INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Mathematics

1. **Subject Code:** MA-101 **Course Title:** Introduction to Mathematical Sciences

2. **Contact Hours: L:** 2 **T:** 0 **P:** 0

3. **Examination Duration (Hrs): Theory:** 02 **Practical:** 0

4. **Relative Weightage: CWS:** 20–35 **MTE:** 20-30 **PRS:** 0 **ETE:** 40-50 **PRE:** 0

5. **Credits:** 02 6. **Semester:** Autumn 7. **Subject Area:** PCC

8. **Pre Requisite:** Nil

9. **Objective:** To provide introductory knowledge to the students about mathematical sciences, commonly used terminologies and history of mathematics.

10. **Detail of Course:**

S. No.	Topics	No. of Lectures
1.	**Ancient Mathematics:** Development of Mathematics in Egypt and Mesopotamia, Development of Hindu-Arabic Number System, Works of Aryabhatta and Brahmagupta, Development of Algebra: Polynomial equations.	09
2.	**Mathematics in Medieval Period:** Introduction to the work of Pythagoras and Archimedes, Axiomatic System of Geometry: Euclidean Geometry, Mathematical logic and proof (direct, indirect and method of contradiction), Axiomatic Structure.	09
3.	**Modern Mathematics:** Development of Calculus and Differential equations, Prime numbers, and Fundamental theorem of Arithmetic, Introduction to the work of Descartes and Fermat, Introduction to the work of Srinivasa Ramanujan.	10
	Total	**28**

11. **Books Recommended:**

S. No.	Name of Books/Authors/Publishers	Year of publication
1.	T. Gowers, The Princeton Companion to Mathematics, Princeton University Press.	2008
2.	R. Courant, H. Robbins and I. Stewart, What is Mathematics? An elementary approach to ideas and methods, Oxford University Press, Oxford.	1996
3.	K. Devlin, Introduction to Mathematical Thinking, Lightning Source Inc California.	2011
4.	Carl B. Boyer and Uta C. Merzbach, A History of Mathematics, Wiley.	2011

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Mathematics

1. **Subject Code:** MA-102 **Course Title**: Elementary Real Analysis
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 03 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 04 6**. Semester:** Spring 7**. Subject Area:** PCC
8. **Pre-requisite:** Nil
9. **Objective:** To introduce the basic concepts of real analysis.
10. **Details of the Course:**

S. No.	Contents	Contact hours
1.	Real number system, ordering, bounded sets, order completeness axiom, mathematical induction, well ordering principle; Archimedean property, complete ordered field, limit point of a set, Bolzano-Weierstrass theorem, open and closed sets, compact sets and Heine-Borel theorem.	10
2.	Sequences and convergence, Cauchy's first and second limit theorems, Cauchy sequences, Cauchy criterion for convergent sequences, bounded and monotonic sequences, Euler's constant, subsequences, limit superior and limit inferior. Series and tests for its convergence.	8
3.	Limit and continuity, uniform continuity, monotonic functions, functions of bounded variation, absolutely continuous functions, Taylor's theorem (finite form), Lagrange's form of remainder.	8
4.	Sequences and series of real valued functions, their point-wise, absolute and uniform convergence, Cauchy's general principle of uniform convergence, continuity of the limit (sum) function, differentiation and integration of the sequences and series of functions, Weierstrass approximation theorem.	9
5.	Riemann integration, Darboux's theorem, necessary and sufficient conditions for integrability, functions defined by integrals, fundamental theorem of calculus, first and second mean value theorems of integral calculus.	7
	Total:	**42**

11. **Suggested Books:**

S. No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	Rudin. W., Principles of Mathematical Analysis**,** 3rd Ed. McGraw Hill Education.	2017
2.	Goldberg, R. R., Methods of Real Analysis, Oxford and IBH Publishing Company Pvt. Ltd.	2020
3.	Robert G. Bartle, Donald R. Sherbert, Introduction to Real Analysis, John Wiley & Sons, Inc.	2010
4.	Royden. H. L. and Fitzpatrick. P.M., Real Analysis, 4th Ed. Pearson.	2022
5.	Apostol, T. M., Mathematical Analysis, 2nd Ed. Narosa Publishing House.	2002
6.	Lang. S., Real and Functional Analysis, Springer-Verlag.	1993

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Mathematics

1. **Subject Code:** MA -103 **Course Title**: Introduction to Computer Programming
2. **Contact Hours:** **L:** 3 **T:** 0 **P:** 2
3. **Examination Duration (Hrs.):** **Theory:** 03 **Practical:** 00
4. **Relative Weightage:** **CWS:** 10-25 **PRS:** 25 **MTE:** 15-25 **ETE:** 30-40 **PRE:** 0
5. **Credits:** 04 6**. Semester:** Autumn 7. **Subject Area:** PCC
8. **Pre-requisite:** Nil
9. **Objective:** To provide basic knowledge of computer programming in C++.
10. **Details of the Course:**

S. No.	Contents	Contact hours
1.	**Computer Fundamentals**: Introduction to computer systems; number system, integer, signed integer, fixed and floating point representations; IEEE standards, integer and floating point arithmetic; CPU organization, ALU, registers, memory, the idea of program execution at micro level.	7
2.	**Basic Programming in C++**: Input/output; Constants, variables, expressions and operators; Naming conventions and styles; Conditions and selection statements; Looping and control structures (while, for, do-while, break and continue); Arrays; File I/O, header files, string processing; Pre-processor directives ; Compiling and linking.	10
3.	**Programming through functional decomposition**: Design of functions, void and value returning functions, parameters, scope and lifetime of variables, passing by value, passing by reference, passing arguments by constant reference, recursive functions; Function overloading and default arguments; Library functions.	10
4.	**Pointers**: Pointers; Dynamic data and pointers, dynamic arrays.	3
5.	**Object Oriented Programming Concepts**: Data hiding, abstract data types, classes, access control; Class implementation-default constructor, constructors, copy constructor, destructor, operator overloading, friend functions; Object oriented design (an alternative to functional decomposition) inheritance and composition; Dynamic binding and virtual functions; Polymorphism; Dynamic data in classes.	12
	Total	**42**

11. **List of Practicals:**

S. No.	
1.	Number systems
2.	Use of constants, variables, expressions and operators; Naming conventions and styles
3.	Conditional statements and Arrays
4.	File input and output, pre-processor directives
5.	Functional decomposition
6.	Recursive functions, overloading
7.	Pointers
8.	Object Oriented Programming: Classes and abstract data types
9.	Constructors and destructors
10.	Operator overloading
11.	Friend functions and virtual functions

12. **Suggested Books:**

S. No.	**Authors/Name of Books/Publisher**	**Year of Publication/Reprint**
1.	B. Stroustrup. The C++ Programming Language. Addison-Wesley, 3rd edition.	1997
2.	S. Prata. C++ Primer Plus. Sams, 5th edition.	2004
3.	R. Lafore. Object-Oriented Programming in C++. Pearson, 4th edition.	2008
4.	H.M. Deitel and P.J. Deitel. C++ How to Program. Prentice Hall, 8th edition.	2011
5.	S.B. Lippman, J. Lajoie, and B.E. Moo. The C++ Primer. Addison-Wesley Professional, 5th edition.	2012
6.	J.P. Mueller. C++ All-in-one for Dummies, Wiley, 4th edition.	2020

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Mathematics

1. **Subject Code:** MA-104 **Course Title**: Number Theory
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 03 **Practical:** 00
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 04 6. **Semester:** Spring 7. **Subject Area:** PCC
8. **Pre-requisite:** Nil
9. **Objective:** To introduce the basic concepts of number theory.
10. **Details of the Course:**

S. No.	Contents	Contact hours
1	Divisibility, Euclidean algorithm, Linear Diophantine equations, Prime numbers, Fundamental theorem of arithmetic, Prime number theorem (statement only).	7
2	Congruences, solutions of linear congruences, Chinese Remainder Theorem, Euler's totient function, Euler-Fermat theorem, Wilson's theorem, non-linear congruences, Hensel's lemma, primitive roots and power residues	12
3	Quadratic residues, quadratic reciprocity, the Jacobi symbols.	7
4	The greatest integer function, Arithmetic functions, Mobius function and Mobius inversion formula.	6
5	Finite continued fractions, infinite continued fractions, approximation to irrational numbers.	6
6	Introduction to cryptography, public key cryptography, RSA.	4
Total		**42**

11. **Suggested Books:**

S. No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1	Niven I., Zuckerman H. S., and Montgomery H. L., "An Introduction to the Theory of Numbers", John Wiley & Sons (5th Ed.)	1991
2	Burton D., M., "Elementary Number Theory", McGraw Hill (7th Ed.)	2012
3	Rosen, K. H., " Elementary Number Theory and its Applications", Addison-Wesley Publishing Company (6th Ed.).	2011
4	Koblitz N., A Course in Number Theory and Cryptography, Springer (2nd Ed.)	1994
5	Hardy, G. H. and Wright, E. M, "An Introduction to the Theory of Numbers ", Oxford University Press (6th Ed.)	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Mathematics

1. **Subject Code:** MA-201 **Course Title**: Basic Abstract Algebra
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 03 **Practical:** 00
4. **Relative Weightage:** **CWS:** 20-35 **PRS: 0** **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 04 6. **Semester:** Autumn 7. **Subject Area:** PCC
8. **Pre-requisite:** Nil
9. **Objective:** To introduce the basic concepts of abstract algebra.
10. **Details of the Course:**

S. No.	Contents	Contact hours
1	Polynomial equations and their roots, relations between the roots and the coefficients of an equation, Descartes' rule of signs, transformation of equations, symmetric functions of roots, solutions of cubic and biquadratic equations.	7
2	Binary operations, groups, examples of groups: symmetric groups, dihedral groups, general linear groups; elementary properties of groups, subgroups, cosets, Lagrange's theorem, homomorphisms of groups, cyclic groups, normal subgroups, quotient groups, isomorphism theorems, correspondence theorem, automorphisms.	14
3	Permutation groups, Cayley's theorem, conjugacy classes, class equation, external direct products of groups.	7
4	Definition and examples of rings, integral domains, division rings and fields, characteristic of a ring, subrings, ideals, quotient rings, homomorphism of rings, prime ideals and maximal ideals, polynomial rings, factorizations of polynomials with integer coefficients.	10
5	Introduction to error-correcting codes, block codes, linear codes, generator and parity-check matrices, syndrome decoding of linear codes.	4
	Total	**42**

11. **Suggested Books:**

S. No.	Authors/Name of Books/Publisher	Year of Publication/Reprint
1	Gallian, J. A., "Contemporary Abstract Algebra", 9th Edition, Cengage Learning, India	2019
2	Herstein, I. N., "Topics in Algebra", 2nd Edition, John Wiley & Sons	2006
3	Fraileigh, J. B., "A First Course in Abstract Algebra", 7th Edition, Pearson Education, India	2013
4	Artin, M., "Algebra", 2nd Edition, Prentice Hall Inc.	2010
5	Prasad, C., "Textbook on Algebra and Theory of Equations", 11th Edition, Pothishala, India	2017
6	Dickson, L. E., "A First Course in the Theory of Equations", E-book, Project Gutenberg	2009

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Mathematics

1. **Subject Code:** MA-202 **Course Title:** Complex Analysis

2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0

3. **Examination Duration (Hrs.)**: Theory: 3 **Practical:** 0

4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0

5. **Credits:** 4 6. **Semester:** Spring 7. **Subject Area:** PCC

8. **Pre-requisite:** Basics of real analysis

9. **Objective:** To introduce the analytical aspects of functions of a complex variable.

10. **Details of the course:**

S. No.	Contents	Contact Hours
1.	**Introduction:** Algebra of Complex Numbers, inequalities. Stereographic Projection, Topological structure of Complex Plane, Simply connected and multiply connected domains.	**2**
2.	**Analytic Functions**: Functions of a complex variable, limits, continuity, uniform continuity, differentiability, analytic function, C-R equations, necessary and sufficient conditions, applications to the problems of potential flow, Harmonic functions, Harmonic conjugates, Milne's method. Sequences, Series, Uniform convergence, power series, elementary functions, exponential, trigonometric and hyperbolic functions and their identities in the complex plane, multiple valued functions, logarithmic functions and functions with complex exponent.	**10**
3.	**Complex Integration:** Rectifiable arcs, contours, complex line integration, Cauchy's theorem for simply and multiply connected domains, Cauchy's integral formula for the derivatives of an analytic function, Winding Numbers, Cauchy's estimate, Morera's theorem, Liouville's theorem, Fundamental theorem of Algebra. Maximum modulus principle, Schwarz Lemma, Taylor series – Laurent series – Zeros and poles of a function – Meromorphic function.	**8**
4.	**Residue Calculus:** The residue at a singularity, Residue theorem, the argument principle, Rouche's theorem, contour integration and its applications, improper integrals, evaluation of a real integral, improper integrals involving sines and cosines, definite integrals involving sines and cosines, integration through branch cut.	**6**
5.	**Conformal Mapping:** Definition, Bilinear transformation, Cross ratio, the mappings from disc to disc, disc to half plane and half plane to half plane, fixed points. Mapping of elementary transformations, the function $1/z$, z^2, $z^{1/2}$, $\exp z$, $\sin z$ and $z + 1/z$.	**7**

6.	**Applications:** Applications of conformal mapping to steady temperature, electrostatic potential, two dimensional fluid flow, stream function. Schwarz-Christoffel transformation and their applications, Poisson formula, Dirichlet problem in the unit disc, Dirichlet problem in the half plane - Neumann problem for the disc and the half plane.	**9**
	Total	**42**

11. **Suggested Books:**

S. No.	Name of Authors/ Books/Publishers	Year of Publication/Reprint
1.	L. V. Ahlfors, Complex Analysis, 3rd Edition, McGraw-Hill.	2017
2.	J. W. Churchill and R.V. Brown, Complex Analysis, McGraw-Hill.	2009
3.	J. B. Conway, Functions of one complex Variable, Vol. I, Springer Verlag, New York	1995
4.	T. W. Gamelin, Complex Analysis, Springer-Verlag	2001
5.	R. Greene and S.G. Krantz, Function Theory of One Complex Variable, 3rd Edition, GSM, Vol. 40, American Mathematical Society.	2006
6.	S. Lang, Complex Analysis, Springer – Verlag.	2003
7.	J. H. Mathews and R.W. Howell, Complex Analysis for Mathematics and Engineering, Narosa	2009
8.	E.B. Saff and A. D. Snider, Fundamentals of Complex Analysis, 3rd Edition, Pearson	2002

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Mathematics

1. **Subject Code:** MA-203 **Course Title**: Design and Analysis of Algorithms
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 03 **Practical:** 00
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 04 6. **Semester:** Autumn 7. **Subject Area:** PCC
8. **Pre-requisite:** Nil
9. **Objective:** To introduce various approaches for designing algorithms and how to analyze their running time-complexity.
10. **Details of the Course:**

S. No.	Contents	Contact Hours
1.	**Basics of Algorithms:** Notion of algorithm, pseudo code conventions, Performance analysis,Time and space complexities, loop-invariant method for correctness, Asymptotic notations: Big-oh, omega and theta notations, Average and worst case analysis, Probabilistic analysis, Amortized analysis.	6
2.	**Divide and Conquer Algorithms:** Recurrence relations, Divide and conquer relations, Solving of recurrences by iteration method and substitution method, Master theorem, Applications of Divide and Conquer designing method: Binary search algorithm, Merger sort, Quick sort, Karatsuba algorithm for fast multiplication, Strassen's matrix multiplication, and fast Fourier transform	8
3.	**Greedy Algorithms:** Huffman coding algorithm, Data structures of disjoint sets, Complexity analysis of Depth first search, Breadth first search, Prim's algorithm, Kruskal's algorithm, Dijkstra's and Bellman-Ford algorithms, Knapsack problem, Warshall's and Floyd's algorithms.	10
4.	**Dynamic Programming based Algorithms:** Principle of optimality, Optimal binary search trees, Matrix-chain multiplication, Longest common subsequence.	6
5.	**String Matching:** The naive string matching algorithm, The Rabin-Karp Algorithm, The Knuth-Morris-Pratt Algorithm, Applications	4
6.	**Computational Complexity Theory:** P, NP and NP-completeness, Reducibility, Polynomial time verification, Some examples of NP-complete problems along with reducibility.	8
	Total	42

11. **Suggested References/Books:**

S.No.	Name of Authors / Books / Publishers	Year of Publication/ Reprint
1.	Cormen T. H., Leiserson C. E., Rivest R. L. and Stein C., "Introduction to Algorithms", Prentice Hall India, Third Edition	2009
2.	Aho A. V., Hopcroft J. E. and Ullman J. D., "The Design and Analysis of Computer Algorithms", Pearson Education, First Edition	2002
3.	Horowitz E., Sahni S. and Rajasekaran S., "Fundamentals of Computer Algorithms", Orient Longman, Second Edition	2008
4.	Kleinberg J. and Tardos E., "Algorithm Design", Pearson Education India, First Edition	2013
5.	Levitin A., "Introduction to the Design and Analysis of Algorithm", Pearson Education, Second Edition	2014

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Mathematics

1. **Subject Code:** MA-204 **Course Title**: Statistical Machine Learning
2. **Contact Hours:** **L:** 3 **T:** 0 **P:** 2
3. **Examination Duration (Hrs.):** **Theory:** 03 **Practical:** 00
4. **Relative Weightage:** **CWS:** 10-25 **PRS:** 25 **MTE:** 15-25 **ETE:** 30-40 **PRE:** 0
5. **Credits:** 04 6. **Semester:** Spring 7. **Subject Area:** PCC
8. **Pre-requisite:** Basic knowledge of linear algebra, probability and statistics.
9. **Objective:** To provide knowledge about theoretical foundations and computational aspects of statistical machine learning.
10. **Details of the Course:**

S. No.	Contents	Contact hours
1.	**Theory of Statistical Learning:** Basics of learning theory, function estimation, understanding data, assessing model accuracy, principles of Maximum likelihood, Bayes and minimax, parametric versus nonparametric methods, Bayesian versus Classical approaches in machine learning.	6
2.	**Supervised Learning**: Linear regression (simple and multiple), confidence interval and hypothesis testing of regression coefficients, model accuracy, qualitative predictors, extension of linear models.	6
3.	**Classification Algorithms:** logistic regression, Bayesian approach for classification, linear discriminant analysis, quadratic discriminant analysis, support-vector machines, K-nearest neighbor (KNN) algorithm.	6
4.	**Resampling methods and Regularization:** Over and under sampling approaches, cross validation, linear model selection, subset selection, shrinkage methods, Ridge and Lasso methods, dimension reduction methods, Principal Component Regression (PCR) and partial least square.	7
5.	**Nonlinear models:** Polynomial regression and regression splines, generalized additive models, Tree-based methods, Random forests, Boosting algorithms.	6
6.	**Unsupervised Learning:** Principal Component Analysis, Clustering methods; k-means and hierarchical, Gaussian mixture model and expectation maximization algorithm, density estimation.	6
7.	**Deep Learning and Neural Networks:** Perceptron Model; Multilayer perceptron; Gradient Descent and Backpropagation algorithm; Convolutional Neural Networks.	5
Total		**42**

11. **List of Practical:**

S. No.	
1.	Hands-on with Numpy/R
2.	Hands-on with Scikit-Learn/R
3	Linear regression
4.	Logistic regression for classification
5.	Discriminant Analysis
6.	Data Resampling methods
7.	Model Selection methods
8.	Dimension reduction Approaches
9.	Nonlinear models-I
10.	Nonlinear models-II
11.	Unsupervised Learning-I
12.	Unsupervised Learning-II
13.	Neural Networks
14.	Convolutional Neural Networks

12. **Suggested Books:**

S. No.	**Authors/Name of Books/Publisher**	**Year of Publication/Reprint**
1.	Christopher Bishop, Pattern Recognition and Machine Learning, Springer, Information Science and Statistics Series	2006
2.	Gareth James, Daniela Witten, Trevor Hastie and Robert Tibshirani, An Introduction to Statistical Learning with Applications in R, Springer Texts in Statistics, Springer, New York	2017
3.	Trevor Hastie, Robert Tibshirani, Jerome Friedman, The Elements of Statistical Learning: Data Mining, Inference, and Prediction, Springer Texts in Statistics, Springer Verlag, New York, Second Edition	2017
4.	Rodrigo Fernandes de Mello, Moacir Antonelli Ponti, Machine Learning: A Practical Approach on the Statistical Learning Theory, Springer Nature	2018
5.	Richard Golden, Statistical Machine Learning: A Unified Framework, Chapman & Hall/CRC Texts in Statistical Science, First Edition	2020

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Mathematics

1. **Subject Code:** MA-205 **Course Title**: Discrete Mathematics
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 03 **Practical:** 00
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 04 6. **Semester:** Autumn 7. **Subject Area:** PCC
8. **Pre-requisite:** Nil
9. **Objective:** To provide a basic knowledge of discrete mathematical structures.
10. **Details of the Course:**

S. No.	Contents	Contact hours
1	**Logic and Proofs:** Propositional logic, propositional equivalences, predicates and quantifiers, introduction to proofs, proof methods and strategy.	5
2	**Counting:** Basic counting principles, the pigeonhole principle, permutations and combinations, binomial coefficients, generalized permutations and combinations.	4
3	**Advanced Counting Techniques:** Recurrence relations, solving linear recurrence relations, generating functions, inclusion-exclusion, applications of inclusion-exclusion, divide-and-conquer algorithms and recurrence relations.	7
4	**Relations:** Relations and their properties, representing relations using matrices and digraphs, closures of relations, Warshall's algorithm, equivalence relation, partial order relation, Hasse diagrams, lattices.	9
5	**Boolean Algebra:** Boolean functions and Boolean expressions, Boolean algebra, representing Boolean functions, logic gates, minimization of circuits, Karnaugh maps.	7
6	**Graphs:** Graphs and graph models, basic terminology and special types of graphs, graph isomorphisms, connectivity, Euler and Hamiltonian paths and cycles, shortest-path problems, graph coloring, introduction to trees, application of trees, spanning trees, minimum spanning trees.	10
	Total	**42**

11. **Suggested Books:**

S. No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1	Rosen, K. H., "Discrete Mathematics and its Applications", 8th Ed., McGraw Hill.	2019
2	Liu, C. L., "Elements of Discrete Mathematics", 4th Ed., Tata McGraw Hill.	2017
3	Deo, N., "Graph Theory with Applications to Engineering and Computer Science", Dover Publications.	2016
4	Chartrand, G. and Zhang, P., "Discrete Mathematics", Waveland Press, Inc.	2011
5	Clark, J. and Holton, D. A., "A First Look at Graph Theory", World Scientific.	1991

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Mathematics

1. **Subject Code:** MA-206 **Course Title**: Stochastic Calculus
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 03 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 04 6. **Semester:** Spring 7. **Subject Area:** PCC
8. **Pre-requisite:** Basic Probability Theory.
9. **Objective:** To introduce the concepts of stochastic calculus.
10. **Details of the Course:**

S. No.	Contents	Contact hours
1.	**Basics of probability theory:** σ-field, probability measure, Borel-Cantelli lemma, random variable, Doob-Dynkin lemma, Radon-Nikodym theorem, convergence of random variables, law of large numbers, central limit theorem, Markov's inequality, Jensen's inequality.	06
2.	**Conditional expectation:** Conditioning on event, discrete random variable, arbitrary random variable and σ-field, properties.	04
3.	**Martingales in discrete and continuous time:** Filtration and adapted processes, stopping time and its properties, martingales, sub-martingales, super-martingales, martingale inequalities.	07
4.	**Brownian motion:** Definition and construction, sample path properties, reflection principle, Brownian motion with drift, Ornstein-Uhlenbeck process.	08
5.	**Itô's calculus:** Indistinguishability and modification, simple processes, Itô's integral for simple process and its properties, Itô's integral for square integrable adapted processes and its properties.	10
6.	**Stochastic differential equations:** Introduction to stochastic differential equations, notion of strong solution, Itô's lemma and Itô's product rule with their applications in solving stochastic differential equations and Itô's integrals.	07
	Total	**42**

11. **Suggested Books:**

S. No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	P. Baldi, Stochastic Calculus: An Introduction Through Theory and Exercises, Springer	2017
2.	G. Kallianpur and P. Sundar, Stochastic Analysis and Diffusion Processes, Oxford University Press, Oxford.	2014
3.	R. Karandikar and B. Rao, Introduction to stochastic calculus. Indian Statistical Institute Series, Springer Nature, Singapore.	2018
4.	I. Karatzas and S. E. Shreve, Brownian motion and stochastic calculus, second edition, Springer, New York.	1991
5.	X. Mao, Stochastic Differential Equations and Applications, second edition, Woodhead Publishing.	2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Mathematics

1. **Subject Code:** MA-207 **Course Title**: Linear Algebra
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 03 **Practical:** 00
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 04 6. **Semester:** Autumn 7. **Subject Area:** PCC
8. **Prerequisite:** Nil
9. **Objective:** To introduce the fundamental knowledge of linear algebra.
10. **Details of the Course:**

S. No.	Contents	Contact hours
1.	**Vector Spaces:** Vector space, subspace, intersection, union, sum and direct sum of subspaces, linear dependence and independence, basis and dimension, ordered bases and coordinates, quotient spaces.	8
2.	**Linear Transformations:** Basic properties, range and null space, rank-nullity theorem, isomorphism, matrix representation of a linear transformation, change of basis, algebra of linear transformations, inverse of a linear transformation, linear functionals and annihilators, dual spaces.	10
3.	**Canonical Forms:** Eigenvalues and eigenvectors, the characteristic polynomial, annihilating polynomials, the minimal polynomial, algebraic and geometric multiplicities, Cayley-Hamilton theorem, triangularization, diagonalization, invariant subspaces, invariant direct sums, primary decomposition theorem, Jordan canonical form.	12
4.	**Inner Product Spaces:** Definition of inner product, orthogonality, Gram-Schmidt orthonormalization process, orthogonal projections, positive definite, adjoint, self-adjoint, unitary and normal operators, spectral theorem for self-adjoint and normal operators on finite-dimensional vector spaces. Bilinear forms, symmetric and skew symmetric bilinear forms, real quadratic forms, Sylvester's law of inertia.	12
	Total	**42**

11. **Suggested Books:**

S. No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	K. Hoffman and R. Kunze, Linear Algebra, 2nd Edition, Prentice Hall of India.	2015
2.	S. Axler, Linear Algebra Done Right, 3rd edition. Undergraduate Texts in Mathematics. Springer.	2015
3.	P. Halmos, Finite Dimensional Vector Spaces, Springer.	1974
4.	S. Lang, Linear Algebra, Undergraduate Texts in Mathematics. Springer-Verlag, New York.	2004
5.	L. Mirsky, An Introduction to Linear Algebra. Reissue edition. Dover Publications, Inc., New York.	2003

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: **MATHEMATICS**

1. **Subject Code:** MA-208 **Course Title:** Technical Communication.
2. **Contact Hours:** L: 2 T: 0 P: 0
3. **Examination Duration (Hrs):** Seminar mode
4. **Relative Weightage: CWS:** 0 **MTE:** 0 **PRS:** 0 **ETE:** 100 **PRE** 0
5. **Credits:** 02 6. **Semester:** Spring 7. **Subject Area:** PCC
8. **Pre Requisite (if any):** Nil

9**. Objective:** To introduce the basics of writing and presenting the mathematical content.

10**. Detail of Course:**

S. No.	Topics	No. of Lectures
1.	**Technical terms:** Basic writing procedure in Mathematics, Difference between Lemma, Proposition, Theorem and Corollary. Various procedures of writing proof. Writing methods in Research Article, thesis, monograph and Book chapters.	4
2.	**Documentation:** Advantage of Latex Documentation system over WYSIWYG programs, Numbering, citation, references and Bibliography. Graphical illustration in Latex, pgf, tikz pictures and eps figures.	6
3.	**Presentation and Seminar :** Beamer presentation, Animation, Keynote and Microsoft power point presentation, hyperlink with external programs and mathematical software.	5
4.	**Software:** Exhibiting results using Mathematical software, Outline of Mathematica, Matlab and Maple Software. Numerical techniques, Graphical illustration, 3D plot, Contour Plot and Parametric plots.	7
5.	**Data simulation:** Statistical and Numerical data formulation and expression, Statistical observation through spreadsheets, Database management software, Software tools for Optimization technique.	6
	Total	**28**

11. **Books Recommended:**

S. No.	**Name of Books/Authors/Publishers**	**Year of Publication / Reprint**
1.	Franco Vivaldi, Mathematical Writing, Springer	2014
2.	L. Lamport, A Document Preparation System (2nd Edition), Pearson Education.	1994
3.	C. Gilderdale, Alison Kiddle, Ems Lord, Beckey Warren, Fran Watson, Approaches to learning and teaching Mathematics, Cambridge University Press, London	2017
4.	M. Abell and J. Braselton, MATHEMATICA by Example (Sixth Edition), Elsevier.	2021
5.	D. Etter, Introduction to MATLAB (Third Edition), Pearson.	2020
6.	Andy Field, Discovering statistics using R, SAGE publications	2000

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Mathematics

1. **Subject Code:** MA-209 **Course Title**: Ordinary and Partial Differential Equations
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 03 **Practical:** 00
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 04 6. **Semester:** Autumn 7. **Subject Area:** PCC
8. **Pre-requisite:** Nil
9. **Objective:** To provide basic concepts of differential equations and their solutions.
10. **Details of the Course:**

S. No.	Contents	Contact hours
1.	**Introduction to Differential Equations:** Formation of differential equations, basic definitions (linearity, order, homogeneous and nonhomogeneous, explicit and implicit solution, general solution, particular solution), review of first order ODE, existence and uniqueness theorem for linear ODE.	5
2.	**Second and Higher Order ODE:** Linear independence of functions, Wronskian and its basic properties, solution of homogeneous and non-homogeneous linear ODE with constant coefficients using method of undetermined coefficients and inverse operator method, equations with variable coefficients, Euler-Cauchy equations, variation of parameters, reduction of order, solution of second order differential equations by changing dependent and independent variables.	8
3.	**Series Solution:** Power series solution of second order homogeneous ODE, ordinary points, singular points, Frobenius series solution, Legendre's and Bessel's equations, elementary properties of Legendre polynomials and Bessel functions.	9
4.	**Partial Differential Equations:** Introduction, curves and surfaces, formation of PDE, classification of solutions (complete, general and singular).	2
5.	**First order PDE:** Classification of first order PDE, Lagrange's method to solve first order PDE, integral surface passing through a given curve, compatibility, Charpit's method to solve first order nonlinear PDE, special types of first order PDE.	9
6.	**Second Order PDE:** Solutions of linear PDE with constant coefficients using differential operators, reducible and irreducible nonhomogeneous linear PDE, homogeneous linear PDE with constant coefficients, classification of second order PDE, canonical forms.	9
	Total	**42**

11. **Suggested Books:**

S. No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	Simmons, G.F., "Ordinary Differential Equations with Applications and Historical Notes", 3rd Ed., CRC Press.	2017
2.	Hildebrand F.B., "Methods of Applied Mathematics", Dover Publications.	1992
3.	Tenenbaum, M. and Polard, H., "Ordinary Differential Equations", Dover Publications.	1985
4.	Sneddon, I.N., "Elements of Partial Differential Equations", Dover Publications.	2006
5.	Rao, K.S., "Introduction to Partial Differential Equations", PHI Learning Pvt. Ltd. 2nd Ed.	2010
6.	Debnath, L. and Myint-U, T., "Linear Partial Differential Equations and Scientists and Engineers", Birkhauser, 3rd Ed.	2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Mathematics

1. **Subject Code:** MA-210 **Course Title**: Transform Techniques
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 03 **Practical:** 00
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 04 6**. Semester:** Spring 7. **Subject Area:** PCC
8. **Pre-requisite:** Nil
9. **Objective:** To provide knowledge of various mathematical transformations and their applications.
10. **Details of the Course:**

S.No.	Contents	Contact hours
1.	**Laplace Transform:** Laplace transform of some standard functions, Existence conditions for the Laplace transform, Shifting theorems, Laplace transform of derivatives and integrals, Inverse Laplace transform and their properties, Convolution theorem, Initial and final value theorem, Laplace transform of periodic functions, error functions, Heaviside unit step function and Dirac delta function, Applications of Laplace transform to solve ODEs and PDEs.	10
2.	**Finite Laplace Transform:** Definition and properties, Shifting and scaling theorem.	5
3.	**Z-Transform:** Z–transform and inverse Z-transform of elementary functions, Shifting theorems, Convolution theorem, Initial and final value theorem, Application of Z-transforms to solve difference equations.	5
4.	**Fourier series:** Trigonometric Fourier series and its convergence. Fourier series of even and odd functions, Gibb's phenomenon, Fourier half-range series, Parseval`s identity, Complex form of Fourier series.	6
5.	**Fourier Transform:** Fourier integrals, Fourier sine and cosine integrals, Complex form of Fourier integral representation, Fourier transform, Fourier transform of derivatives and integrals, Fourier sine and cosine transforms and their properties, Convolution theorem, Applications of Fourier transforms to Boundary Value Problems, Discrete Fourier transform, Fast Fourier Transform.	9
6.	**Wavelets and Wavelet Transform**: Introduction of wavelets, Properties of wavelets, Continuous wavelet transform, Applications of wavelets to solve ODEs/PDEs.	7
Total		**42**

11. **Suggested Books:**

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	Kreyszig, E., Advanced Engineering Mathematics, John Wiley and Sons	2011
2.	Jain, R. K. and Iyenger, S. R. K., Advanced Engineering Mathematics, Narosa Publishing House.	2009
3.	Hildebrand F. B., Methods of Applied Mathematics, Courier Dover Publications.	1992
4.	Debnath L. and Bhatta D., Integral Transforms and Their Applications, 2nd edition, Taylor and Francis Group.	2007
5.	Oran Brigham, E., The Fast Fourier Transform, Prentice Hall Publications.	1973
6.	Prasad, L. and Iyengar, S. S., Wavelet Analysis with Applications to Image Processing, CRC Press.	1997
7.	E. Hernandez & G.Weiss, A First Course on Wavelets, CRC Press.	1996

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Mathematics

1. **Subject Code:** MA- 301 **Course Title**: Fluid Dynamics
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 03 **Practical:** 00
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 04 6. **Semester:** Autumn 7. **Subject Area:** PCC
8. **Pre-requisite:** Nil
9. **Objective:** To introduce the basic concepts of fluid dynamics.
10. **Details of the Course:**

S.No.	Contents	Contact hours
1.	**Basic Concepts:** A broad perspective of fluid dynamics, Definition of fluid, Distinction between solid and fluid, Concept of continuum, pressure and stress in a fluid, Fluid properties.	4
2.	**Description of Fluid Motion:** Lagrangian and Eulerian approaches, Continuity of mass flow, Circulation, Rotational and irrotational flows, Boundary surface, Streamlines, Path lines, Streak lines, Vorticity.	4
3.	**Equations of Motion and Mechanical Energy**: Inviscid case, Bernoulli's theorem, Compressible and incompressible flows, Kelvin's theorem, Constancy of circulation, Concepts of static pressure, Flow through orifices and mouthpieces.	7
4.	**Flow of Ideal Fluids**: Stream function, Complex-potential, Source, sink and doublets, Circle theorem, Method of images, Theorem of Blasius, Stokes stream function, Motion of a sphere, Helmholtz's vorticity equation, Vortex filaments, Vortex pair.	8
5.	**Incompressible Viscous Flow:** Reynolds transport theorem**,** Derivation of Navier-Stokes equations, Derivation of energy equation, Dissipation of energy, Diffusion of vorticity, Couette flow, Poiseuille flow, Hagen-Poiseuille flow, Annular flow.	14
6.	**Laminar Boundary Layers:** Dynamical similarity, Dimensional analysis, Large Reynold's numbers, Laminar boundary layer equations, Similar solutions.	5
Total		**42**

11. **Suggested Books:**

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	Batechelor, G.K., "An Introduction to Fluid Dynamics", Cambridge Press.	2002
2.	Schliting, H., Gersten K., "Boundary Layer Theory", Springer, 8th edition.	2004
3.	Rosenhead, L., "Laminar Boundary Layers", Dover Publications	1989
4.	Tritton, D.J., ''Physical Fluid Dynamics'', Oxford University press	2011
5.	Yuan, S.W., "Foundations of Fluid Mechanics", New Delhi: Prentice_Hall of India	1988

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Mathematics

1. **Subject Code:** MA-302 **Course Title**: Mathematical Modeling and Simulation
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 03 **Practical:** 00
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 04 6. **Semester:** Spring 7. **Subject Area:** PCC
8. **Pre-requisite:** Nil
9. **Objective:** To develop skills of mathematical modeling.
10. **Details of the Course:**

S. No.	Contents	Contact Hours
1.	**Introduction:** History of mathematical modeling, Importance of mathematical modeling, Latest developments in mathematical modeling, Limitations of mathematical modeling, Construction of mathematical models, Mathematical models and functions, Units and Dimension, Dimensional analysis, Scaling.	9
2.	**Continuous models:** Introduction to continuous models, Steady state solutions, Linear stability analysis, Phase plane diagrams of linear systems, Carbon Dating, Drug Distribution , Growth and decay of current in a L-R Circuit, Mechanical oscillations, Dynamics of rowing model, Arms race models, Combat Models, Epidemic Models (SI, SIS, SIR, SIRS), Malthusian, Logistic and Gomperzian growth models, Predator-prey models, Competition models.	12
3.	**Discrete models:** Introduction to difference equations, Steady state solution and linear stability analysis. Introduction to discrete models, Growth and decay models, Newton's law of cooling, Bank account and mortgage model, Drug delivery model, Harrod model of economic growth, Lake pollution model, Linear predator-prey models, Density dependent growth models (including harvesting).	7
4.	**Numerical solutions:** Numerical solutions of the discrete and continuous models and its graphical representation, using mathematical software tools.	7
5.	**Computer simulations:** Modeling and simulation concepts, Discrete event simulation, Continuous simulation, Data fitting methods using mathematical software tools, Parameter estimation for discrete and continuous models, Verification and validation of simulation models.	7
	Total	**42**

11. **Suggested References/Books:**

S. No.	Name of Books / Authors/ Publishers	Year of Publication/ Reprint
1.	Albright, B. and Fox, W.P., "Mathematical Modeling with Excel", CRC Press, Taylor and Francis group.	2019
2.	Marotto, F. R., "Introduction to Mathematical Modeling using Discrete Dynamical Systems", Thomson Brooks/Cole.	2006
3.	Barnes, B. and Fulford, G. R., "Mathematical Modelling with Case Studies", CRC Press, Taylor and Francis Group.	2009
4.	Edsberg, L., "Introduction to Computation and Modeling for Differential Equations", John Wiley and Sons.	2008
5.	Murray, J. D., Mathematical Biology: An Introduction, Springer-Verlag New York.	2002
6.	Mityushev, V., Nawalaniec, W. and Rylko, N., "Introduction to Mathematical Modeling and Computer Simulations", CRC Press, Taylor and Francis group.	2018
7.	Jain, S. Modeling and Simulation using MATLAB - Simulink, 2nd Ed, Wiley India	2021
8.	Mathematical Modeling: Models, Analysis and Applications, 2nd Ed, CRC Press	2022

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Mathematics

1. **Subject Code:** MA-303 **Course Title**: Numerical Analysis
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 03 **Practical:** 00
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 04 6**. Semester:** Autumn 7. **Subject Area:** PCC
8. **Pre-requisite:** Basic course in numerical methods
9. **Objective:** To discuss the numerical methods and their analysis for solving differential equations.
10. **Details of the Course:**

S.No.	Contents	Contact hours
1.	**Computation of Eigenvalues of a Matrix:** Method of inflation, Jacobi, Givens and Householder methods for symmetric matrices, LR and QR methods.	5
2.	**Initial Value Problems:** Multistep methods, Error and stability analysis.	6
3	**Stiff Problems and Boundary Value Problems:** Stability of numerical methods for stiff systems, Backward differentiation methods for stiff systems, Gear's method, Boundary value problems, Shooting methods, Matrix methods for linear and non-linear boundary values problems, Collocation method.	8
4.	**Finite Differences:** Review of finite difference operators, finite difference methods, inverse interpolation- developments and applications.	2
5.	**Elliptic PDE:** Error analysis of the Poisson problem, The general diffusion equation, Boundary conditions on a curved boundary, Error analysis using a maximum principle, Asymptotic error estimates.	7
6.	**Parabolic PDE:** Concept of compatibility, convergence and stability, explicit, full implicit, Crank-Nicholson, du-Fort and Frankel scheme, ADI methods to solve two-dimensional equations with error analysis.	7
7.	**Hyperbolic PDE:** Characteristics, The CFL condition, Error analysis of the upwind scheme, Fourier analysis of the upwind scheme, The Lax–Wendroff scheme, The box scheme, The leap-frog scheme.	7
Total		**42**

11. **Suggested Books:**

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1	Smith, G. D., Numerical Solution of Partial Differential Equations, Oxford University Press.	2001
2	Gerald, C. F. and Wheatly P. O., Applied Numerical Analysis, 6th Ed., Addison-Wesley Publishing.	2002
3	Froberg, C. E., Introduction to Numerical Analysis, 2nd Ed., Addison-Wesley.	2004
4	Fausett, L. V., Applied Numerical Analysis, Prentice Hall, 2nd Ed.	2007
5	Morton K. W. and Mayers D. F. Numerical Solution of Partial Differential Equations, 2nd Ed., Cambridge University Press.	2012
6	Iserles A. A first course in the numerical analysis of differential equations, 2nd Ed, Cambridge University Press.	2012

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Mathematics

1. **Subject Code:** MA-304 **Course Title**: Theory of Computation
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 03 **Practical:** 00
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 04 6. **Semester:** Spring 7. **Subject Area:** PCC
8. **Pre-requisite:** Nil
9. **Objective:** To introduce the theory of automata, languages and grammars.
10. **Details of the Course:**

S.No.	Contents	Contact hours
1.	Basic definitions, deterministic and non-deterministic finite automata, regular languages, equivalence of deterministic and nondeterministic finite automata, state equivalence and minimization, regular expressions, equivalence of regular expressions and finite automata	10
2.	Properties of regular languages, Pumping lemma, Grammars, Types of grammars.	6
3.	Context-free languages, parse tree, simplifications of context-free grammars, Chomsky normal form, Greibach normal form.	6
4.	Pushdown automata, deterministic and non-deterministic pushdown automata, equivalence of pushdown automata with context free languages.	6
5.	Properties of context-free languages, pumping lemma for context free languages.	4
6.	Turing machines, computable languages and functions, modifications of Turing machines.	6
7.	Computability and decidability, undecidable problems, Halting problem, Complexity classes: P, NP and NP complete.	4
Total		**42**

11. **Suggested Books:**

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	Hopcroft J. E., Motwani R. and Ullman J. D., "Introduction to automata Theory, languages and Computation", Pearson Education (3rd Ed.)	2008
2.	Linz P., "An Introduction to Formal Languages and Automata", Jones and Bartlett (6th Ed.)	2016
3.	Sipser M., "Introduction to the Theory of Computation", Cengage Learning (3rd Ed.)	2013
4.	Lewis H. R. and Papadimitriou C. H., "Elements of the Theory of Computation", Prentice Hall (2nd Ed.)	1998
5.	Kozen D., "Automata and Computability", Springer	2012
6.	Cohen D. I. A., "Introduction to Computer Theory", John Wiley & Sons (2nd Ed.)	1996

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Mathematics

1. **Subject Code:** MA-305 **Course Title**: Operations Research
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 03 **Practical:** 00
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 04 6**. Semester:** Autumn 7. **Subject Area:** PCC
8. **Pre-requisite:** Nil
9. **Objective:** To acquaint the students with the basics of operations research.
10. **Details of the Course:**

S.No.	Contents	Contact hours
1.	**Basics of LPP:** Different Types of OR Models, Convex Sets, Graphical Method, Simplex Method, Big –M Method, Two Phase Method, Revised Simplex Method.	10
2.	**Duality Theory:** Duality theory, Dual Simplex Method, Sensitivity Analysis, Parametric Linear Programming.	7
3.	**Integer Program:** Cutting Plane and, Branch and Bound Techniques for all Integer and Mixed Integer Linear Programming Problems.	5
4.	**Transportation Problems:** Balanced and unbalanced transportation problems-formulation, Dual problem, NWCM, LCEM and VAM, *u-v* method. Assignment Problems; Formulation, Hungarian method.	5
5.	**Game Theory:** Minimax (Maximin) criterion, Saddle point, Notion of dominance, Graphical and Linear Programming Methods for Rectangular Games.	4
6.	**Queuing Theory:** Steady-state solutions of Markovian Queuing Models: M/M/1, M/M/1 with limited waiting space, M/M/C, M/M/C with limited space, M/G/1.	6
7.	**Inventory Models:** Static, Dynamic and Probabilistic models.	5
	Total	**42**

11. **Suggested Books:**

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	Ravindran, A., Phillips, D.T. and Solberg, J.J., Operations Research: Principles and Practice, John Wiley and Sons, NY, Second Edition (Reprint).	2012
2.	Taha, H.A., Operations Research: An Introduction, Pearson Education Limited, NY, Tenth Edition.	2018
3.	Pant, J.C., Introduction to Optimization/ Operations Research, Jain Brothers, New Delhi, Seventh Edition.	2015
4.	Bazaraa, M.S., Jarvis, J. J. and Sherali, H. D., Linear Programming and Network Flows, John Wiley and Sons, Fourth Edition.	2013
5.	Sharma, J. K., Operations Research: Theory and Applications, Laxmi Publications Pvt. Ltd., Sixth Edition.	2016

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Mathematics

1. **Subject Code:** MA-401 **Course Title**: Abstract Algebra
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 03 **Practical:** 00
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 04 6. **Semester:** Autumn 7. **Subject Area:** PCC
8. **Pre-requisite:** Basic group theory and ring theory.
9. **Objective:** To introduce the fundamental concepts of groups, rings, modules and fields.
10. **Details of the Course:**

S. No.	Contents	Contact hours
1	**Groups:** Review of groups, subgroups and group homomorphism; group actions, class equation, Sylow's theorems, simplicity of alternating groups, direct product of groups, fundamental theorem of finite abelian groups.	14
2	**Rings:** Review of basic ring theory, ideals and their properties, Chinese Remainder Theorem, prime and maximal ideals, rings of fractions, factorization in integral domains, principal ideal domains, Euclidean domains, unique factorization domains, polynomial rings over unique factorization domains.	11
3	**Modules:** Basic definitions and examples, submodules and direct sums, quotient modules, homomorphism of modules and isomorphism theorems, cyclic modules, simple (irreducible) modules, free modules.	5
4	**Fields:** Field extensions, algebraic extensions, splitting fields and algebraic closures, normal and separable extensions, finite fields, automorphisms and fixed fields, Galois extensions, The Fundamental Theorem of Galois theory.	12
	Total	**42**

11. **Suggested Books:**

S. No.	Authors/Name of Books/Publisher	Year of Publication/Reprint
1	Dummit , D. S. and Foote, R. M., "Abstract Algebra", 3rd Edition, John Wiley & Sons	2003
2	Bhattacharya, P. B., Jain, S. K. and Nagpaul, S. R., "Basic Abstract Algebra", 2nd Edition, Cambridge University Press	1995
3	Artin, M., "Algebra", 2nd Edition, Prentice Hall Inc.	2010
4	Hungerford, T. W., "Algebra", Springer	1980
5	Herstein, I. N., "Topics in Algebra", 2nd Edition, John Wiley & Sons	2006
6	Jacobson, N., "Basic Algebra: Volume I", 2nd Edition, Dover Publications Inc.	1985

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Mathematics

1. **Subject Code:** MA-404 **Course Title**: Functional Analysis
2. **Contact Hours: L:** 3 **T:** 1 **P:** 0
3. **Examination Duration(Hrs.): Theory:** 03 **Practical:** 00
4. **Relative Weightage: CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 00
5. **Credits:** 04 6. **Semester:** Spring 7. **Subject Area:** PCC
8. **Pre-requisite:** Basic knowledge of real analysis.
9. **Objective:** To introduce the concepts of Banach spaces, Hilbert spaces, linear operators and their properties.
10. **Details of the Course:**

S.No.	Contents	Contact hours
1.	Normed linear spaces, convergence and absolute convergence of series in a normed linear space, Banach spaces.	7
2.	Inner product spaces, Cauchy-Schwarz inequality, Hilbert spaces, relation between Banach and Hilbert spaces.	2
3.	Convex sets, existence and uniqueness of a vector of minimum length, projection theorem. Orthogonal and orthonormal systems in Hilbert spaces with examples, Bessel's inequality, Parseval's identity, Characterization of complete orthonormal systems.	5
4.	Continuity of linear maps on normed linear spaces, four equivalent norms on the space of linear bounded operators, conjugate and dual spaces, The Riesz Representation Theorem, Compact operators, spectrum of bounded linear operators, spectral theorem on finite dimensional spaces.	8
5.	Adjoint operators, self adjoint operators, normal operators, unitary operators on Hilbert spaces and their properties, Isometric isomorphism of a Hilbert space onto itself under unitary operators, Projection operators on Banach spaces and Hilbert spaces. Orthogonal projections.	9
6.	The Closed Graph Theorem, The Uniform Boundedness Principle and its applications, The Hahn–Banach Extension and Separation theorems, Open Mapping Theorem and its applications.	11
	Total	**42**

11. **Suggested Books:**

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	Bachman G. and Narici L., Functional Analysis, Dover Publications.	1998
2.	Conway J. B., A Course in Functional Analysis, 2nd Ed., Springer.	2007
3.	Debnath L. K. and Mikusinski P., Introduction to Hilbert Spaces with Applications, 3rd Ed., Academic Press.	2005
4.	Kreyszig E., Introductory Functional Analysis with Applications, Wiley.	2007
5.	Limaye B. V., Functional Analysis, Revised 3rd Ed., New Age International Publishers.	2014
6.	Nair, M. T., Functional Analysis: A First Course, PHI Pvt. Ltd.	2001
7.	Rudin W., Functional Analysis, 2nd Ed., McGraw Hill.	1991
8.	Simmons G. F., Introduction to Topology and Modern Analysis, McGraw Hill.	2017
9.	Yosida K., Functional Analysis, 6th Ed., Springer.	1995

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Mathematics

1. **Subject Code:** MA-408 **Course Title**: Theory of Partial Differential Equations
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 03 **Practical:** 00
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 04 6. **Semester:** Spring 7. **Subject Area:** PCC
8. **Pre-requisite:** Basic concepts of ordinary and partial differential equations.
9. **Objective:** To introduce theoretical concepts of partial differential equations.
10. **Details of the Course:**

S.No.	Contents	Contact hours
1.	**Introduction:** Surfaces and curves, simultaneous differential equations of the first order and first degree, integral curves of vector fields, methods of solution of dx/P = dy/Q = dz/R, orthogonal trajectories of a system of curves on a surface, Pfaffian differential forms and equations, solution of Pfaffian differential equations in three variables.	5
2.	**First order PDE:** Classification, initial value problem for quasi-linear first order equations: existence and uniqueness of solution, nonexistence and non-uniqueness of solutions, orthogonal surfaces, nonlinear PDEs of first order, Cauchy's method of characteristics, compatible systems of first order equations, Charpit's method, derivation of one complete integral from another, Jacobi's method.	7
3.	**Second order PDE:** Equations with variable coefficients, classification and canonical forms of second order equations, characteristic curves of second order equations in two variables, importance of characteristic curves.	5
4.	**Laplace and Poisson equations:** Laplace equation in Cartesian, polar, spherical and cylindrical coordinates and its solution by Fourier series method, Poisson equation in 2D, Green's function, eigenfunction method for finding Green's function, method of images.	9
5.	**Wave equation:** One and two dimensional wave equations, solution by method of characteristics, Fourier series and Fourier transform methods, existence and uniqueness results.	9
6.	**Diffusion equation:** Solution of homogeneous and non-homogeneous diffusion equation (1D), Duhamel's principle, Fourier series and Fourier transform methods, existence and uniqueness results.	7
	Total	**42**

11. **Suggested Books:**

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	Zachmanoglou, E.C. and Thoe, D.W., "Introduction to Partial Differential Equations with Applications", Dover Publications.	1986
2.	Sneddon, I.N., "Elements of Partial Differential Equations", Dover Publications.	2006
3.	Rao, K.S., "Introduction to Partial Differential Equations", PHI Learning Pvt. Ltd., 2nd Ed..	2012
4.	Evans, L.C., "Partial Differential Equations", American Mathematical Society, 2nd Ed.	2014
5.	Debnath, L. and Myint-U, T., "Linear Partial Differential Equations and Scientists and Engineers", Birkhauser, 3rd Ed.	2007
6.	McOwen, R.C., "Partial Differential Equations", Pearson Education Inc., 2nd Ed.	2003
7.	John, F. "Partial Differential Equations", Springer, 4th Ed.	1991

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Mathematics

1. **Subject Code:** MA-409 **Course Title**: Real Analysis
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 03 **Practical:** 00
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 04 6. **Semester:** Autumn 7. **Subject Area:** PCC
8. **Pre-requisite:** Basic knowledge of elementary real analysis
9. **Objective:** To introduce some advanced topics in theory of real functions of several variables and metric spaces.
10. **Details of the Course:**

S. No.	Contents	Contact hours
1.	Definition and existence of Riemann-Stieltjes integral, Properties of integrals, Integration and differentiation, Fundamental theorem of calculus, first and second mean value theorems, Integration of vector-valued functions.	10
2.	Linear transformations, Derivatives in several variable calculus, Partial and directional derivatives, Chain rule, Double derivatives and Clairaut's theorem, The inverse function theorem, The implicit function theorem, Integration on n-dimensional Euclidean space, Stokes' Theorem.	12
3.	Metric spaces, Convergence of sequences, Open and closed subsets, Continuity, Cauchy sequences, completeness, Compactness, Iteration and the Contraction Mapping Theorem.	12
4.	Length of open sets and closed sets, Inner and outer measure, Measurable sets, Properties of measurable sets, Measurable functions.	8
Total		**42**

11. **Suggested Books:**

S. No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	Rudin. W., Principles of Mathematical Analysis**,** 3rd Ed. McGraw Hill Education.	2017
2.	Goldberg, R. R., Methods of Real Analysis, Oxford and IBH Publishing Company Pvt. Ltd.	2020
3.	Royden. H. L. and Fitzpatrick. P.M., Real Analysis, 4th Ed. Pearson.	2022
4.	Apostol, T. M., Mathematical Analysis, 2nd Ed. Narosa Publishing House.	2002
5.	Lang. S., Real and Functional Analysis, Springer-Verlag.	1993
6.	D. J. H, Garling, "A Course in Mathematical Analysis" Volume 2.	2014
7.	Robert G. Bartle, Donald R. Sherbert, Introduction to Real Analysis, John Wiley & Sons, Inc.	2010

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Mathematics

1. **Subject Code:** MA-410 **Course Title**: Topology
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 03 **Practical:** 00
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 04 6. **Semester:** Spring 7. **Subject Area:** PCC
8. **Pre-requisite:** Basic knowledge of real analysis.
9. **Objective:** To introduce the elementary properties of topological spaces and structures defined on them.
10. **Details of the Course:**

S.No.	Contents	Contact hours
1	**Review of set theory:** Finite, countable and uncountable sets, functions, relations, axiom of choice, Zorn's lemma.	4
2	**Topological spaces and continuous functions:** Open sets, closed sets, basis for a topology, sub basis, Hausdorff spaces, order topology, product topology, subspace topology, limit points, continuous functions, general product topology, metric spaces and their topology, quotient topology, gluing, and identification spaces.	14
3	**Connectedness and compactness:** Connected spaces, connected subspaces, path connected spaces, locally connected spaces, connected components, compact spaces, limit point compactness, local compactness, one-point compactification.	12
4	**Countability and separation axiom:** Countability axioms, separation axioms, regular and normal spaces, Urysohn's lemma, Urysohn metrization theorem, Tietze extension theorem, Tychonoff theorem.	12
Total		**42**

11. **Suggested Books:**

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	Munkres, J.R., "Topology", 2nd edition, Prentice-Hall India.	2010
2.	Janich, K., "Topology", 8th edition, Springer-Verlag, UTM series.	2005
3.	Simmons, G.F., "Introduction to Topology & Modern Analysis", Krieger Publishing Company.	2003
4.	Armstrong, M. A., "Basic Topology", Springer-Verlag, UTM series.	1983
5.	Gamelin, T.W. and Greene, R.E., "Introduction to Topology", 2nd Ed., Dover Publications.	1999
6.	Min, Y., "Introduction to Topology: Theory & Applications", Higher Education Press.	2010

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Mathematics

1. **Subject Code:** MA-411 **Course Title**: Theory of Ordinary Differential Equations
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 03 **Practical:** 00
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 04 6. **Semester:** Spring 7. **Subject Area:** PCC
8. **Pre-requisite:** Basic concepts of ordinary differential equations.
9. **Objective:** To introduce the theoretical concepts of ordinary differential equations.
10. **Details of the Course:**

S.No.	Contents	Contact hours
1.	Existence, uniqueness and continuation of solutions of first order differential equations and system of differential equations, differential and integral inequalities, fixed point methods.	9
2.	Linear systems, properties of homogeneous and non-homogeneous systems, behaviour of solutions of n^{th} order linear homogeneous equations.	7
3.	Review of power series, Power series solution of second order homogeneous equations, ordinary points, regular singular points, Legendre's and Bessel's equations, solution of Gauss hypergeometric equations, oscillation theory, Sturm's separation and comparison theorems.	6
4.	Boundary value problems for second order differential equations, Green's function and its applications, eigenvalue problems, self-adjoint form, Sturm-Liouville problem and its applications.	8
5.	Autonomous systems, phase plane and its phenomena, critical points and stability for linear and non-linear systems, Lyapunov's direct method, periodic solutions, limit cycle, the Poincare-Bendixson theorem.	12
Total		**42**

11. **Suggested Books:**

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	Braun, M. "Differential Equations and Their Applications", 4th Ed., Springer.	2011
2.	Brauer, F. and Nohel, J.A., "The Qualitative Theory of Ordinary Differential Equations", Dover Publications.	1989
3.	Coddington, E. A. and Levinson, N., "Theory of Ordinary Differential Equations", McGraw Hill Education.	2017
4.	Deo, S.G., Lakshmikantham, V., and Raghvendra, V., "Text Book of Ordinary Differential Equations", 2nd Ed., Tata McGraw Hill.	2010
5.	Simmons, G.F., "Ordinary Differential Equations with Applications and Historical Notes", 3rd Ed., CRC Press.	2017
6.	Agarwal, R.P. and O'Regan, D., "An Introduction to Ordinary Differential Equations", Springer-Verlag.	2008
7.	Ahmad, S. and Rao, M.R.M., "Theory of Ordinary Differential Equations", Affiliated East-West Press Private Limited.	2014