations, representing relations using digraphs and matrices, closure of relations, paths in diagraph, Transitive closure using Warshall's algorithm, Posets, Hasse diagram, Lattices.

Unit III:

Boolean algebra and Boolean functions, different representations of Boolean function, application to synthesis of circuits, circuit minimization and simplification, Karnaugh map.

Unit IV:

Automata theory, Finite state automaton, Types of automaton, Deterministic finite state automaton, Non-deterministic finite state automaton, Non-deterministic finite state automaton withϵ, Equivalence of NFA and DFA, Equivalence of NFA and NFA-ϵ, Equivalence of NFA-ϵ and DFA, Finite state machines: Moore and Mealy machine and their conversion, Turing machine.

Reference Books:

- C.L Liu, Elements of Discrete Mathematics, Tata McGraw- Hill, 2000.
- Kenneth Rosen, WCB McGraw-Hill, 6th edition, 2004.
- J.P Tremblay and R.P Manohar, Discrete Mathematical structures with Application to Computer science, McGraw-Hill (1975).

Course Code- B260803T

Course Name- Operations Research (Credits: 04)

Course Objectives:

CO1: Formulate and solve the LPP including those that lead to cycling and degeneracy.
CO2: Apply integer programming to the LPP's where integer solution is sought.
CO3: Solve transportation and assignment problems and their importance.
CO4: Apply the above concepts to real life problems.
CO5: Make models using Game Theory and apply in real world.

Unit I:

Origin of OR and its definition, Phases of OR problem approach, Formulation of Linear Programming problems, Graphical solution of LPP, Solution of LPP by Simplex method, Two phase method, Big-M method, Methods to solve degeneracy in LPP.

Unit II:

Concept of duality in LPP, Comparison of solutions of Dual and Primal, Dual Simplex method, Sensitivity Analysis, Integer Programming.

Unit III:

Mathematical formulation of Transportation problem, Tabular representation, Methods to find initial basic feasible solution, Optimality test, Method of finding Optimal solution, Degeneracy in Transportation problem, Unbalanced Transportation problem, Mathematical formulation of Assignment problem, Hungarian Assignment method.

Unit IV:

Theory of Games: Introduction, Two-Person Zero-Sum Games, Saddle point, Maximin-Minimax Criteria for Optimal Strategy, Minimax Theorem, Principle of Dominance, Graphical Method, Arithmetic Method, Game without Saddle Points- Mixed Strategies, Solution of Games by LPP.

Reference Books:

- Rao, S.S, Optimization theory and applications, 2nd edition, Willey Eastern Ltd., New-Delhi.
- Hiller, F.S and Liberman, Introduction to Operations Research, 6th Ed. McGraw- Hill, International Edition, Industrial Engg. Series, 1995.
- Taha, H.A, Operations Research, An Introduction, 8thEd, Prentice Hall Publishers.
- Gupta, P.K, Hira, D.S, Operations Research, S. Chand & Company Pvt. Ltd.
- Sharma, S. D, Operations Research, Kedar Nath Ram Nath and Co. Meerut, 2002.

Course Code- B260903T
Course Name- Data Structures (Credits: 04)
Course Objectives:

CO1: Identify and apply appropriate data structures to solve problems and improve their efficiency.

CO2: Analyze and understand the complexity of data structures and associated methods.

CO3: provide an overview of data structures and algorithms commonly used in Computer Science.
CO4: solve complex problems by applying appropriate Data Structures and algorithms.
CO5: Apply the above concepts to other disciplines.

Unit – I

Linear Data Structures: Introduction – Abstract Data Types (ADT) – Stack –Queue – Circular Queue – Double Ended Queue – Applications of stack –Evaluating Arithmetic Expressions-Other Applications-Applications of Queue

Linked Lists – Singly Linked List – Circularly Linked List – Doubly Linked lists, Applications of linked list.

Unit – II

Non-Linear Data Structures: Binary Tree – expression trees – Binary tree

Traversals – Applications of Trees – Huffman Algorithm – Binary Search Tree –

Balanced Trees – AVL Tree – B-Tree – Splay Trees – Heap- Heap operations—Binomial Heaps Fibonacci Heaps- Hash set.

Unit -III

Graphs: Graphs Terminology, Graph ADT, Representations, Graph Search Methods DFS and BFS, Applications of Graphs-Minimum Cost Spanning tree Using Kruskal's algorithm, Dijkstra's algorithm for Single Source Shortest Path Problem.

Unit – IV

Algorithm Analysis – Asymptotic Notations – Divide and Conquer – Merge Sort –Quick Sort – Binary Search – Greedy Algorithms – Knapsack Problem – Dynamic Programming– Optimal Binary Search Tree –Back Tracking- N Queen's Problem.

Reference Books:

- Mark Allen Weiss,— Data Structures and Algorithm Analysis in C++", 2nd Edition,Pearson, 2004.
- M T Goodrich, Roberto Tamassia, —Data Structures and Algorithms in Java‖, 6thEdition, Wiley, 2014.
- Sartaj Sahni, —Data Structures, Algorithms and Applications in Java, 2nd Edition,Universities Press, 2005.
- M T Goodrich, Roberto Tamassia, Algorithm Design, John Wiley, 2002.

DSE Courses-I (Any One)

(Choose any one from following 1-4)

1. **Course Code- B260805T** **(Credit 04 each)**

Course Name- Cyber Security
Course Objectives:

CO1. understand the concept of security, types of attack experienced, encryption and authentication for deal with attacks
CO1. understand the concepts of Intrusion prevention, detection and firewall and attack detection and prevention.
CO3. Have the knowledge of plaintext, cipher text, RSA and other cryptographic algorithm, Key Distribution, Intrusion detection, attacks and their prevention.
CO4. Apply the above concepts to other disciplines.

Syllabus:

Unit-I: Critical characteristics of Information - NSTISSC Security Model - Components of information System - SDLC - Information assurance - Security Threats and vulnerabilities - Overview of Security threats - Security Standards.

Unit-II: Classical cryptography-symmetric Cryptography-Asymmetric Cryptography- Modern Cryptography -Access Control - DRM - Steganography - Biometrics. Cyber laws.

Unit-III: Network Security - Intrusion Prevention, detection and Management - Firewall- Ecommerce Security - Computer Forensics - Security for VPN and Next Generation Networks.

Unit-IV: Host and Application security -Control hijacking, software architecture and a Simple buffer overflow - Common exploitable application bugs, shell code -Buffer Overflow - Side-channel attacks - Timing attacks.

Unit-V: Power analysis, **c**old-boot attacks, defenses - Malware - Viruses and worms, spyware, key loggers, and botnets; defenses auditing, policy - Defending weak applications- Isolation, sandboxing, virtual machines.

Reference Books:

1. William Stallings, Cryptography and Network Security: Principles and Practice, 6th Edition, PHI, 2014.
2. Michael E. Whitman and Herbert J Mattord, ―Principles of Information Security, 6th Edition, Vikas Publishing House, 2017

2. Course Code- B260806T **(Credit 04 each)**

Course Name- Graph Theory

Course Objectives:

CO1. Students will achieve command of the fundamental definitions and concepts of graph theory.
CO2. Students will understand and apply the core theorems and algorithms, generating examples as needed, and asking the next natural question.
CO3. Students will achieve proficiency in writing proofs, including those using basic graph theory proof techniques such as bijections, minimal counterexamples, and loaded induction.
CO4. Students will work on clearly expressing mathematical arguments, in discussions and in their writing
CO5. Students will become familiar with the major viewpoints and goals of graph theory: classification, extremality, optimization and sharpness, algorithms, and duality**Unit I:**

Syllabus

Unit I (8 Lectures)
Graph and its terminology, Directed and undirected graph, Multi graph, Simple graph, Complete graph, Weighted graph, Planar and non-planar graph, Regular graph, Graph isomorphism and homeomorphism, Euler's formula, Statement and applications of Kuratowski's theorem, Path factorization of a graph, representing graphs in computer system, Coloring of graph.

Unit II (8 Lectures)
Graph connectivity, Konigsberg bridge problem, Eulerian path and Eulerian circuit, Hamiltonian path and Hamiltonian circuit, Shortest path, Dijkstra's algorithm, Paths between the vertices, Path matrix, Warshall's algorithm, Cut point, bridge, cut sets and connectivity, Menger's theorem.

Unit III (8 Lectures)
Tree and related terminology, spanning tree, Finding minimum spanning tree by Kruskal's algorithm and Prim's algorithm, in order, preorder, and post order tree traversals, Binary tree.

Unit IV (8 Lectures)
Flow network, Feasible flows, Multiple sources and multiple sinks, Cut sets in flow network, Relation between flows and cuts, Max flow problem, Max flow min-cut theorem, Matching, Covering, Introduction to CPM and PERT.

Reference Books:

- Graph Theory, F. Harary, Addison- Wesley 1969.
- Introduction to Graph Theory, D. B. West, Prentice Hall 1996.
- Graph Theory and Its Applications, Jonathan Gross and Jay Yellan, CRC 1998.

3. **Course Code- B260807T** **(Credit 04 each)**

Course Name- BIG DATA ANALYTICS
Course Objectives:

CO1. Understand Big Data and its analytics in the real world

CO2. Analyze the Big Data framework like Hadoop and

CO3. Design of Algorithms to solve Data-Intensive Problems using the Map Reduce Paradigm

CO4. Design and Implementation of Big Data Analytics using pig and spark to solve data-intensive problems and generate analytics

CO5. Implement Big Data Activities using Hive

SYLLABUS

Unit-1: Essentials of Big Data and Analytics: Data, Characteristics of data and Types of digital data, Sources of data, Working with unstructured data, Evolution, and Definition of big data, Characteristics and Need of big data, Challenges of big data; Overview of business intelligence, Data Science and Analytics, Meaning and Characteristics of big data analytics, Need of big data analytics, Classification of analytics, Challenges to big data analytics, Importance of big data analytics.

Unit-2: Hadoop: Introducing Hadoop, Need of Hadoop, limitations of RDBMS, RDBMS versus Hadoop, distributed computing challenges, History of Hadoop, Hadoop overview, Use case of Hadoop, Hadoop distributors, HDFS (Hadoop Distributed File System), Processing data with Hadoop, Managing resources and applications with Hadoop YARN (Yet Another Resource Negotiator), Interacting with Hadoop Ecosystem.

Unit-III: Mapreduce Programming: Introduction, Mapper, Reducer, Combiner, Partitioner, Searching, Sorting, Compression, Real-time applications using Map Reduce, Data serialization, and Working with common serialization formats, Big data serialization formats.

Unit-IV: HIVE: Introduction to Hive, Hive architecture, Hive data types, Hive file format, Hive Query Language (HQL), User-Defined Function (UDF) in Hive.

Unit-V: PIG: The anatomy of Pig, Pig on Hadoop, Pig Philosophy, Use case for Pig: ETL Processing, Pig Latin overview, Data types in Pig, Running Pig, Execution modes of Pig, HDFS commands, Relational operators, Piggy Bank, Word count example using Pig.

LAB WORK: Implementation of any 2-3 algorithms from each UNIT (selected by the instructor) using Python.

Reference Books:

1. Seema Acharya, Subhashini Chellappan, "Big Data Analytics", Ist Edition, Wiley, 2015.
2. Boris Lubinsky, Kevin 1. Smith, Alexey Yakubovich, "Professional Hadoop Solutions", 1st Edition, Wrox, 2013.
3. Chris Eaton, Dirk Deroos et. al., "Understanding Big data", Indian Edition, McGraw Hill, 2015.
4. Tom White, "HADOOP: The Definitive Guide", 3rd Edition, O Reilly, 2012.
5. Vignesh Prajapati, "Big Data Analytics with R and Hadoop", Ist Edition, Packet Publishing Limited, 2013.

CHHATRAPATI SHAHU JI MAHARAJ UNIVERSITY, KANPUR

STRUCTURE OF SYLLABUS FOR THE

PROGRAM: M.Sc. in Mathematics with Artificial Intelligence & Data Science

Semester III

Course Code- B260901T
Course Name- DATABASE MANAGEMENT SYSTEMS (Credits: 04)
Course Objectives:

CO1: Use the basic concepts of Database Systems in Database design.
CO2: Apply SQL queries to interact with Database.
CO3: Design a Database using ER modeling
CO4: Apply normalization on database design to eliminate anomalies.
CO5: Analyze database transactions and can control them by applying ACID properties.

Unit I:

INTRODUCTION: Introduction and applications of DBMS, Purpose of data base, Data, Independence, Database System architecture- Levels, Mappings, Database, users and DBA

DATABASE DESIGN: Database Design Process, ER Diagrams – Entities, Attributes, Relationships, Constraints, keys, extended ER features, Generalization, Specialization, Aggregation, Conceptual design with the E-R model.

Unit II:

THE RELATIONAL MODEL: Introduction to the relational model, Integrity constraints over Relations, Enforcing integrity constraints, Querying relational data, Logical database design: E-R to Relational, Introduction to views, Destroying/altering tables and views.

RELATIONAL ALGEBRA AND CALCULUS: Preliminaries, relational algebra operators, relational calculus – Tuple and domain relational calculus, expressive power of algebra and calculus.

Unit III:

SQL: Basics of SQL, DDL, DML, DCL, structure – creation, alteration, defining constraints – Primary Key, foreign key, unique, not null, check, IN operator, Functions – aggregate functions, Built-in functions – numeric, date, string functions, set operations, sub-queries, correlated sub-queries, Use of group by, having, order by, join and its types, Exist, Any, All, view and its types. Transaction control commands – Commit, Rollback, save point, cursors, stored procedures, Triggers

Unit IV:

TRANSACTIONS MANAGEMENT: Transaction concept, transaction state, implementation of atomicity and durability, concurrent executions, Serializability, recoverability, implementation of Isolation, transaction definition in SQL, testing for Serializability.

CONCURRENCY CONTROL AND RECOVERY SYSTEM: Concurrency control, lock based Protocols, time-stamp based protocols, validation based protocols, multiple granularities. Recovery System – failure classification, storage structure, recovery and atomicity, log- based recovery, Shadow paging, buffer management, failure with loss of non-volatile storage, advanced recovery techniques, remote backup systems.

OVERVIEW OF STORAGE AND INDEXING: Tree structured indexing – intuition for tree indexes,

Indexed sequential access method (ISAM), B+ Trees – a dynamic tree structure.

Reference Books:

- Raghurama Krishnan, Johannes Gehrke, Database Management Systems, 3rd edition, Tata McGraw Hill, New Delhi,India.
- Elmasri Navate, Fundamentals of Database Systems, Pearson Education,India.
- Abraham Silberschatz, Henry F. Korth, S. Sudarshan (2005), Database System Concepts, 5th Edition, McGraw-Hill, New Delhi,India.
- Peter Rob, Carlos Coronel (2009), Database Systems Design, Implementation and Management, 7th edition

Course Code- B260902T
Course Name- Introduction to Machine Learning (Credits: 04)
Course Objectives:

CO1: Explain the Bayesian concepts of and design/implement NBC & GDA as generative classifiers and Bayesian linear and logistic regression as a discriminative model.
CO2: Appreciate the importance of exponential family. Mixture models, sparse linear models, and kernels in supervised learning and apply EM, SVMS, kernels, and Gaussian processes for regression and classification tasks.
CO3: Discuss the theory of and formulate probabilistic graphical models: HMM, MRF, and CRF in order to solve real-life problem
CO4: Illustrate the mathematical theory of perception models and backpropagation algorithm and implement the models/BPA in Python
CO5: Explain the theory of and implement unsupervised machine learning algorithms: dimensionality reduction and clustering algorithms in Python.

Unit-1:

Introduction, generative models for discrete data (Bayesian concept learning, Naïve Bayes' classifier), Gaussian discriminant analysis, Inference in jointly Gaussian distributions, Bayesian statistics, Bayesian linear and logistic regression.

Unit-2:

General linear models and exponential family. Mixture models and EM algorithm, Sparse linear models, Review of SVM, Multiclass SVM, kernels for building generative models, Multiple kernels, kernels for strings, trees, and graphs, Gaussian Processes.

Unit-3:

Graphical models-DIRECTED Graphical models (Bayesian networks), Markov and Hidden Markov Models, Markov Random fields, Conditional Random fields, Neural Networks-Perception, MLP, and back propagation, Methods of acceleration of convergence of BPA.

Unit-4:

Dimensionality Reduction and Cluster Analysis: Factor analysis, Kernel PCA. Independent Component Analysis, ISOMAP, LLE, feature Selection, DBSCAN Algorithm, DENCLUE, Spectral clustering.

Reference Books:

- Kevin P. Murphy, Machine learning a Probabilistic Perspective, MIT Press, 2012
- Jeeva Jose, Introduction to Machine Learning using Python.
- Christopher Bishop, Pattern Recognition and Machine Learning, Springer, 2007
- Simon Hay kin, Neural Network a comprehensive foundation, Pearson Education-1994
- Tom Mitchell, Machine Learning – McGraw Hill Science, 1997.

Course Code- B260808T **(Credit 04 each)**
Course Name- DESIGN AND ANALYSIS OF ALGORITHMS
Course Objectives:

CO1. Identify various Time and Space complexities of various algorithms
CO2. Understand Tree Traversal method and Greedy Algorithms
CO3. Apply Dynamic Programming concept to solve various problems
CO4. Apply Backtracking, Branch and Bound concept to solve various problems
CO5. Implement different performance analysis methods for non-deterministic algorithms

SYLLABUS

UNIT - I

INTRODUCTION: Algorithm, pseudo code for expressing algorithms, performance analysis-space complexity, time complexity, asymptotic notation- big (O) notation, omega notation, theta notation and little (o) notation, recurrences, probabilistic analysis, disjoint set operations, union and find algorithms.

UNIT - II

DIVIDE AND CONQUER: General method, applications-analysis of binary search, quick sort, merge sort, AND OR Graphs.

GREEDY METHOD: General method, Applications-job sequencing with deadlines, Fractional knapsack problem, minimum cost spanning trees, Single source shortest path problem.

UNIT - III

GRAPHS (Algorithm and Analysis): Breadth first search and traversal, Depth first search and

traversal, Spanning trees, connected components and bi-connected components, Articulation points.
DYNAMIC PROGRAMMING: General method, applications - optimal binary search trees, 0/1 knapsack problem, All pairs shortest path problem, Travelling sales person problem, Reliability design.
UNIT - IV
BACKTRACKING: General method, Applications- n-queen problem, Sum of subsets problem, Graph coloring and Hamiltonian cycles.
BRANCH AND BOUND: General method, applications - travelling sales person problem, 0/1 knapsack problem- LC branch and bound solution, FIFO branch and bound solution.
UNIT - V
NP-HARD AND NP-COMPLETE PROBLEMS: Basic concepts, non-deterministic algorithms, NP-hard and NP-complete classes, Cook's theorem.

Reference Books:

1. Ellis Horowitz, Satraj Sahni, Rajasekharam (2007), Fundamentals of Computer Algorithms, 2nd edition, University Press, New Delhi.
2. R. C. T. Lee, S. S. Tseng, R.C. Chang and T. Tsai (2006), Introduction to Design and Analysis of Algorithms A strategic approach, McGraw Hill, India.
3. Allen Weiss (2009), Data structures and Algorithm Analysis in C++, 2nd edition, Pearson education, New Delhi.
4. Aho, Ullman, Hopcroft (2009), Design and Analysis of algorithms, 2nd edition, Pearson education, New Delhi.

B260904P Practical – 2 Lab based on the courses B260901T to B260903T
Credits:04

B260905R Master's Dissertation
Credits: 04

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STRUCTURE OF SYLLABUS FOR THE

PROGRAM: M.Sc. in Mathematics with Artificial Intelligence & Data Science

Semester IV

Course Code- B261001T

Course Name- Cryptography & Data Privacy (Credits: 04)

Course Objectives:

CO1: Understand fundamental concepts of cryptography.
CO2: Describe the difference among symmetric, asymmetric and public key Cryptography.
CO3: Define basic requirements of cryptography.
CO4: Apply concepts of Encryption & Decryption.
CO5: Describe the process for implementing cryptographic systems.

UNIT 1:

Introduction to cryptology: Monoalphabatic and Polyalphabatic cipher, The Shift Cipher, The Substitution Cipher, The Affine Cipher, The Vigenere Cipher, The Hill Cipher, Cryptanalysis, Some Cryptanalytic Attacks, Stream & Block ciphers, Mode of operations in block cipher.

UNIT 2:

Shannon's Theory of Perfect Secrecy: Perfect Secrecy, Random Numbers, Pseudorandom Numbers. DES & AES: The Data Encryption Standard (DES), Feistel Ciphers, Description of DES, Security analysis of DES, Differential & Linear Cryptanalysis of DES, The Advanced Encryption Standard(AES), Description of AES, analysis of AES, Prime Number Generation: Trial Division, Fermat Test, Carmichael Numbers, Miller Rabin Test

UNIT 3:

Public Key Cryptography: Principle of Public Key Cryptography, *RSA Cryptosystem*, Factoring problem, Cryptanalysis of RSA, Quadratic Residue Problem, Diffie-Hellman (DH) Key Exchange Protocol, Discrete Logarithm Problem (DLP), *ElGamal Cryptosystem*, ElGamal & DH, Algorithms for DLP. Elliptic Curve, Elliptic Curve Cryptosystem (ECC), Elliptic Curve Discrete Logarithm Problem (ECDLP).

UNIT 4:

Cryptographic Hash Functions: Hash and Compression Functions, Security of Hash Functions, Message Authentication Codes.

UNIT 5:

Digital Signatures: Security Requirements for Signature Schemes, Signature and Hash Functions, RSA Signature, ElGamal Signature, Digital Signature Algorithm (DSA), ECDSA.

Reference Books:

- Wenbo Mao, Modern Cryptography: Theory and Practice. Pearsion Education, 2004
- W Starling, Cryptography and Network security, Pearson Education, 2004.

- J Buchmann, Introduction to Cryptography, Springer (India) 2004
- D R Stinson, Cryptography: Theory and Practice. CRC Press, 2000.
- Bruce Schenier, Applied cryptography, John Wiley & Sons, 1996.
- B Forouzan, Cryptography and Network security, Tata McGraw Hill, 2011

Course Code- B261002T
Course Name- Deep Learning & Neural Networks (Credits: 04)
Course Objectives:

CO1. Understand the theoretical foundations, algorithms and methodologies of Neural Network.
CO2. Recognize the characteristics of deep learning models that are useful to solve real-world problems.
CO3. Design and develop an application using specific deep learning models.
CO4. Implement different deep learning algorithms.
CO5. Depict practical knowledge in handling and analysing real world applications.

UNIT 1:
Introduction to Deep Learning: Definition, Applications, Neural Networks, Machine Learning vs Deep Learning, Deep Learning Libraries (Tensor flow, Keras, PyTorch), Types (Supervised Learning, Unsupervised Learning, Reinforcement Learning) and their Comparison. Datasets: Numerical Data, Categorical Data, Data Quality, Data Remediation, Data Pre-processing (Dimensionality Reduction, Feature Transformation, Feature Subset Selection).

UNIT 2:
Neural Networks: Basics, Types, Intuitions, Neurons, Kernels, Biases, Weights, Initialization, Gradient Descent, Heuristics, Training (Holdout Method, K-Fold n Cross-Validation Method, Bootstrap Sampling, Lazy vs Eager Learner), Evaluation (Regression, Classification and Clustering), Perceptrons, Derivatives, Computation graph, Vectorization, Broadcasting, Propagation (Forward and Back), Parameters vs Hyper parameters.

UNIT 3:
Deep Feed Forward Network: Feed-forward Networks, Gradient-based Learning, Hidden Units, Architecture Design, Computational Graphs, Back Propagation, Regularization, Parameter Penalties, Data Augmentation, Multitask Learning, Bagging, Dropout and Adversarial Training and Optimization.

UNIT 4:

Convolution Networks: Convolution Operation, Pooling, Basic Convolution Function, Convolution Algorithm, Unsupervised Features and Neuroscientific for convolution Network. Sequence Modelling: Recurrent Neural Networks (RNNs), Bidirectional RNNs, Encoder Decoder Sequence-to-Sequence Architectures, Deep Recurrent Network, Recursive Neural Networks and Echo State networks.

Reference Books:

- Goodfellow L., Bengio Y. and CourvilleA., Deep Learning, MIT Press, 2016.
- Patterson J. and Gibson A., Deep Learning: A Practitioner's Approach, O'Reilly First Edition, 2017.
- Haykin S., Neural Network and Machine Learning, Prentice Hall Pearson Third Edition, 2009.

DSE Courses-II (Any One)

(Choose any one from following 1-4)

1. **Course Code- B261004T** **(Credit 04 each)**

Course Name- Reinforcement Learning (Mathematical Approach)
Course Objectives: CO1. Explore a computational approach to learn from the environment.

CO2. Understand key concepts and application of Reinforcement learning
CO3. Understand the theoretical background of the subject.
CO4. Use it in some practical applications.
CO5. Have an idea about different kinds of learning methods.

SYLLABUS

UNIT 1:
Introduction: Problem formulation and motivating examples, Elements of Reinforcement Learning, History of Reinforcement learning, Probability, Eigen Value, Eigen Vector, Steady State.

UNIT 2:
Evaluative Feedback n-Armed Bandit Problem, Action Value Methods, Evaluation vs. Instruction, Incremental Implementation, Tracking non-stationary problems, Problem Definition Agent-Environment Interface, Goals and rewards, Returns and Utility, The Markov Property, Value functions, Optimal value functions, Optimality and approximation.

UNIT 3:
Dynamic Programming Policy Evaluation, Policy improvement, Policy Iteration, Value Iteration, Asynchronous Dynamic Programming. Monte Carlo Methods Monte Carlo

Policy Evaluation, Estimation of Action Values, Monte Carlo Control, Incremental Implementations.

UNIT 4:
Temporal Difference Learning Classical Conditioning, TD Prediction, Optimality of TD (0), TD(Lambda), Q-Learning, Actor-Critic Method. Function Approximator Grandmother Cell Theory, Function Approximators, Perceptron-Linear Function approximator, Neural Network-Non- Linear Function Approximator, Brief of Genetic Algorithm.

Reference Books:

1. Reinforcement Learning: An Introduction, Richard S. Sutton & Andrew G. Barto.

2. Course Code- B261005T (Credit 04 each)

Course Name- AI in Cybersecurity & Adversarial Machine Learning
Course Objectives:

CO1. Understand the concept of security, types of attack experienced.
CO2. Understand the concepts of encryption and authentication to deal with attacks.
CO3. Understand the concept of Intrusion prevention detection and firewall
CO4. Apply concepts of Encryption & Decryption.
CO5. Understand the concept of attack detection and prevention.

SYLLABUS

UNIT 1:
Critical characteristics of Information - NSTISSC Security Model - Components of information System - SDLC - Information assurance - Security Threats and vulnerabilities - Overview of Security threats - Security Standards.

UNIT 2:
Classical Cryptography - Symmetric Cryptography- Asymmetric Cryptography - Modern Cryptography -Access Control - DRM - Steganography - Biometrics.

UNIT 3:
Network Security - Intrusion Prevention, detection and Management - Firewall - Ecommerce Security - Computer Forensics - Security for VPN and Next Generation Networks.

UNIT 4:

Host and Application security -Control hijacking, Software architecture and a Simple buffer overflow - Common exploitable application bugs, shellcode - Buffer Overflow - Side-channel attacks - Timing attacks, power analysis, Cold-boot attacks, defenses - Malware - Viruses and worms, spyware, key Loggers, and botnets; defenses auditing, policy - Defending weak applications - Isolation, sandboxing, virtual machines.

Reference Books:

1. William Stallings, Cryptography and Network Security: Principles and Practice, 6th Edition, PHI, 2014.
2. Michael E. Whitman and Herbert J Mattord, Principles of Information Security, 6th Edition, Vikas Publishing House, 2017.

3. Course Code- B261006T **(Credit 04 each)**

Course Name- Natural Language Processing (NLP) & AI Applications

Course Objectives:

CO1. Acquire basic understanding of linguistic concepts.
CO2. Acquire basic understanding of natural language complexity, variability.
CO3. Acquire basic understanding of machine learning techniques as applied to language.
CO4. Use Naive Bayes Probabilistic language modeling and its Applications
CO5. Implement N-grams Models

SYLLABUS

UNIT 1:

Introduction: Natural Language Processing, hands-on demonstrations. Ambiguity and uncertainty in language. The Turing test. Regular Expressions, Chomsky hierarchy, regular languages, and their limitations. Finite-state Automata, Practical regular expressions for finding and counting language Phenomena, exploring a large corpus with regex tools. An introduction to Programming in Python- Variables, numbers, strings, arrays, dictionaries, Conditionals, iteration. The NLTK (Natural Language Toolkit) String Edit Distance and Alignment Key algorithmic tool: dynamic programming, a simple Example, use in optimal alignment of sequences. String edit operations, edit Distance, and examples of use in spelling correction, and machine translation.

UNIT 2:

Context Free Grammars Constituency, CFG definition, use and limitations.
Chomsky Normal Form, Top-down parsing, bottom-up parsing, Non Probabilistic Parsing Efficient CFG parsing with CYK, another dynamic Programming algorithms. Early parser. Designing a little grammar, and parsing with it on some test data-

Examples of applications in natural language. Information Theory The ―Shannon game- motivated by language! Entropy, Cross entropy, Information gain. Its application to some language phenomena.

UNIT 3:
Language modelling and Naive Bayes Probabilistic language modeling and its Applications, Markov models, N-grams. Estimating the probability of a word, and smoothing. Generative models of language. Part of Speech Tagging and Hidden Markov Models, Viterbi Algorithm for Finding HMM Path Dynamic programming with Hidden Markov Models, and its use for part of-speech tagging, Chinese word segmentation, prosody, information Extraction, etc.

UNIT 4:
Probabilistic Context Free Grammars, Weighted context free grammars, Weighted CYK. Pruning and beam search, Parsing with PCFGs, A tree bank, The probabilistic version of CYK, how do humans parse, Experiments with Eye tracking, Modern parsers, Maximum Entropy Classifiers, The maximum Entropy principle and its relation to maximum likelihood, Maximum entropy Classifiers and their application to document classification, sentence Segmentation, and other language tasks. Maximum Entropy Markov Models& Conditional Random Fields Part-of- speech tagging.

Reference Books:
1. Jurafsky and Martin, ―Speech and Language Processing, 2nd Edition, PrenticeHall, 2008.
2. Manningand Schutze―Statistical Natural Language Processing‖, MIT Press, 2001.
3. James Allen, ―Natural Language Understanding, The Benajmins /Cummings Publishing Company, 1998.

4. Course Code- B261007T **(Credit 04 each)**
Course Name- Data Mining & Warehousing

Course Objectives:

CO1. Identify the scope and necessity of Data Mining& warehousing for the society

CO2. Describe various Data models and design methodologies of Data Warehousing destined to solve the root problems
CO3. Understand various tools of Data mining and their techniques to solve the real time problems
CO4. Analyze the data, identify the problems, and choose the relevant algorithms to apply.
CO5. Understand to assess the Pros and cons of various algorithms and analyze their behavior on real datasets.

SYLLABUS

UNIT 1:

Introduction – Steps in KDD – System Architecture – Types of Data- Data Mining functionalities- Classification of Data mining systems –Integration of data mining system with a data warehouse – Issues- Data Processing –Data Mining Application.

UNIT 2:

Data warehousing Components-Building a data warehouse-Multi Dimensional Data Model –OLAP Operation in the Multi-Dimensional Model – Three Tier Data Warehouse Architecture – Schemas for Multidimensional Data Model – Online Analytical Processing (OLAP) –OLAP vs OLTP integrated OLAM and OLAP Architecture.

UNIT 3:

Mining frequent patterns – Associations and correlations – Mining methods – Finding Frequent item set using Candidate Generation – Generating Association rules from Frequent Item sets – Mining Frequent item set without candidate Generation- Mining various kinds of association Rules – Mining Multi level Association rule- Mining Multi-Dimensional Association Rule- Mining Correlation analysis- Constraint based association mining.

UNIT 4:

Mining Classification and prediction – Issues regarding Classification and Prediction – Classification by Decision Tree Induction –Bayesian classification Naïve Bayesian Classification - Linear Regression frequent patterns – Associations and correlations- Cluster analysis – Types of data in Cluster Analysis-Social Impacts of Data Mining- Recent trends in Data Mining.

Reference Books:

1. Sandy Ryza, Uri Laserson, Sean Owen, Josh Wills, Advanced Analytics with Spark: Patterns for Learning from Data at Scale‖, Oreilly, 2015.

CHHATRAPATI SHAHU JI MAHARAJ UNIVERSITY, KANPUR

STRUCTURE OF SYLLABUS FOR THE

PROGRAM: M.Sc. in Mathematics with Artificial Intelligence & Data Science

B261008R Master's Dissertation / Research Thesis
Credits: 04