Draft Model Curriculum for 3yr./4yr. Degree Course with Apprenticeship Embedded Degree program

B.A/B.Sc in Mathematics with Double Major in Computing

Higher Education Department
Government of Odisha

Under National Education Policy 2020

Semester	Course (paper)	Course Name	Credit
Semester I	MJ -1.1	Calculus & Analytic Geometry	4
	MJ -1.2	Introduction to Algebra & Number Theory	4
	MJ -1.3	Real Analysis-I	4
	MJ- 1.4	Algebra-I	4
	MJ -2.1	Programming and Data structures with Lab	4
	AEC (Ability Enhancement Courses)	English: Business communication	4
	VAC (Value Added Course)	Environmental Studies & Disaster Management	3
		TOTAL	**27**
Semester II	MJ 1.5	Probability	4
	MJ 1.6	Differential Equations-I	4
	MJ 1.7	Linear Algebra	4
	MJ- 1.8	Real Analysis-II	4
	MJ 2.2	Computer organization and operating system	4
	AEC (Ability Enhancement Courses)	English: Word and Presentation skill	4
	VAC (Value Added Course)	Good Citizenship / **or any other discipline**	3
		TOTAL	**27**
Semester III	MJ 1.9	Complex Analysis-I	4
	MJ 1.10	Algebra-II	4
	MJ 1.11	Statistical Methods -Add	4
	MJ- 1.12	Differential Equations-II	4
	MJ 2.3	Designing and Analysis of Algorithm with Lab	4
	MJ -2.4	Data management system with Lab	4
	MDC (Multidisciplinary Course)	Discreate Mathematics/**or any other discipline**	3
	SEC (Skill Enhancement Course)	Analytical thinking and logical reasoning / **or any other discipline**	3
		TOTAL	**30**
Semester IV	MJ -1.13	Numerical Analysis & Scientific Computing	4
	MJ- 1.14	Multivariable Calculus	4
	MJ- 1.15	Real Analysis-III	4
	MJ -2.5	Computer network and software engineering	4
	MJ -2.6	AI & Machine Learning with Lab	4

	MDC (Multidisciplinary Course)	Optimization techniques/ **or any other discipline**	3
	SEC (Skill Enhancement Course)	IOT with lab **or any other discipline**	3
		TOTAL	**26**
Semester V	**Internship/Apprenticeship/Industry Training**		**20**
Semester VI	**Internship/Apprenticeship/Industry Training**		**20**
TOTAL			**150**

**** The 4yr. program of AEDP shall be as per 3 yr./4yr. UG Degree Program under NEP-2020***

Programme Outcome

- To prepare the students for a career in Mathematics.
- To prepare the students for Higher Education and Research in Mathematics.
- To develop a conceptual understanding of the subject and to develop an inquisitiveness in the subject.
- To enable the student to acquire basic skills necessary to understand the subject and to master the skills to handle equipment's utilized to learn the subject.
- To generally promote wider reading on the subject and allied inter disciplinary subject.

Major I **Credit 04**

1.1 Calculus & Analytic Geometry

Course Objective:

The main emphasis of this course is to equip the student with necessary analytic and technical skills to handle problems of mathematical nature as well as practical problems. More precisely, main target of this course is to explore the different tools for higher order derivatives to plot the various curves and to solve the problems associated with differentiation and integration of vector functions.

Learning Outcomes:

After completing the course the student will be able to

- Trace a curve and find asymptotes.
- Talculate integrals of typical type using reduction formulae, etc.
- Calculate arc length, surface of revolution and know about conics
- Calculate triple products, gradient divergence, curl, etc.

Unit I

Hyperbolic functions, higher order derivatives, Leibnitz rule and its applications to problems of the type $e^{ax+b}sinx$, $e^{ax+b}cosx$, $(ax+b)^n sinx$, $(ax+b)^n cosx$, concavity and inflection points, asymptotes, curve tracing in Cartesian coordinates, tracing in polar coordinates of standard curves, L'Hospital rule, application in business, economics and life sciences.

Unit II

Riemann integration as a limit of sum, integration by parts, reduction formulae, derivations and illustrations of reduction formulae of the type $\int sin^n x dx$,$\int cos^n x dx$,$\int tan^n x dx$,$\int sec^n x dx$, $\int (log x)^n dx$,$\int sin^n x cos^n x dx$, definite integral, integration by substitution.

Unit III

Volumes by slicing, disks and washers methods, volumes by cylindrical shells, parametric equations, parameterizing a curve, arc length, arc length of parametric curves, area of surface of revolution, techniques of sketching conics, reflection properties of conics, rotation of axes and second degree equations, classification into conics using the discriminant, polar equations of conics.

Unit IV

Triple product, introduction to vector functions, operations with vector-valued functions, limits and continuity of vector functions, differentiation, partial differentiation, div, curl and integration of vector functions, tangent and normal components of acceleration.

Books Recommended:

- ✓ *H. Anton, I. Bivens and S. Davis: Calculus,10th Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.*
- ✓ *Shanti Narayan, P. K. Mittal: Differential Calculus, S. Chand, 2014.*
- ✓ *R. J. T Bell: An elementary Treatise on coordinate geometry, MacMillan and Company Limited, 2005.*

Books for Reference:

- ✓ *James Stewart: Single Variable Calculus, Early Transcendental, 8th edition, Cengage Learning, 2016.*
- ✓ *G.B. Thomas and R. L. Finney: Calculus, 9th Ed., Pearson Education, Delhi, 2005.*
- ✓ *M. J. Strauss, G. L. Bradley and K. J. Smith: Calculus, 3rd edition, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2007.*
- ✓ *Suggested digital platform: NPTEL/SWAYAM/MOOCs.*
- ✓ *e-Learning Source http://ndl.iitkgp.ac.in ; http://ocw.mit.edu ; http://mathforum.org*

Major I **Credit 04**

1.2 Introduction to Algebra & Number Theory

Course Objectives:

- To present a systematic introduction to number theory and a basic course on algebra.

Learning Outcomes:

After completing the course the student will be able to

- Understand the equivalence relations and concept of group with different examples.
- Understand the properties of cyclic groups, rings, and integral domain.
- Know divisibility and division algorithm and find *gcd* using Euclidean Algorithm.
- Solve linear Diophantine equations, find least common multiples, solve linear congruence applying the Chinese remainder theorem.

Unit I

Integers and equivalence relations**,** properties of integers, modular arithmetic, mathematical inductions, equivalence relations, Introduction to groups**,** symmetries of a square, the dihedral groups, definitions and examples of groups, elementary properties of groups, subgroups, examples of subgroups.

Unit II

Cyclic groups, properties of cyclic groups, classification of subgroups of cyclic groups, definitions and examples of normal subgroups, Introduction to rings, definition and examples of rings, properties of rings, subrings, definition and examples of integral domain and fields.

Unit III

Divisibility**,** division algorithms, prime and composite numbers, Fibonacci and Lucas numbers, Fermat numbers, greatest common divisor, Euclidean algorithm.

Unit IV

Fundamental theorem of arithmetic, least common multiple, linear Diophantine equations, congruence, linear congruence, Chinese remainder theorem, Wilson's theorem, Fermat little theorem, Euler's theorem.

Books Recommended:

- ✓ *Joseph A. Gallian, Contemporary Abstract Algebra (4th Edition), Narosa Publishing*

House, New Delhi, 1999.(IX Edition 2010).

- ✓ *Thomas Koshy, Elementary Number Theory with Applications (2nd Edition), Academic Press, 2007.*

Books for Reference:

- ✓ *I. N. Herstein: Topics in Algebra, Wiley Eastern Limited, India, 1975.*
- ✓ *David M. Burton: Elementary N u m b e r Theory (6th Edition), Tata McGraw-Hill Edition, Indian Reprint, 2007.*
- ✓ *Suggested digital platform: NPTEL/SWAYAM/MOOCs.*
- ✓ *e-Learning Source http://ndl.iitkgp.ac.in ; http://ocw.mit.edu ; http://mathforum.org.*

1.3 Real Analysis-I

Course Objective:

The objective of the course is to introduce the basics of real number system and the properties of sequence and series of real numbers. The ideas of completeness, least upper bound property, denseness, limit, continuity and uniform continuity will also be introduced. This is one of the core courses essential to start doing mathematics.

Learning Outcomes:

On successful completion of this course, students will be able to

- Learn basics of real number system and test countability of a set.
- Know on sequence of real numbers and their basic properties.
- Test convergence of an infinite series.
- Find limit and continuity of functions and test uniform continuity of functions.

Unit I

Finite and infinite sets, countable and uncountable sets, examples, algebraic and order Properties of R, uncountability of R, completeness property of **R,** applications of the supermom property, Intervals, nested interval property, denseness of rationals in R.

Unit II

Sequence and their limits, limit theorems, monotone sequences, monotone Convergence theorem, subsequences, divergence criteria, monotone subsequence theorem, Bolzano Weierstrass theorem for sequences, Cauchy sequence, Cauchy's convergence criterion.

Unit III

Infinite series, convergence and divergence of infinite series, Cauchy criterion, Tests for convergence: comparison test, limit comparison test, ratio test, Cauchy's nth root test, Raabe's test, integral test, alternating series, Leibniz test, absolute and conditional convergence.

Unit IV

Limits of functions, limit theorems, some extensions of limit concept, continuous functions and their combinations, continuous functions on intervals, boundedness theorem, maximum minimum theorem, intermediate value theorem, uniform continuity, examples, uniform continuity theorem.

Books Recommended:

- ✓ *R. G. Bartle and D. R. Sherbert, Introduction to Real Analysis, 3rd Edn., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.*
- ✓ *G. Das and S. Pattanayak, Fundamentals of Mathematical Analysis, TMH Publishing Co., 30th reprints, 2021.*

Books for Reference:

- ✓ S. *C. Mallik and S. Arora, Mathematical Analysis, New Age International Publications.*
- ✓ *A. Kumar, S. Kumaresan, A basic course in Real Analysis, CRC Press, 2014.*
- ✓ *Brian S. Thomson, Andrew. M. Bruckner, and Judith B. Bruckner, Elementary Real Analysis, Prentice Hall, 2001.*
- ✓ *Gerald G. Bilodeau , Paul R. Thie, G. E. Keough, An Introduction to Analysis, Jones & Bartlett, Second Edition, 2010.*
- ✓ *e-Learning Source http://ndl.iitkgp.ac.in ; http://ocw.mit.edu ; http://mathforum.org*
- ✓ *Suggested digital platform: NPTEL/SWAYAM/MOOCs.*

1.4 Algebra-I

Course Objectives:

To present a systematic and rigorous study on algebraic structures like groups, rings and some important results with their applications. After pursuing this course, one can opt for advanced topics in groups, rings and their applications to

problems in physics, computer science and engineering.

Learning Outcomes:

After completing this course, students will able to

- Understand permutation groups with some results and application in Rubik's cube.
- Understand the concept of homomorphisms, isomorphisms, normal subgroups and factor groups.
- Explore more properties of rings and ideals rigorously.
- Get introduced to the concept of reducibility and irreducibility of polynomials and concept of unique factorization domain.

Unit I

Permutation groups, definition and notations, cyclic notation, properties of permutations, isomorphisms, definition and examples, Cayley's theorem, properties of isomorphisms, automorphisms, cosets, properties of cosets, Lagrange's theorem and consequences, an application of cosets to permutation groups, an application of cosets to Rubik's cube.

Unit II

External direct products, definition and examples, properties of external direct products, the group of units modulo n as an external direct product, applications, normal subgroups, factor groups, application of factor groups, internal direct products, group homomorphisms, definition and examples, properties of homomorphisms, the first isomorphism theorem.

Unit III

Characteristic of a ring, ideals, factor rings, prime ideals and maximal ideals, ring homomorphisms, definition and examples, the field of quotients, polynomial rings, notations and terminology, division algorithm and consequences.

Unit IV

Factorization of polynomials, reducibility test, irreducibility test, unique factorization in Z[x], divisibility in integral domains, irreducible, primes, unique factorization domain, Euclidean domain.

Books Recommended:

- ✓ *Joseph A. Gallian, Contemporary Abstract Algebra (9th Edition), Narosa Publishing House, New Delhi, 2010.*
- ✓ *I. N. Herstein, Topics in Algebra, Wiley Eastern Limited, India, 1975.*

Books for Reference:

- ✓ *John B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.*
- ✓ *D. S. Dummit, R. M. Foote, Abstract Algebra, Wiley-India edition, 2013.*
- ✓ *Joseph 1. Rotman, An Introduction to the Theory of Groups, 4th Ed., Springer Verlag, 1995.*
- ✓ *M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.*
- ✓ *Suggested digital platform: NPTEL/SWAYAM/MOOCs.*
- ✓ *e-Learning Source http://ndl.iitkgp.ac.in ; http://ocw.mit.edu ; http://mathforum.org*

Major II **Credit 04**

2.1 Programming and Data Structures with Lab

Objective: The objective of the course is to learn the basics about C and C++ programming languages such as variables, data types, arrays, pointers, functions and classes etc. It also covers the concept of linear data structures like linked list, stack and queue.

Expected Outcome:

On successful completion of the course, students should have a good understanding about the concept of C, object-oriented programming using C++ and be able to write basic C and C++ code. Students can also implement the linked list, stack and queue using both C and C++.

Unit I: Programming in C: Programming methodology, overview of C, Lexical elements, syntax rules, basic data types, operators, expressions, flow of control, function definitions, conditional execution, loops.

Unit II: One-dimensional array, two-dimensional arrays, sparse matrix, recursion, pointers, strings, preprocessor, file input/ output.

Unit III: Introduction to C++, variables and constant declarations, expressions, input using the extraction operator >> and cin, output using the insertion operator << and cout, Preprocessor directives, increment (++) and decrement(--) operators, operators, if-else statement, switch and break statements, loops, Continue statement, nested control statement. Functions, arrays.

Unit-IV: Data Structures: ADTs, linear data structures, linked list, stacks and queues, applications. Lab Work: Execution of simple programmes using C and C++.

Recommended Texts:

1. Brian W. Kernighan and Dennis M. Ritchie: The C Programming Language.

2. Bruce Eckel: Thinking in C++.

3. Byron S. Gottfried: Theory and Problems of Programming with C.

4. A. Kelly, I. Pohl, A book on C, Pearson Education, 2000.

5. D. S. Malik: C++ Programming Language, Course Technology, Cengage Learning, India Edition, 2009.

AEC Paper I

English: Business Communication

Credits: 4

S. No	Modules	Outcomes
1.	**English Language and Communication: Introduction**	• Communication, its Importance and Factors • Types of Communication • Verbal and Non-verbal Communication • Styles of Communication
2	**English Language and Communication: Listening and Speaking**	• Types of Listening • Speaking to communicate effectively • Style of speaking in Various Situations • English Pronunciation
3	**English Language and Communication: Reading and Writing**	• Reading methods and techniques. • Reading texts to Understand meaning • Writing Process • Writing short and Long texts
4	**English Language and Communication: Grammar and Vocabulary**	• Grammar • Sentence structure • Functions of Language

Reference Book: A Course book for ENGLISH COMMUNICATION (Publisher: Orient BlackSwan)

VAC Paper I

Environmental Studies & Disaster Management

(Credit-3)

Unit 1: Multidisciplinary nature of environmental studies (8 Period)

Definition, scope and importance

Need for public awareness

Environmental Pollution

Definition

• Cause, effects and control measures of:-

a) Air pollution

b) Water pollution

c) Soil pollution

d) Marine pollution

e) Noise pollution

f) Radiation pollution

Unit 2: Natural Resources: (8 Period)

Renewable and non-renewable resources:

Natural resources and associated problems.

a) Forest resources: Use and over-exploitation, deforestation, case studies. Timber extraction, mining, dams and their effects on forest and tribal people.

b) Water resources: Use and over-utilization of surface and ground water, floods, drought, conflicts over water, dams-benefits and problems.

c) Mineral resources: Use and exploitation, environmental effects of extracting and using mineral resources, case studies.

d) Food resources: World food problems, changes caused by agriculture and overgrazing, effects of modern agriculture, fertilizer-pesticide problems, waterlogging, salinity, case studies.

e) Energy resources: Growing energy needs, renewable and non-renewable energy sources, use of alternate energy sources. Case studies.

Biodiversity:- Introduction-Definition; Biogeographically classification of India

India as a mega diversity nation. Hot sports of biodiversity, Threats to biodiversity. Endangered and endemic species of India. Conservation of biodiversity. In Situ and Ex-so conservation of biodiversity

Unit-3: Disaster Management (8 Period)

1. Disaster Management: Types of disasters (natural and Man-made) and their causes and effect)

2. Vulnerability Assessment and Risk analysis: Vulnerability to various disasters (Flood, Cyclone, Earthquake, Heat waves, Desertification and Lighting)

3. Institutional Framework: Institutional arrangements for disaster management (National Disaster Management Authority (NDMA), State Disaster Management Authority (SDMA), Disaster Management Act, 2005, District Disaster Management Authority (DDMA), National Disaster Response Force(NDRF) and Odisha Disaster Rapid Action Force(ODRAF)

4. Preparedness measures: Disaster Management cycle, Early Warning System, Pre Disaster and Post-Disaster Preparedness, strengthening of SDMA and DDMA, Community Preparedness for flood cyclone, heat waves, fire safety, lightening and snake biting. Stake holders participation, Corporate Social Responsibility (CSR)

5. Survival Skills: Survival skills adopted during and after disaster (Flood, Fire, Earthquake, Cyclone and Lightening), Disaster Management Act-2005, Compensation and Insurance

Unit 4: Social Issues and the Environment (6 Period)

A. a) Environmental Ethics: Issues and possible solutions.

b) Climate change, global warming, acid rain, ozone layer depletion, nuclear accidents and holocaust. Case studies

c) Environment Protection Act

d) Air (Preservation Control of Pollution) Act

e) Water (Preservation Control of Pollution) Act

f) Wildlife Protection Act

g) Forest Conservation Act

h) Solid waste management Cause, effect and Control Measure of Urban and Industrial waste (Role of each individual in conservation of Natural resources and prevention of pollution)

B. Human Population and the Environment

Population Ecology: Individuals, species, population, community

Human population growth, population control method

Urbanisation and its effect on society

Unit 5: Field work (15 Periods of 30 hrs)

- Visit to an area to document environmental assets: river/forest/flora/fauna, etc.
- Visit to a local polluted site- Urban/Rural/Industrial/Agricultural
- Study of common plants, insects, birds and basic principles of identification.
- Study of simple ecosystems-pond, river, Delhi Ridge , etc.

Semester-II

Major I **Credit 04**

1.5 Probability

Course Objective:

The objective of the course is to make the student understand basics of probability which is of use in everyday life.

Learning Outcomes:

After completing the course the student will be able to

- Learn the basics of probability and random variables with axioms of probability.
- Know the discrete and continuous distributions and learn how to calculate mean, variance and moments of them.
- Learn on limit theorems with their applications and know about the conditional expectations.
- Learn on Markov chains and their applications.

Unit I

Sample space and events, probability axioms, probability defined on events, conditional probabilities, Independent events, Bayes formula, real random variables, discrete and continuous random variables, probability distribution function, probability mass/density functions, mathematical expectation, and properties, variance and standard deviation.

Unit II

Discrete distributions: uniform, binomial, Poisson, geometric, negative binomial, continuous distributions: uniform, normal, exponential, their expectations and variance, moments, moment generating function, characteristic function and computation of these for the distributions, joint distribution function and its properties, joint probability density functions, marginal and conditional distributions, independent random variables.

Unit III

Limit theorems: Markov inequality, Chebyshev's inequality, statement and interpretation of (weak) law of large numbers and strong law of large numbers, application to problems, conditional probability and conditional expectation, discrete case, continuous case, applications, expectation of function of two random variables, conditional expectations, bivariate normal distribution, correlation coefficient, joint moment generating function and calculation of covariance, linear regression for two variables.

Unit IV

Central limit theorem for independent and identically distributed random variables with finite variance, Markov chains, Chapman-Kolmogorov equations, classification of states, Gambler Ruin problem.

Book Recommended

1. *Sheldon Ross, Introduction To Probability Models (9th Edition), Academic Press, Indian Reprint, 2007.*
2. *Robert V. Hogg, Joseph W. Mckean And Allen T. Craig, Introduction To Mathematical Statistics, Pearson Education, Asia, 2007.*
3. *Kai Lai Chung, Elementary Probability Theory With Stochastics Process, Springer International Students Edition, (Narosa Publ.)*

Book for Reference

- ✓ *Alexander M. Mood, Franklin A. Graybill and Duane C. Boes, Introduction to the Theory of Statistics, (3rd Edition), Tata McGraw- Hill, Reprint 2007.*
- ✓ *Chow Y S , Teicher H Probability theory Springer International edition*
- ✓ *Irwin Miller and Marylees Miller, John E. Freund's Mathematical Statistics with Applications (7th Edition), Pearson Education, Asia, 2006.*
- ✓ *e-Learning Source http://ndl.iitkgp.ac.in ; http://ocw.mit.edu ; http://mathforum.org*
- ✓ *Suggested digital platform: NPTEL/SWAYAM/MOOCs.*

Major I **Credit 04**

1.6 Differential Equations-I

Course Objective:

Differential Equations introduced by Leibnitz in 1676 models almost all Physical, Biological, Chemical systems in nature. The objective of this course is to familiarize the students to various methods of solving differential equations, partial differential equations and to have a qualitative applications through models. The students have to solve problems to understand the methods.

Learning Outcomes:

After completing the course the student will be able to

- Get the idea to solve first order linear ordinary differential equations of different types those are arising in physical problems.
- Get the idea to solve second order linear ordinary differential equations of different types those are arising in physical problems.
- Get basic ideas of first order partial differential equations, its formulation in two, three variables and variable separable method for identify the solutions.
- Get idea to solve various mathematical models of ODEs and PDEs which may be helpful for simulation process.

Unit I

Differential equations and mathematical models, general, particular, explicit, implicit and singular solutions of a differential equation, exact differential equations and integrating factors, separable equations and equations reducible to this form, linear equations and Bernoulli's equation, compartmental model, population model for single species.

Unit II

General solution of homogeneous equation of second order, principle of superposition, Wronskian, its properties and applications, method of undetermined coefficients, method of variation of parameters, linear homogeneous and non-homogeneous equations of higher order with constant coefficients, Euler's equations.

Unit III

Partial Differential Equations - Basic concepts and definitions, origin of first order PDEs, Classification of first order PDEs, Pfaffian differential forms and equations, solution of Pfaffian differential equations in three variables, Cauchy's problem for first order PDEs, linear equations of first order, integral surfaces passing through a given curve, Cauchy's method of characteristics, compatible systems, method of separation of variables for solving first order and second order partial differential equations.

Unit IV (Practical)

The students will implement the following problems in the computer Lab using *Matlab / Mathematica / Maple* etc.

1. Plotting of second order solution family of differential equations.
2. Plotting of third order solution family of differential equations.
3. Population growth model (exponential case only).
4. Population decay model (exponential case only).
5. Solution of Cauchy problem for first order PDEs.
6. Finding the characteristics for the first order PDEs.
7. Plot the integral surfaces of a given first order PDE with initial data.

Books Recommended:

- ✓ *J. Sinha Roy and S. Padhy: A course of Ordinary and Partial differential equations, Kalyani Publishers, New Delhi,2018.*
- ✓ *Belinda Barnes and Glenn R. Fulford, Mathematical Modeling with Case Studies, A Differential Equation Approaching Maple and Matlab, 2nd Edn. Taylor and Francis group, London and New York, 2009.*
- ✓ *Sneddon; Elements of Partial Differential Equations, McGraw-Hill, International Students Edition, 1957.*

Books for Reference:

- ✓ *G. F. Simmons, Differential equation, Tata McGraw Hill, 1991.*
- ✓ *J. N. Sharma and Kehar Singh, PDE for Engineers and Scientists, Narosa, New Delhi, 2009.*
- ✓ *Martin Braun, Differential Equations and their Applications, Springer International Student Ed.1978.*
- ✓ *S. L. Ross, Differential Equations, 3rd Edition, John Wiley and Sons, India, 2014.*
- ✓ *C.Y. Lin, Theory and Examples of Ordinary Differential Equations, World Scientific, 2011.*
- ✓ *Suggested digital platform: NPTEL/SWAYAM/MOOCs.*

1. e-Learning Source http://ndl.iitkgp.ac.in ; http://ocw.mit.edu ; http://mathforum.org

Major I **Credit 04**

1.7 Linear Algebra

Course Objective:

The objective of this course is to acquaint students with matrix operations, solution of system of equations, vector spaces and linear transformations. In addition, the student will learn about eigenvalues, diagonalization, canonical forms, etc., which has many applications in almost all areas of science and engineering.

Learning Outcomes: After completing the course the student will be able to

- Determine basis and the dimension of a finite-dimensional vector space, know the relation between rank and nullity of a linear transformation.
- The relation between matrix and linear transformation.
- To find solution of system of linear equations, compute eigenvalues, eigenvectors of a matrix and linear transformation.
- About orthogonality of vectors and application of it to different form of matrix, introduced to different operators.

Unit I

Vector spaces, subspaces, span of a set, more about subspaces, linear dependence, independence, product and quotient space, dimension and basis, linear transformations, range and kernel of a linear map, rank and nullity of linear map.

Unit II

Inverse of linear transformation, consequences of rank – nullity theorem, the space L(U, V), composition of linear maps, matrix associated with linear map, linear map associated with matrix, rank and nullity of a matrix, determinant minors and rank of a matrix, transpose of a matrix and special type of matrices, elementary row operations

Unit III

System of linear equations, matrix inversion, application of determinant to linear equations, eigenvalues and eigenvectors, similarity of matrices, invariant subspaces, minimal polynomial (eigenvalues and the minimal polynomial), upper triangular matrices, diagonalizable operators (diagonal matrices, conditions for diagonalizability).

Unit IV

Inner product space: inner products and norms, orthonormal bases, orthogonal complements, self-adjoint and normal operators, spectral theorems, isometries, unitary operators, characteristic polynomial, Cayley – Hamilton theorem, Jordan form, trace, quadratic form, application to reduction of quadrics.

Books Recommended:

- ✓ *V. Krishnamurthy. V.P. Mainra, J. L. Arora, An introduction to linear algebra, Affiliated East – West press Pvt. Ltd., New Delhi, 1976.*
- ✓ *Sheldon Axler, Linear algebra done right (Fourth edition),Springer, 2024.*

Books for References:

- ✓ *Seymour Lipschutz and Marc Lars Lipson, Linear Algebra (Schaum's outlines, Fourth Edition), McGraw Hill, New York, 2009.*
- ✓ *A. Ramachandra Rao and P. Bhimsankaram, Linear Algebra (Second Edition), Hindustan Book Agency, 2000.*
- ✓ *Stephen H. Friedberg, Arnold J. Insel, Lawrence E. Spence, Linear Algebra (Fourth Edition), Prentice-Hall of India Pvt. Ltd., New Delhi, 2004.*
- ✓ *Gilbert Strang, Linear Algebra and its Applications, Thomson, 2007.*
- ✓ *S. Kumaresan, Linear Algebra- A Geometric Approach, Prentice Hall of India, 1999.*
- ✓ *Suggested digital platform: NPTEL/SWAYAM/MOOCs.*
- ✓ *e-Learning Source http://ndl.iitkgp.ac.in ; http://ocw.mit.edu ; http://mathforum.org ; https://linear.axler.net; and https://library.oapen.org/handle/20.500.12657/85067*

Major I **Credit 04**

1.8 REAL ANALYSIS-II

Course Objective:

As a second course in real analysis, the objective is to learn on the concept of differentiation, Riemann Integration and their applications. The series of functions and the improper integrals have also been introduced.

Learning Outcomes: After completing the course the student will be able to

- Learn working out problems on derivatives of function and their applications.
- Learn about Riemann Integration and their properties including Improper Integrals.
- Learn on pointwise and uniform convergence of power series.
- Learn to calculate value of improper integrals.

Unit I

Differentiability of a function at a point and in an interval, Caratheodory's theorem, algebra of differentiable functions, relative extrema, interior extremum theorem. Rolle's theorem, Mean value theorems, Cauchy's mean value theorem, Lagrange mean value theorem, intermediate value property of derivatives, Darboux's theorem, applications of mean value theorem, Taylor's theorem and applications.

Unit II

Riemann integration: partitions, conditions of integrability, definition of Riemann integral properties of the Riemann integral, Riemann integral as limit of a sum, mean value theorem for integrals, integration by parts, Fundamental theorems of calculus, Taylor theorem with remainder.

Unit III

Pointwise and uniform convergence of sequence of functions, Cauchy criterion for uniform convergence and Weierstrass M-test, uniform convergence and continuity, term by term integration and differentiation of a series, power series, Abel's theorem, Weierstrass approximation theorem, Taylor series

Unit IV

Improper integrals, integration of unbounded functions with finite limits of integration, comparison tests of convergence, infinite range of integration, integrand as product of functions convergent at infinity, absolutely convergent integral,tests of convergence, convergence of Beta and Gamma functions, applications.

Books Recommended:

- ✓ *R.G. Bartle D.R. Sherbert, Introduction to Real Analysis, John Wiley and Sons (Asia) Pvt. Ltd., Singapore*
- ✓ *G. Das and S. Pattanayak, Fundamentals of Mathematics Analysis, TMH Publishing Co.*
- ✓ *S. C. Mallik and S. Arora, Mathematical Analysis, New Age International Ltd., New Delhi.*

Book for Reference:

- ✓ *K. A. Ross, Elementary Analysis: The theory of Calculus, Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.*
- ✓ *Charles G. Denlinger, Elements of Real Analysis, Jones and Bartlett (Student Edition), 2011.*
- ✓ *A. Kumar, S. Kumaresan, A basic course in Real Analysis, CRC Press, 2014*
- ✓ *e-Learning Source http://ndl.iitkgp.ac.in ; http://ocw.mit.edu ; http://mathforum.org*
- ✓ *Suggested digital platform: NPTEL/SWAYAM/MOOCs.*

Major II **Credit 04**

2.2 Computer Organization & Operating System

Course Objectives:

This course will discuss the basic concepts of computer architecture and organization that can help the students to have a clear view as to how a computer system works. Starting from the basics, the students will be introduced to the state-of-the-art in this field. Operating System is a computer software that manages the hardware components. It acts as an intermediary between the users and the hardware. It is responsible for managing the system resources and providing a smooth working environment for the users.

Expected Outcomes:

This course will address all the fundamental points, starting from the foundations to the architectural issues to correlation with existing commercial operating systems. Students shall learn process management, processor management, memory management, storage management, user management, protection and security. As a subject, it is an amalgamation of the fields like computer architecture, and operating system. A course on operating systems is essential to equip the students for taking up the challenges in understanding and designing of computer systems.

Computer Organization

Unit-I:

Introduction to computer architecture, Instruction set, Instruction set principles and trade offs, Computer arithmetic, ALU design, Assessing computer system performance, Amdahl's Law.

Unit-II:

Pipelining, Pipeline control, pipeline hazards, Basics of caching, Cache mapping, virtual memory, Main memory, Disks and buses, Interfacing Input/ output devices to the memory, processor and operating system.

Operating System

Unit-III:

Process Management (Processes, CPU Scheduling, critical section problem, semaphore, Dead lock-prevention and avoidance & detection & recovery)

Unit-IV:

Storage Management (Memory management- paging & segmentation, virtual memory, file system interface), I/ O system, secondary - storage structure, protection and security. Case study of UNIX/ LINUX system.

Recommended Texts:

- ✓ *J. L. Hennessy, and D. A .Patterson, Computer Organization: The Hardware/Software Interface, Morgan Kaufman Publishers 1994.*
- ✓ *J. L. Hennessy, and D. A .Patterson, Computer Architecture: A Quantitative Approach, Morgan Kaufman Publishers 1990.*
- ✓ *Silberschatz & P. B. Galvin, Operating System concepts, John Wiley.*
- ✓ *P. C. Bhatt, An Introduction to operating systems, PHI.*

AEC Paper II

English: Word and Presentation skill

Credits: 4

S. No	Modules	Outcomes
1.	**Basic Communication**	● Explain: ○ Structures in present and present continuous tense ○ Structures in past & past continuous tense ○ Structure in present perfect & present perfect continuous tense ○ Structures in future tense ○ Modals: helping verbs ○ Prepositions ○ Idioms ● Practice speech on a given topic. ● Practice Extempore speech
2	**Communication**	● Describe communication. ● Describe the Process of communication. ● Discuss the Importance of communication ● Explain various Types of communication. ● Demonstrate Useful Phrases for Everyday Use ● Explain the technique of Asking Questions
3	**Hotel English**	● Describe the Essential qualities of a good speaker. ● Discuss Speech improvement- pronunciation. ● Explain the importance of Stress in speech. ● Describe Intonation and modulation. ● Describe Common phonetics- difficulties

VAC Paper I

Good Citizenship

Credits:3

Objectives/Learning Goals of the Course

- Development of good human being and a responsible citizen
- Developing a sense of right and wrong leading to ethically correct behavior.
- Inculcating a positive attitude and a healthy work culture.

Learning Objectives:

- Understanding Basic Values of Indian Constitution.
- Understand how to be a patriot.
- Develop professionalism and understand the ethics relating to various professions.

1. **Indian Constitution (1 Credit= 15 hours)**

   Salient Values of Preamble: Sovereign, Socialist, Secular, Democratic, Republic, Justice, Liberty, Equality and Fraternity

2. **Patriotism (1 Credit= 15 hours)**

   Patriotic Value and ingredients of nation building, Concept of Good Citizenship, Emotional connection with the country, Duties of citizens and Qualities of good citizens

3. **Work Ethics (1 Credit= 15 hours)**

   Punctuality, Cleanliness, Law abidingness, Rational Thinking and Scientific Temper

Semester-III

Major I **Credit 04**

1.9 Complex Analysis-I

Course Objectives:

The objective of the course is to introduce the theories for functions of a complex variable. The concepts of analyticity and complex integration and its applications, are discuss in detail. This course is prerequisite to many other advance analysis courses such as advanced complex analysis, geometric functions, theory, potential theory, theory of entire and meromorphic functions, etc.

Learning Outcomes:

After completing the course the student will be able to

- Understand the geometric aspects of complex numbers system, convergence of series of complex numbers.
- Understand the significance of complex differentiability, analyticity and construction of analytic functions from given harmonic functions.
- Relate the notion of line integral, Cauchy fundamental theorems on integrals and its applications.
- Classify the nature of singularities, properties of zeros and poles and be able to know the applications of residue theorem.

Unit I

Basic properties of complex number and, Stereographic projection, power series, absolute convergence, uniform convergence, Cauchy-Hadamard formula for the radius of convergence, circle of convergence, exponential, logarithmic, sine and cosine functions for complex numbers.

Unit II

Continuity and differentiability of a complex valued function, analytic function, necessary and sufficient conditions for analytic functions, Cauchy-Riemann equations (Cartesian and polar form), harmonic and conjugate harmonic functions, construction of analytic function (Milne-Thomson's method).

Unit III

Line integral, path independence, complex integration, Green's theorem, anti-derivative

theorem, Cauchy-Goursat theorem, Cauchy integral formula, Cauchy's inequality, derivative of analytic function and its generalizations, Liouville's theorem, Morera's theorem, Taylor's and Laurent's theorem, expansion of analytical function in Taylor and Laurent series.

Unit IV

Zeroes of an analytic function, singularities of complex functions and its classifications, residues, Cauchy's residue theorem, residue at infinity, residues at poles and its examples, maximum modulus theorem.

Books Recommended:

- ✓ *Elias M. Stein & Rami Shakarchi: Complex Analysis, Princeton University press, Princeton and Oxford, 2003.*
- ✓ *Joseph Bak and Donald J. Newman: Complex analysis (3rd Edition), Undergraduate Texts in Mathematics, Springer-Verlag, NewYork, 1997.*

Books for Reference:

- ✓ *S. Ponnusamy and Herb Silverman: Complex variables with Applications: Birkhauser, (2006) (Indian Edition 2012).*
- ✓ *H. A. Priestly: Introduction to Complex Analysis, Oxford University Press, 2008.*
- ✓ *Donald Sarason: Complex Function Theory: AMS, Second Edition, 2007.*
- ✓ *James Ward Brown and Ruel V.Churchill: Complex Variables and Applications (Eighth Edition), McGraw-Hill International Edition, 2009.*
- ✓ *Suggested digital platform: NPTEL/SWAYAM/MOOCs*
- ✓ *e-Learning Source http://ndl.iitkgp.ac.in ; http://ocw.mit.edu ; http://mathforum.org*

1.10 Algebra-II

Course Objectives:

To present a systematic study on finite abelian groups, Sylow's theorems and Modules.

Learning Outcomes:

After completing the course the student will be able to

- Know on finite abelian groups, the class equation and Sylow's theorems.
- Know on applications of Sylow's theorems and test the simplicity of groups.
- Learn on group action, composition series, nilpotent groups and solvable groups.
- Solve problems in modules and related results.

Unit I

Fundamental theorem of finite abelian groups, isomorphism classes of abelian groups, proof of the fundamental theorem, Sylow's theorems, conjugacy classes, the class equation, Sylow's first theorem, Cauchy theorem, Sylow's second and third theorems.

Unit II

Application of Sylow's theorem, finite simple groups, non-simplicity tests, the simplicity of alternating group A_5, free groups, classification of groups of order up to 15, characterization of dihedral groups.

Unit III

Group actions and permutation representations, composition series and holder programs, nilpotent groups, solvable groups.

Unit IV

Introduction to modules, definition and examples, direct sum, free modules, quotient modules, homomorphisms, simple modules, modules over PIDs.

Books Recommended:

- ✓ *Joseph A. Gallian, Contemporary Abstract Algebra (4th Edition), Narosa Publishing House, New Delhi, 1999.(IX Edition 2010).*
- ✓ *D. S. Dummit, R. M. Foote, Abstract Algebra, Wiley-India edition, 2013.*
- ✓ *C. Musili, Introduction to Rings and Modules, Narosa Publishing House.*

Books for Reference:

- ✓ *John B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.*
- ✓ *N. Herstein, Topics in Algebra, Wiley Eastern Limited, India, 1975.*
- ✓ *M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.*
- ✓ *S. Nanda, Topics in Algebra, Allied Publishers, New Delhi.*
- ✓ *Suggested digital platform: NPTEL/SWAYAM/MOOCs*
- ✓ *e-Learning Source http://ndl.iitkgp.ac.in; http://ocw.mit.edu; http://mathforum.org*

Major I **Credit 04**

1.12 Differential Equations-II

Course Objective:

The objective of this course is to understand basic methods for solving nonlinear first order ordinary differential equations and existence of solutions along with some special type of second order ordinary differential equations of mathematical physics. Also, students will be exposed to second order partial differential equations arising in thermal physics and thermodynamics.

Learning Outcomes:

After completing the course the student will be able to

- Understand first order nonlinear ordinary differential equations and existence of solutions
- Learn the methods to find solutions of second order linear ordinary differential equations with constant coefficients and variable coefficients.
- The different methods for solving first and second order partial differential equations and can take more courses on wave equation, heat equation, diffusion equation, gas dynamics, nonlinear evolution equations etc. All these courses are important in engineering and industrial applications for solving boundary value problems.
- Get idea to solve various mathematical models of ODE and PDE which may be helpful for simulation process.

Unit I

Existence and Uniqueness of Solutions: Lipschitz condition, Gronwall type inequality, successive approximations, Picard's theorem, non-uniqueness of solutions, continuation and dependence on initial conditions, existence of solutions in the large.

Unit II

Solution of second order ODE with constant coefficients, power series solutions of ordinary and singular points, and special functions of Legendre's differential equations, Bessel's differential equations and their properties.

Unit III

Charpit's method, special types of first order PDE, Jacobi's method, Linear second order PDE, canonical forms of second order PDE and characteristics curves, one dimensional wave equation, its origin and elementary solutions, vibration of an infinite string, vibration of a semi finite string, vibration of a string of finite length, existence of unique solution.

Unit IV (Practical)

Laboratory work for the following problems using *MATLAB / Mathematica / Maple* etc.

1) Plot the Fourier series of the following functions:

i. $f(x) = x^2, x \in [-1, 1]$

ii. $f(x) = \begin{cases} 1, & 0 < x < \pi \\ -1, & -\pi < x < 0 \end{cases}$

iii. $f(x) = \sin x, \ \ 0 < x < \frac{\pi}{2}$

2) Solution of wave equation $\frac{\partial^2 u}{\partial t^2} - c^2 \frac{\partial^2 u}{\partial x^2} = 0$ for the following associated conditions:

(i) $u(x,0) = \varphi(x), u_t(x,0) = \sigma(x), x \in \mathbb{R}, t > 0$

(ii) $u(x,0) = \varphi(x), u_t(x,0) = \sigma(x), u(0,t) = 0 \ x \in (0,\infty), t > 0$

(iii) $u(x,0) = \varphi(x), u_t(x,0) = \sigma(x), u_x(0,t) = 0 \ x \in (0,\infty), t > 0$

(iv) $u(x,0) = \varphi(x), u_t(x,0) = \sigma(x), u(0,t) = 0, \ u(l,t) = 0, \ 0 < x < l, t > 0$

3) Solution of one dimensional heat equation $\frac{\partial u}{\partial t} - k \frac{\partial^2 u}{\partial x^2} = 0$ for the following conditions

(i) $u(x,0) = \varphi(x), u(0,t) = a, u(l,t) = b, 0 < x < l, t > 0$

(ii) $u(x,0) = \varphi(x), x \in \mathbb{R}, 0 < t < T$

(iii) $u(x,0) = \varphi(x), u(0,t) = a, x \in (0,\infty), t \geq 0.$

Books Recommended:

- ✓ *Deo and Raghavendra, Text Book of Ordinary Differential Equations, Tata McGraw-Hill Pub. Company Ltd, New Delhi,2017.*
- ✓ *Simmons G F, Differential equation, Tata McGrawHill,1991.(Ch-5. 28-30, Ch-8. 44-47, Ch-6, 33-36)*
- ✓ *I. Sneddon, Elements of Partial Differential Equations,McGraw-Hill, International Students Edition.(Ch-2. 10,11,13; Ch-3. 4-7; Ch-5. 1,2), 2006.*
- ✓ *Tyn Myint-U and Lokenath Debnath, Linear Partial Differential Equations for Scientists and Engineers, 4th edition, Birkhauser, Indian reprint,2014.*

Books for Reference:

- ✓ *J. N. Sharma and Kehar Singh, PDE for Engineers and Scientists, Narosa, New Delhi,2009.*
- ✓ *T Amarnath, An Elementary Course in Partial Differential Equations, Narosa Publications, 2003.*
- ✓ *Martin Braun, Differential Equations and their Applications, Springer International Student Ed. 1978.*
- ✓ *S. L. Ross, Differential Equations, 3rd Edition, John Wiley and Sons, India, 2014.*
- ✓ *C.Y. Lin, Theory and Examples of Ordinary Differential Equations, World Scientific, 2011.*
- ✓ *e-Learning Source http://ndl.iitkgp.ac.in ; http://ocw.mit.edu ;* http://mathforum.org
- *Suggested digital platform: NPTEL/SWAYAM/MOOCs*

Major II **Credit 04**

2.3 Design and Analysis of Algorithms with Lab

Objectives:

To understand the importance of algorithm and its complexity. To analyze the complexity of an algorithm in terms of time and space complexities. To design and implement various programming paradigms and its complexity.

Course Outcome:

Ability to analyze the time and space complexity, given an algorithm. Apply the techniques of algorithm in solving real world problems. Systematic development of an algorithm for solving a problems.

Unit I:

Data structures: Binary trees, binary search trees, heaps, sets and disjoint sets union, graphs (representation, BFS, DFS).

Unit-II:

Algorithms: The role of algorithms in computing, Introduction to design and analysis of algorithms, functions. Asymptotic notations, recurrences. Divide and conquer: (Heap sort, Quick sort, Lower bounds for sorting, counting sort, FFT, Strassen's matrix multiplications).

Unit-III:

Dynamic programming: (Matrix Chain Multiplication, Floyd Warshall algorithm, Longest common subsequence), Greedy method: Fractional knapsack problem, (Huffman codes, Kruskal and Prim's algorithm for finding minimum spanning tree, Dijkstra's algorithm).

Unit-IV:

Backtracking (8-queens problem, sum of subsets), Max flow, min cuts, Ford Fulkerson method, string matching (Rabin-Karp algorithm), NP-Completeness and approximation algorithms. Lab Work: Implementation of the algorithms using C or C++.

Recommended Texts:

- ✓ *Dexter Kozen, Algorithms, Springer Verlag, 1992.*
- ✓ *Thomas H. Cormen, Charles E. Leiesersen, Ronald L. Rivest, Introduction to Algorithms, MIT press, 2000.*
- ✓ *Jon Kleinberg and Eva Tardos, Algorithm Design, Pearson/ Addison-wesley, 2006.*
- ✓ *E. Horowitz, S. Sahni, and S. Rajasekharan, Fundamental of Computer Algorithms, Galgotia Publications, 2002.*
- ✓ *Aho, J. Hopcroft and J. Ullman: Data Structures and Algorithms.*
- ✓ *T. A. Standish: Data Structure Techniques, Addison Wesley*

Major II **Credit 04**

2.4 Database Management System with Lab

Course Objectives:

At the end of the course, the students will be able to: Understand the basic concepts and the applications of database systems. Master the basics of SQL and construct queries using SQL. Understand the relational database design principles. Familiar with the basic issues of transaction processing and concurrency control. Familiar with database storage structures and access techniques.

Expected Outcomes:

After completing this course the student must demonstrate the knowledge and ability to: Demonstrate the basic elements of a relational database management system.Identify the data models for relevant problems. Design entity relationship and convert entity relationship diagrams into RDBMS and formulate SQL queries on the respect data into RDBMS and formulate SQL queries on the data. Demonstrate their understanding of key notions of query evaluation and optimization techniques. Extend normalization for the development of application software's.

Unit-I:

Overview of database systems, Introduction to database design, The relational model, Relational algebra and calculus, SQL (queries, constrains, Triggers).

Unit-II:

Overview of storage and indexing, storing data - disks & files, Tree - structured indexing, overview of query evaluation, Evaluating relational operators, A typical relational query optimizer, schema refinement,

Unit-III:

Functional dependencies, Normal forms, Physical database design and tuning, security and authorization.

Unit-IV:

Laboratory work SQL 30

Recommended Texts:

- ✓ R. Ramakrishnan and J. Gehrke - Database Management Systems - MC Grawhill - 3rd Edition 2003.
- ✓ Elmarsi, Navathe: Fundamentals of Database System, Addison Wesley.
- ✓ Silberschata, H. Korth, S. Sudarshan, Database System Concepts, Mc Grawhill.

Semester IV

Major I **Credit 04**

1.13 Numerical Analysis & Scientific Computing

Course Objectives:

The objective of this course is to acquaint the students with a wide range of numerical methods to solve algebraic and transcendental equations, linear system of equations, interpolation and curve fitting problems, numerical integration, initial and boundary value problems, etc. Develop adequate skills to apply those methods in real world problems.

Learning Outcomes:

After completing the course the student will be able to

- Understand the errors in computation, find the roots of algebraic and transcendental equations, familiarize with convergence, advantages and limitations of those numerical techniques, learn to apply Gauss−Jacobi, Gauss−Seidel methods to solve system of linear equations.
- Get aware of using interpolation techniques to solve polynomials.
- Learn numerical differentiation and integrations by using different techniques.
- Understand the techniques to find approximate solutions of ODE and PDE.

Unit I

Errors in approximation, absolute, relative and percentage errors, round-off error, solution of algebraic and transcendental equations: bisection method, Regula-Falsi method, secant method, method of iteration, Newton Raphson method, order of convergence, systems of simultaneous equations: Gauss elimination method, Gauss Jordon method, LU decomposition method, Iterative methods: Jacobi method and Gauss-Seidel method.

Unit II

Finite differences, interpolation techniques for equal intervals-Newton forward and backward, Gauss forward, Gauss backward, interpolation, interpolation with unequal intervals-Newton's divided difference method, Lagrange method, Hermite interpolation,

Numerical differentiation using Newton forward and backward formulae, numerical integration using Newton-Cotes formulas, trapezoidal rule, Simpson rules, Gauss-Legendre, Gauss-Chebyshev formulas.

Unit III

Solution of ordinary differential equations: Taylor series method, Picard's method, Euler method, Euler modified method, Runge–Kutta methods.

Unit IV (Practical)

Practical / Lab work to be perform in Computer Lab:

Use of computer algebra system (CAS) software: Python/ Sage Math / Mathematica/ MATLAB/ Maple/ Maxima/ Scilab/ R or any other (open source) software etc., for developing at least the following numerical programs:

1. Bisection method, Newton-Raphson method and Secant method.
2. LU decomposition method.
3. Gauss−Jacobi method and Gauss−Seidel method.
4. Lagrange interpolation and Newton interpolation.
5. Trapezoidal rule and Simpson's rules.
6. Taylor series method, Picard's method, Euler method, Euler modified method and Runge−Kutta Methods.

Note: ***Non-programmable scientific calculator is allowed in the examination.***

Books Recommended:

- ✓ *M. K. Jain, S. R. K. Iyengar & R. K. Jain: Numerical Methods for Scientific and Engineering Computation, New Age International Publisher, India, 2016.*
- ✓ *R. K. Gupta: Numerical Methods: Fundamentals and Applications, Cambridge University Press, 2019.*

Books for Reference:

- ✓ *Brian Bradie: A Friendly Introduction to Numerical Analysis. Pearson Education India. Dorling Kindersley (India) Pvt. Ltd. Third impression, 2011.*
- ✓ *Curtis F. Gerald & Patrick O. Wheatley: Applied Numerical Analysis, Pearson Education. India, 2007.*
- ✓ *S. D. Conte & S. de Boor: Elementary Numerical Analysis: An Algorithmic Approach, 1980.*
- ✓ *Suggested digital platform: NPTEL/SWAYAM/MOOCs*
- ✓ *e-Learning Source http://ndl.iitkgp.ac.in ; http://ocw.mit.edu ; http://mathforum.org*

Major I **Credit 04**

1.14 Multivariable Calculus

Course Objectives:

The primary objective of this course is to introduce students, the extension of the studies of single variable differential and integral calculus to functions of two or more independent variables with the geometry and visualization of curves and surfaces. To aware the students about the techniques multiple integrations and higher order derivatives.

Learning Outcomes:

After completing the course the student will be able to

- Learn the concept of limit, continuity and differentiations of functions of more than one.
- Understand the maximization and minimization of multivariable functions with the given constraints on variables.
- Learn about inter-relationships amongst the line integral, double, and triple integral formulations.
- Familiarize with the Green's, Stokes' and Gauss divergence theorems and their applications.

Unit I

Functions of several variables, limit and continuity of functions of two variables: partial differentiation, total differentiability, sufficient condition for differentiability, chain rule for one and two independent parameters, directional derivatives, the gradient, maximal and normal property of the gradient, tangent planes.

Unit II

Extrema of functions of two variables, method of Lagrange multipliers, constrained optimization problems, double integration over rectangular region, double integration over non rectangular region, double integrals in polar co-ordinates.

Unit III

Triple integrals, triple integral over a parallelepiped and solid regions, volume by triple integrals, cylindrical and spherical co- ordinates, change of variables in double integrals and triple integrals.

Unit IV

Definition of vector field, divergence and curl, line integrals, applications of line integrals: mass and work, fundamental theorem for line integrals, conservative vector fields, independence of path, Green's theorem, surface integrals, integrals over parametrically defined surfaces. Stokes' theorem, the divergence theorem.

Books Recommended:

- ✓ *M. J. Strauss, G. L. Bradley and K. J. Smith: Calculus, 3rd Edition, Dorling Kindersley (India) Pvt. Ltd. Pearson Education, Delhi, 2007.*
- ✓ *E. Marsden, A. J. Tromba and A. Weinstein: Basic Multivariable Calculus, Springer Student International Edition, Indian reprint, 2005.*

Book for References:

- ✓ *S. C. Mallik and S. Arora: Mathematical Analysis, New Age International Publications, New Delhi, 2005.*
- ✓ *Tom Apostol: Mathematical Analysis, Narosa Publishing House, 2002.*
- ✓ *G. B. Thomas and R. L. Finney: Calculus, 9th Ed., Pearson Education, Delhi, 2005.*
- ✓ *Suggested digital platform: NPTEL/SWAYAM/MOOCs.*
- ✓ *e-Learning Source http://ndl.iitkgp.ac.in ; http://ocw.mit.edu ; http://mathforum.org*

Major I **Credit 04**

1.15 Real Analysis-III

Course Objective:

After a first course in real analysis in undergraduate program, the ideas of uniform continuity, uniform convergence and approximation by polynomials are crucial in analysis. In addition to the functions of bounded variation and their integrators, the student has to learn differentiating functions from R^n to R^m. The techniques of integration of a function with respect to another function and the basic ideas of finding a Fourier series are also included.

Learning Outcomes:

After completing the course the student will be able to

- Find the Fourier series of a function.
- Calculate Riemann Stieltjes integrals and know whether a function is of bounded variation or not.
- Learn how to define derivatives on R^n including the existence of partial derivatives, inverse function theorem and implicit function theorem.
- Learn about metric spaces and their topological properties.

Unit I

Basic concepts of Fourier series, Fourier series of even and odd functions, half range series, Fourier series on other intervals, orthogonal systems of functions, theorem on best approximation, properties of Fourier coefficients, Riesz-Fisher theorem, Riemann-Lebesgue lemma, Dirichlet integral, Integral representation for the partial sum of a Fourier series, convergence of Fourier series.

Unit II

Function of bounded variation, examples, total variation, function of bounded variation expressed as difference of increasing functions, rectifiable paths, Riemann-Stieltjes integrals, properties and techniques, necessary and sufficient condition for existence of the integral, mean value theorem for Riemann-Stieltjes integrals, reduction to Riemann integrals.

Unit III

Differentiation in R^n, partial derivatives, directional derivatives, sufficient condition for differentiability, chain rule, , mean value theorem, Jacobians, contraction mapping principle, inverse function theorem, implicit function theorem, rank theorem, differentiation of integrals, Taylor theorem in many variables.

Unit IV

Metric spaces, definitions and examples, open and closed sets, interior and exterior points, convergence and completeness, continuity and uniform continuity, compactness, connectedness.

Books Recommended:

- ✓ *W. Rudin, Principles of Mathematical Analysis, McGraw Hill, 3rd edition.*
- ✓ *T. Apostol, Mathematical Analysis, Pearson, 2nd edition.*
- ✓ *S C Malik and Savita Arora, Mathematical Analysis- New Age International, 5th edition*

Books for Reference:

- ✓ *Terrence Tao, Analysis-I, Hindustan book agency.*
- ✓ *Terrence Tao, Analysis-II, Hindustan book agency*
- ✓ *K. A. Ross, Elementary Analysis: The theory of Calculus, Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.*
- ✓ *Charles G. Denlinger, Elements of Real Analysis, Jones and Bartlett, Student Edition, 2011.*
- ✓ *Suggested digital platform: NPTEL/SWAYAM/MOOCs*
- ✓ *e-Learning Source http://ndl.iitkgp.ac.in ; http://ocw.mit.edu ; http://mathforum.org*

Major II **Credit 04**

2.5 Computer Network and Software Engineering

Objectives:

To introduce the concept, terminologies, and technologies used in modern data communication and computer networking. To identify importance of OSI and TCP/IP models. To make students to get familiarized with different protocols and network components. Able to analyze the concept of local area networks, their topologies, protocols and applications. Be able to evaluate the performance of competing network technologies and protocols. Develop an ability to use the techniques, skills, and modern engineering tools and processes necessary for software engineering.

Course Outcomes: Illustrate the working principle of different protocols at different layers. The student installs and configures workstations, servers and networked printers, inter networking devices such as switches and routers. Analyze the requirements for a given organizational structure and select the most appropriate networking architecture and technologies. Practice and building the skills of subnetting and routing mechanisms. To be familiar with contemporary issues in networking technologies, network tools and network programming. Allow the student to gain expertise in some specific areas of networking such as the design and maintenance of individual networks. Analyze, specify and design the topological and routing strategies for an IP based networking infrastructure. Specify and identify deficiencies in existing protocols, and then go onto formulate new and better protocols. Develop an ability to apply software engineering perspective through software design and construction, requirements analysis, verification, and validation, to develop solutions to modern problems such as security, data science, and systems engineering.

Computer Networks

Unit I: Introduction, Network models, Physical layer (Signals, digital and analogue transmission, Multiplexing, circuit switching), Data Link Layer (Error detection and correction, Data link control and Protocols, PPP, Local area networks, connecting LANS, Cellular telephone and satellite network), Network Layer (Host-to-host delivery - inter networking, addressing, and routing), Network layer protocols),

Unit-II: Transport Layer (Process to process Delivery : VDP and TCP, Congestions control and quality of service), Application Layer (Client server models, Domain name system, SMTP, FTP, HTTP and WWW), Security (Cryptography, Manage security, user authentication and key management).

Software Engineering

Unit III: Introduction, Software life cycle modules, Requirements Analysis and specification, software design, Function oriented software design. Coding and Testing, Software reliability and quality management, Computer Aided Software Engineering, Software maintenance. Introduction to object oriented Analysis and Design, Iterative Development and the unified process, case study-The next-Gen POS, Inception, Understanding Requirements, Use case Model, Identifying other requirements, Elaboration, Use case Model.

Unit-IV: Drawing system sequence diagrams, Visualizing concepts, Adding Associations, Adding attributes, Adding details with operation contracts, Interaction diagram notation. PATTERNS, GRASP, Creating design class diagrams, GOF Design pattern Planning and project queues comments on iterative development and the UP, Rational Unified Process.

Textbook:

- ✓ Crag Larman: Applying UML and Patterns-An introduction OOAP & D and the Unified process, Pearson Education Asia.
- ✓ Rajib Mail: Fundamentals of software Engineering, PHI.

Recommended Texts:

- ✓ *B. A. Forouzan- Data Communications and Networking, TMH, 3rd Edition, 2004.*
- ✓ *S. Tanenbaum, Computer Networks, Prentice Hall 3. W. Stallings, Computer Networking with Internet Protocols and Technology Prentice Hall*

Major II **Credit 04**

2.6 AI and Machine Learning with Lab

Objectives:

1. Differentiate between supervised, unsupervised machine learning approaches
2. Ability to choose appropriate machine learning algorithm for solving a problem
3. Design and adapt existing machine learning algorithms to suit applications
4. Understand the underlying mathematical relationships across various machine learning algorithms
5. Design and implement machine learning algorithms to real world applications

Expected Outcomes:

Upon successful completion of this course students will able to understand the concepts and can implement simple and multiple linear regression, Logistic regression, Linear discriminate analysis, Ridge regression, Cross-validation and boot strap, Fitting classification and regression trees, K-nearest neighbours, Principal component analysis and K-means clustering algorithm.

Unit-I: Linear Methods for Regression and Classification: Overview of supervised learning, Linear regression models and least squares, Multiple regression, Multiple outputs, Subset selection, Ridge regression, Lasso regression, Linear Discriminant Analysis, Logistic regression, Principal Component Analysis.

Unit-II: Model Assesment and Selection: Bias, Variance, and model complexity, Bias-variance trade off, Estimate of In-sample prediction error, Effective number of parameters, Bayesian approach and BIC, Cross- validation, Boot strap methods, conditional or expected test error.

Unit-III: Additive Models, Trees, and Boosting: Generalized additive models, Regression and classification trees, Boosting methods-exponential loss and AdaBoost, Random forests and analysis.

Unit-IV: Neural Networks(NN), Support Vector Machines(SVM), and K-nearest Neighbor: Fitting neural networks, Back propagation, Issues in training NN, SVM for classification, Reproducing Kernels, SVM for regression, K-nearest –Neighbour classifiers, clustering and K-means.

Lab work

Implementation of following methods using Python or R:

Simple and multiple linear regression, Logistic regression, Linear discriminate analysis, Ridge regression, Cross-validation and boot strap, Fitting classification and regression trees, K-nearest neighbours, Principal component analysis, K-means clustering.

Recommended Texts:

- ✓ *Trevor Hastie, Robert Tibshirani, Jerome Friedman, The Elements of Statistical Learning-Data Mining, Inference, and Prediction, Second Edition , Springer Verlag, 2009.*
- ✓ *G. James, D. Witten, T. Hastie, R. Tibshirani-An introduction to statistical learning with applications in R, Springer, 2013.*
- ✓ *E. Alpaydin, Introduction to MachineLearning, Prentice Hall Of India, 2010*