INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Mathematics

1. **Subject Code:** MA-401 **Course Title**: Abstract Algebra
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:** 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.	Name of Authors/Book/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: Department of Mathematics

1. **Subject Code:** MA-402 **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/Book/Publisher	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, SpringerVerlag, 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: Department of Mathematics

1. **Subject Code:** MA-403 **Course Title**: Introduction to Computer Programming
2. **Contact Hours:** **L:** 3 **T:** 0 **P:** 2
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 10-25 **PRS:** 25 **MTE:** 15-25 **ETE:** 30-40 **PRE:** 0
5. **Credits:** 4 **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:

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.	Name of Authors/Book/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: Department of Mathematics

1. **Subject Code:** MA-404 **Course Title**: Functional 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:** 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: Department of Mathematics

1. **Subject Code:** MA-405 **Course Title**: Linear Algebra
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:** 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: Department of Mathematics

1. **Subject Code:** MA-406 **Course Title:** Technical Communication
2. **Contact Hours:** **L:** 2 **T:** 0 **P:** 0
3. **Examination Duration (Hrs):** Seminar mode
4. **Relative Weightage:** **CWS:** 100 **PRS:** 0 **MTE:** 0 **ETE:** 0 **PRE:** 0
5. **Credits:** 2 **6. Semester:** Spring **7. Subject Area:** PCC
8. **Pre-requisite:** Nil
9. **Objective:** To introduce the basics of Communication techniques in mathematics.
10. **Detail of Course:**

S.No.	Contents	Contact Hours
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. Suggested Books:

S.No.	Name of Authors/Book/Publisher	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: Department of Mathematics

1. **Subject Code:** MA-407 **Course Title**: Probability and Statistics
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:** Autumn **7. Subject Area:** PCC
8. **Pre-requisite:** Nil
9. **Objective:** To introduce the basic concepts of probability and statistics.
10. **Details of the Course:**

S.No.	Contents	Contact Hours
1.	**Random variables**: Distribution functions, probability mass function and probability density function, moments and moment generating functions.	4
2.	**Special distributions**: Binomial, Poisson, negative binomial, geometric, hypergeometric, uniform, exponential, gamma, beta, Weibull, normal, lognormal.	6
3.	**Bivariate random variables:** Joint, marginal and conditional distributions, statistical independence, product moments, correlation, regression, functions of random variables and their probability distributions.	7
4.	**Convergence of random variables:** Modes of convergence, Chebyshev's inequality, law of large numbers, central limit theorem	3
5.	**Random sampling**: Random sampling with replacement and without replacement, sampling distribution of samples from normal population: normal, t, χ^2, F distributions.	4
6.	**Theory of estimation**: Basic concepts of estimation, point estimation, method of moments, method of maximum likelihood, unbiasedness, consistency, efficiency, minimum variance estimation, interval estimation.	9
7.	**Testing of hypothesis**: Null and alternative hypothesis, type I and II errors, power function, Neyman Pearson lemma, uniformly most powerful tests, tests for one sample and two sample problems for normal populations, tests for proportions.	9
Total		**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication/ Reprint
1	Hogg, R. V., McKean, J. and Craig, A., Introduction to Mathematical Statistics, Pearson Education, 8th Ed.	2019
2.	Miller, I. and Miller, M., John E. Freund's Mathematical Statistics with Applications, Prentice Hall, 8th Ed.	2013
3.	Rohatgi, V. K. and Md. Ehsanes Saleh, A. K., An Introduction to Probability and Statistics, John Wiley and Sons, 2nd Ed.	2000
4.	Casella, G., Berger, R. L., Statistical Inference, Duxbury Press, 2nd Ed.	2002
5.	Lehmann, E.L. and Romano J.P., Testing Statistical Hypotheses, Springer, 3rdEd.	2010
6.	Papoulis, A. and Pillai, S.U., Probability, Random Variables and Stochastic Processes, Tata McGraw-Hill, 4th Ed.	2021

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of 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:** 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:** 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-uniquenessof 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: Department of Mathematics

1. **Subject Code:** MA-409 **Course Title**: Real 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:** 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, JohnWiley & Sons, Inc.	2010

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Mathematics

1. **Subject Code:** MA-410 **Course Title**: Topology
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:** 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, subspacetopology, 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: Department of 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:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Autumn **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 HistoricalNotes", 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

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Mathematics

1. **Subject Code:** MA-501 **Course Title**: Numerical 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:** 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: Department of Mathematics

1. **Subject Code:** MA-503 **Course Title**: Operations Research
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:** 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