# INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mathematics**

1. Subject Code: **MAN-511** Course Title: **Theory of Ordinary Differential Equations**

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

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

4. Relative Weightage**: CWS: 25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 0**

5. Credits**: 3** 6. Semester**: Autumn** 7. Subject Area**: PCC**

8. Pre-requisite**: Nil**

9. Objective: To introduce the theoretical concepts of ordinary differential equations.

10. Details of Course:

| S. No. | Contents | Contact Hours |
|---|---|---|
| **1.** | Existence, uniqueness and continuation of solutions of a differential equation 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, solution of Gauss hypergeometric equations, Hermite and Chebyshev polynomials. | **8** |
| **4.** | Boundary value problems for second order differential equations,Green's function and its applications. Eigen value problems, self adjoint form, Sturm –Liouville problem and its applications. | **8** |
| **6.** | Autonomous systems, phase plane and its phenomenon, critical points and stability for linear and non linear systems, Liapunov's direct method, periodic solutions, limit cycle, Poincare-Bendixson theorem. | **10** |
| | **Total** | **42** |

11. Suggested Books:

| S.No. | Name of Authors / Books / Publishers | 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., "Ordinary Differential Equations", Tata McGraw Hill | 2002 |
| 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., "Differential Equations with Applications and Historical Notes", 2nd Edition, Tata McGraw Hill | 2003 |

# INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mathematics**

1. Subject Code: **MAN-512** 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: 25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 0**
5. Credits**: 4** 6. Semester**: Spring** 7. Subject Area**: PCC**
8. Pre-requisite**: Nil**
9. Objective: To impart knowledge of numerical analysis in solving differential equations.
10. Details of Course:

| S. No. | Contents | Contact Hours |
|---|---|---|
| **1.** | **Computations of Eigen-values of a Matrix:** Power method for dominant, sub-dominant and smallest eigen-values, Method of inflation, Jacobi, Givens and Householder methods for symmetric matrices, LR and QR methods. | **10** |
| **2.** | **Solutions of ODE:** Multistep methods, predictor-corrector Adam-Bashforth Milne 's method, their error analysis and stability analysis. | **6** |
| **3.** | **Finite Differences:** Review of finite difference operators, finite difference methods, inverse interpolation, their developments and applications | **6** |
| **4.** | **Elliptic PDE:** Five point formulae for Laplacian, replacement for Dirichlet and Neumann's boundary conditions, curved boundaries, solution on a rectangular domain, block tri-diagonal form and its solution using method of Hockney, condition of convergence | **5** |
| **5.** | **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. | **5** |
| **6.** | **Hyperbolic PDE:** Solution of hyperbolic equations using FD, and Method of characteristics ,Limitations and Error analysis | **5** |
| **7.** | **Weighted Residual Methods:** Collocation, least squares, Galerkins, Rayleigh-Ritz methods and their compatibility | **5** |
| | **Total** | **42** |

11. Suggested Books:

| S.No. | Name of Authors / Books / Publishers | Year of Publication/ Reprint |
|---|---|---|
| 1. | Gerald, C. F. and Wheatly P. O., "Applied Numerical Analysis", 6th Ed., Addison-Wesley Publishing | 2002 |
| 2. | Smith, G. D., "Numerical Solution of Partial Differential Equations", Oxford University Press. | 2001 |
| 3. | Jain, M. K., "Numerical Solution of Differential Equations", John Wiley. | 1991 |
| 4. | Fausett, L. V., "Applied Numerical Analysis", Prentice Hall, 2nd Ed. | 2007 |
| 5. | Froberg, C. E., "Introduction to Numerical Analysis", 2nd Ed., Addison Wesley. | 2004 |

# INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mathematics**

1. Subject Code: **MAN-513** 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: 25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 0**
5. Credits**: 4** 6. Semester**: Autumn** 7. Subject Area**: PCC**
8. Pre-requisite**: Nil**
9. Objective: To impart the knowledge of advanced topics in theory of real functions and metric space properties

10. Details of Course:

| S. No. | Contents | Contact Hours |
|---|---|---|
| **1.** | **Riemann Integrals:** Existence and properties of the integrals, Fundamental theorem of calculus, first and second mean value theorems. | **10** |
| **2.** | **Metric Spaces:** Review of complete metric spaces, compact metric spaces, compactness and uniform continuity and connected metric spaces. | **12** |
| **3.** | **Measures:** Introduction to the properties of general measure and measurable spaces, Borel algebras, complete measure. | **5** |
| **4.** | **Lebesgue Measures:** Measurable sets and their properties, translation invariance and completeness of Lebesgue measure, Lebesgue integral of a simple function, comparison of Lebesgue and Riemann integrals. | **15** |
| | **Total** | **42** |

11. Suggested Books:

| S.No. | Name of Authors/ Books/Publishers | Year of Publication/Reprint |
|---|---|---|
| 1. | Aliprantis, C.D.and Burkinshaw, W., "Principles of Real Analysis", Elsevier. | 2011 |
| 2. | Apostol, T.M., "Mathematical Analysis", Narosa Publishing House. | 2002 |
| 3. | Barra, G.D., "Measure Theory and Integration", Woodhead Publishing. | 2003 |
| 4. | Lang, S., "Real and Functional Analysis", Springer-Verlag. | 1993 |
| 5. | Rana, I.K., "An Introduction to Measure and Integration", Narosa Publishing House. | 2007 |
| 6. | Rudin, W., "Principles of Mathematical Analysis", McGraw-Hill Book Company. | 1976 |

# INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mathematics**

1. Subject Code: **MAN-514** 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: 25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 0**
5. Credits**: 4** 6. Semester**: Spring** 7. Subject Area**: PCC**
8. Pre-requisite**: Nil**
9. Objective: To introduce some advanced topics of linear algebra.
10. Details of Course:

| S.No. | Contents | Contact Hours |
|---|---|---|
| 1 | **Vector Spaces and Linear Transformations:** Review of vector spaces, basis and dimension, examples of infinite dimensional spaces, ordered bases and coordinates, linear transformations, algebra of linear transformations, rank-nullity theorem, matrix representation of a linear transformation, change of basis, linear functional, dual spaces, reflexivity. | **8** |
| 2 | **Modules:** Review of basic properties of modules, rank of a free module and epimorphisms, Noetherian module, Hilbert basis theorem, free module over a principal ideal domain, torsion free and free modules, primary decomposition, cyclic decomposition of a primary module, the invariant factor decomposition. | **8** |
| 3 | **Linear Operators:** Brief review, the module associated with a linear operator, orders and the minimal polynomial, cyclic modules and cyclic subspaces, the decomposition of vector space V, the rational canonical form, characteristic polynomial of an operator, eigenvalues and eigenvectors of linear operators, eigen-space, minimal polynomial, Jordan canonical form, triangularizability and Schur'slemma, diagonalizable operators, projections, algebra of projections, resolution of the identity, spectral resolution, exponential of a square matrix | **12** |
| 4 | **Inner Product Spaces:** Inner product between two vectors, orthogonal and orthonormal vectors, normed space, isometries, projection theorems and best approximations, orthogonal direct-sum, Riesz representation theorems, adjoint of a linear operator, unitary diagonalizability, normal operators, special types of normal operators, self-adjoint operators, unitary operators and isometries, structure of normal operators, orthogonal projection, orthogonal resolution of identity, spectral theorem, positive operators. Gram-Schmidt process for orthogonalisation, projection operator, quadratic forms, positive definite forms. | **14** |
| | **TOTAL** | **42** |

11. Suggested Books:

| S.No. | Name of Authors / Books / Publishers | Year of Publication/ Reprint |
|---|---|---|
| 1. | Roman,S., “Advanced Linear Algebra”, 3rd Edition, Springer | 2007 |
| 2. | Hoffman, K. and Kunze, R., "Linear Algebra", 2nd Edition, Pearson Education (Asia) Pvt. Ltd/ Prentice Hall of India | 2004 |
| 3. | Leon, S.J., "Linear Algebra with Applications", 8th Edition, Pearson | 2009 |
| 4. | Olver, P. J. and Shakiban, C., "Applied Linear Algebra", 1st Edition , Prentice Hall | 2005 |
| 5. | Strang, G., "Linear Algebra and its Applications", 3rd Edition, Thomson Learning Asia Pvt Ltd | 2003 |

# INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mathematics**

1. Subject Code: **MAN-515** Course Title: **Topology**

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

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

4. Relative Weightage**: CWS: 25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 0**

5. Credits**: 3** 6. Semester**: Autumn** 7. Subject Area**: PCC**

8. Pre-requisite**: Nil**

9. Objective: To impart the knowledge of the basic concepts of Topology.

10. Details of Course:

| S.No. | Contents | Contact Hours |
|---|---|---|
| **1** | **Introduction:** Finite, countable, uncountable sets, functions, relations, axiom of choice, Zorn's Lemma | **2** |
| **2** | **Topological Spaces and Continuous Functions:** Open sets, closed sets, basis for a topology, sub basis, $T_1$ and $T_2$ spaces, order topology, product topology, subspace topology, limit point, continuous function, general product topology, metric space and its topology, quotient topology | **14** |
| **3** | **Connectedness and Compactness:** Connected spaces, connected subspaces, local connectedness, compact subspace, limit point compactness, local compactness | **12** |
| **4** | **Countability and Separation Axioms:** Countability axioms, separation axioms, regular and normal spaces, Urysohn's Lemma, Urysohn Metrization Theorem, Tietze Extension Theorem, Tychonoff Theorem | **14** |
| | **TOTAL** | **42** |

11. Suggested Books:

| S.No. | Name of Authors / Books / Publishers | Year of Publication/ Reprint |
|---|---|---|
| 1. | Munkres, J.R., "Topology", 2nd Edition, PHI | 2010 |
| 2. | Mansfield, M.J., "Introduction to Topology", East-West Student Edition | 1973 |
| 3. | Simmons, G.F., "Introduction to Topology and Modern Analysis", Krieger Publishing Company. | 2003 |
| 4. | Mendelson, B., "Introduction to Topology," 3rd Edition, Dover Publications | 1988 |
| 5. | Gamelin, T.W. and Greene, R.E., "Introduction to Topology", 2nd Edition, Dover Publications | 1999 |
| 6. | Min, Y., "Introduction to Topology: Theory & Applications", Higher Education Press | 2010 |

# INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mathematics**

1. Subject Code: **MAN-516** Course Title: **Probability & Statistics**
2. Contact Hours: **L: 3** **T: 1** **P: 0**
3. Examination Duration (Hrs.): **Theory: 3** **Practical: 0**
4. Relative Weightage**: CWS: 25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 0**
5. Credits**: 4** 6. Semester**: Spring** 7. Subject Area**: PCC**
8. Pre-requisite**: Nil**
9. Objective: To impart knowledge of Probability and Statistics.
10. Details of Course:

| S.No. | Contents | Contact Hours |
|---|---|---|
| 1 | **Random variables:** Distribution functions, probability mass function and probability density function, moments and moment generating functions. Chebyshev's inequality, law of large numbers, central limit theorem | 07 |
| 2 | **Special distributions:** Binomial, Poisson, Negative binomial, Geometric, Hypergeometric. Uniform, Exponential, Gamma, Beta, Weibull, Normal, Lognormal, Pearsons. | 06 |
| 3 | **Bivariate random variables:** Statistical independence, joint, marginal, conditional distribution, Product moment, correlation, regression , function of random variables and their probability distribution. | 07 |
| 4 | **Sampling:** Random sampling with replacement and without replacement, Sampling distribution on samples from normal population: normal, t, $\chi^2$, F distribution. | 04 |
| 5 | **Theory of estimation:** Basic concepts of estimation, point estimation, methods of estimation, method of moments, method of maximum likelihood, unbiasedness, minimum variance estimation, interval estimation. | 09 |
| 6 | **Testing of hypothesis:** Null and alternative hypothesis, type I and II errors, power function, method of finding tests, likelihood ratio test, Neyman Pearson lemma, uniformly most powerful tests, some results based on normal population. | 09 |
| | **TOTAL** | 42 |

11. Suggested Books:

| S.No. | Name of Authors / Books / Publishers | Year of Publication/ Reprint |
|---|---|---|
| 1. | Miller, I. and Miller, M: John E. Freund's Mathematical Statistics with Applications, 7th Edition, Prentice Hall. | 2006 |
| 2. | Hogg, R. V., McKean, J. and Craig, A.: Introduction to Mathematical Statistics, 7th Edition, Pearson Education. | 2006 |
| 3. | Rohatgi, V.K and Md. Ehsanes Saleh, A.K.: An Introduction to Probability and Statistics, 2nd Edition, John Wiley and Sons. | 2000 |
| 4. | Casella, G., Berger, R..: Statistical Inference, 2nd Edition, Duxbury Press | 2002 |
| 5. | Rao, C.R. : Linear Statistical Inference and its Applications, 2nd Edition, Wiley Eastern Ltd. | 2002 |
| 6. | Lehmann, E.L. and Romano J. P.: Testing Statistical Hypothesis, 3rd Edition, Springer. | 2005 |
| 7. | Lehmann, E.L. and Casella G.: Theory of Point Estimation, 2nd Edition, Springer. | 1998 |
| 8. | Papoulis, A. and Pillai, S.U.: Probability, Random Variables and Stochastic Processes, 4th Edition, Tata McGraw-Hill. | 2002 |

# INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mathematics**

1. Subject Code: **MAN-517** 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: 25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 0**
5. Credits**: 4** 6. Semester**: Autumn** 7. Subject Area**: PCC**
8. Pre-requisite**: Nil**
9. Objective: To give an introduction to the basic concepts of Abstract Algebra.
10. Details of Course:

| S. No. | Contents | Contact Hours |
|---|---|---|
| **1.** | **Groups:** Groups and their homomorphisms, Normal Subgroups, Quotient Groups, Isomorphism Theorems. Group actions, Cayley's Theorem, Class Equation of a group, Cauchy's Theorem, p-groups, Sylow' s Theorems and their applications. | **15** |
| **2.** | **Rings:** Rings, Ideals and Homomorphisms, Quotient rings, Isomorphism theorems, Prime and Maximal ideals, Rings of fractions, Integral domain, Euclidean Domains, Principal Ideal Domains and Unique Factorization Domains. Polynomial rings over UFD's, Criteria for irreducibility of polynomials over UFD's. | **12** |
| **3.** | **Modules:** Basic definitions and examples, Submodules and Direct sums, Quotient modules, Homomorphism and Isomorphism theorems, Cyclic modules, Free modules. | **5** |
| **4.** | **Fields:** Fields and their extensions, Algebraic and finitely generated field extensions, Splitting fields and normal extensions, Algebraic closures, Finite fields, Separable and inseparable extensions. Galois groups, Fundamental Theorem of Galois Theory. | **10** |
| | Total | **42** |

11. Suggested Books:

| S.No. | Name of Authors / Books / Publishers | Year of Publication/ Reprint |
|---|---|---|
| 1. | Dummit D. S. and Foote R. M., "Abstract Algebra", John Wiley & Sons (3rd Edition) | 2003 |
| 2. | Bhattacharya P. B., Jain S. K. and Nagpaul S. R., "Basic Abstract Algebra", Cambridge University Press (2nd Edition) | 1995 |
| 3. | Herstein I. N., "Topics in Algebra", John Wiley & Sons (2nd Edition) | 1999 |
| 4. | Hungerford T. W., "Algebra", Springer | 1980 |
| 5. | Lang S., "Algebra", Springer (3rd Edition) | 2005 |
| 6. | Jacobson N., "Basic Algebra Vol. 1" Dover Publications (2nd Edition) | 2009 |

# INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mathematics**

1. Subject Code: **MAN-518** Course Title: **Theory of Partial Differential Equations**
2. Contact Hours: **L: 3** **T: 0** **P: 0**
3. Examination Duration (Hrs.): **Theory: 3** **Practical: 0**
4. Relative Weightage**: CWS: 25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 0**
5. Credits**: 3** 6. Semester**: Spring** 7. Subject Area**: PCC**
8. Pre-requisite**: Nil**
9. Objective: To provide the knowledge of theoretical concepts of partial differential equations.
10. Details of 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. | **6** |
| **2.** | **First Order PDE:** Partial differential equations, Origins and classification of first order PDE, Initial value problem for quasi-linear first order equations: Existence and uniqueness of solutions, Non-existence and non-uniqueness of solutions. Surfaces orthogonal to a given system of surfaces. Nonlinear PDE of first order, Cauchy method of characteristics, Compatible systems of first order equations, Charpit's method, Solutions satisfying given conditions. Jacobi's method. | **8** |
| **3.** | **Second Order PDE:** The origin of second order PDE. Equations with variable coefficients, Classification and canonical forms of second order equations in two variables. Classification of second order equations in n variables. Characteristic curves of second order equations in two variables. Importance of characteristic curves. | **5** |
| **5.** | Review of Integral Transform and Fourier series. | **2** |
| **6.** | **Elliptic Equations:** Laplace equation in Cartesian, polar, spherical and cylindrical coordinates and its solution by Fourier series method, Poisson equation in 2D. Green's function for Laplace equation, method of images, eigenfunction method for finding Green's function. | **9** |
| **7.** | **Hyperbolic Equations:** One and two dimensional wave equation, solution by method of characteristics and Fourier series method. | **7** |
| **8.** | **Parabolic Equations:** Solution of homogeneous and non-homogeneous diffusion equation (1D). Duhamel's principle. | **5** |
| | Total | **42** |

11. Suggested Books:

| S.No. | Name of Authors / Books / Publishers | Year of Publication/ Reprint |
|---|---|---|
| 1. | Zachmanoglou, E.C., Thoe, D.W., "Introduction to Partial Differential Equations with Applications", Dover Publications. | 1986 |
| 2. | Sneddon, I. N., "Elements of Partial Differential Equations", McGraw-Hill Book Company. | 1988 |
| 3. | Amarnath, T., "An Elementary Course in Partial Differential Equations", Narosa Publishing House ($2^{nd}$ Edition). | 2012 |
| 4. | Rao, K. S., "Introduction to Partial Differential Equations", PHI Learning Pvt. Ltd. ($2^{nd}$ Edition). | 2012 |
| 5. | Lawrence C. Evans, "Partial Differential Equations", American Mathematical Society | 2010 |

# INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mathematics**

1. Subject Code: **MAN-519** Course Title: **Computer Programming**
2. Contact Hours: **L: 3** **T: 0** **P: 2**
3. Examination Duration (Hrs.): **Theory: 3** **Practical: 0**
4. Relative Weightage**: CWS: 15** **PRS: 25** **MTE: 20** **ETE: 40** **PRE: 0**
5. Credits**: 4** 6. Semester**: Autumn** 7. Subject Area**: PCC**
8. Pre-requisite**: Nil**
9. Objective: To provide the basic knowledge of C++ programming.
10. Details of Course:

| S. No. | Contents | Contact Hours |
|---|---|---|
| **1.** | **Basic 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. | **07** |
| **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 such as #include, #define, #ifdef, #ifndef; 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. | **08** |
| **4.** | **Pointers:** Pointers; dynamic data and pointers, dynamic arrays, use of pointers in linked structures. | **05** |
| **5.** | **Object Oriented Programming Concepts:** Data hiding, abstract data types, classes, access control; class implementation, constructors, 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. Suggested Books:

| S.No. | Name of Authors / Books / Publishers | Year of Publication/ Reprint |
|---|---|---|
| 1. | Deitel, H. M. and Deitel, P. J., C++ How to Program. Prentice Hall, 8th Ed. | 2011 |
| 2. | Eckel, B., Thinking in C++ Volume 1 & 2. Prentice Hall, 2nd Ed. | 2003 |
| 3. | Schildt, H., C++: The Complete Reference. McGraw-Hill, 4th Ed. | 2002 |
| 4. | Lafore, R., Object-Oriented Programming in C++. Sams Publishing, 4th Ed. | 2001 |
| 5. | Lippman, S. B. and Lajoie, J. and Moo, B.E., The C++ Primer. Addison-Wesley Professional, 5th Ed. | 2012 |
| 6. | Stallings, W., Computer Organization and Architecture: Designing for Performance. Prentice-Hall, 7th Ed. | 2005 |
| 7. | Stroustrup, B., The C++ Programming Language. Addison-Wesley, 3rd Ed. | 1997 |

# INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Mathematics**

1. Subject Code: **MAN-520** 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: 25 PRS: 0 MTE: 25 ETE: 50 PRE: 0**

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

8. Pre requisite**:** A first course on Complex Analysis

9. Objective: To introduce some advanced topics of complex analysis.

10. Details of Course:

| S. No. | Contents | Contact Hours |
|---|---|---|
| **1.** | **Complex Integration:** Revisit to Cauchy integral formula, winding numbers, Morera's theorem, Maximum modulus principle, Schwarz Lemma, Meromorphic functions, the argument principle, Rouche's theorem, improper integrals, evaluation of a real integral, improper integrals involving sines and cosines, integration through branch cut. | **14** |
| **2.** | **Conformal Mapping:** Definition, bilinear transformation, cross ratio, mappings from disc to disc, disc to half plane and half plane to half plane. Mappings of elementary transformations, Schwarz, Christoffel transformations and their applications. | **10** |
| **3.** | **Applications:** Applications of conformal mapping to steady temperature, electrostatic potential, two dimensional fluid flow, stream function, Poisson integral formula, Dirichlet problem in the unit disc, Dirichlet problem in the half plane, Neumann problem for the disc and the half plane. | **12** |
| **4.** | **Analytic Continuation**: Definition and uniqueness of analytic continuation, standard method of analytic continuation using power series, the principle of reflection. | **6** |
| | Total | **42** |

11. Suggested Books:

| S. No. | Name of Authors/ Books/Publishers | Year of Publication/Reprint |
|---|---|---|
| **1.** | Ahlfors, L.V., Complex Analysis, McGraw Hill | 1988 |
| **2.** | Conway, J.B., Functions of one complex Variables I, Narosa Publishing House. | 2000 |
| **3.** | Gamelin, T.W., Complex Analysis, Springer-Verlag | 2001 |
| **4.** | Greene, R. and Krantz, S.G., Function Theory of One Complex Variable, 3rd Edition, GSM, Vol. 40, American Mathematical Society. | 2006 |
| **5.** | Lang, S., Complex Analysis, Springer-Verlag. | 2003 |
| **6.** | Mathews, J.H. and Howell, R.W., Complex Analysis for Mathematics and Engineering, Narosa | 2009 |

**INDIAN INSTITUTE OF TECHNOLOGY ROORKEE**

NAME OF DEPTT./CENTRE: **Department of Mathematics**

1. Subject Code: **MAN-531** Course Title:**Fuzzy Sets and Fuzzy Logic**

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

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

4. Relative Weightage**:** **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits**:** **3** 6. Semester**: Autumn/Spring** 7. Subject Area**: PEC**

8. Pre-requisite**:** Nil

9. Objective: To introduce the basic concepts of Fuzzy sets and Fuzzy logic.

10. Details of Course:

| S. No. | Contents | Contact Hours |
|---|---|---|
| 1 | **Fuzzy Sets and Uncertainty:** Uncertainty and information, fuzzy sets and membership functions, chance verses fuzziness, properties of fuzzy sets, fuzzy set operations. | **5** |
| 2 | **Fuzzy Relations:** Cardinality, operations, properties, fuzzy cartesian product and composition, fuzzy tolerance and equivalence relations, forms of composition operation. | **5** |
| 3 | **Fuzzification and Defuzzification:** Various forms of membership functions, fuzzification, defuzzification to crisp sets and scalars. | **5** |
| 4 | **Fuzzy Logic and Fuzzy Systems:** Classic and fuzzy logic, approximate reasoning, Natural language, linguistic hedges, fuzzy rule based systems, graphical technique of inference. | **7** |
| 5 | **Development of Membership Functions:** Membership value assignments: intuition, inference, rank ordering, neural networks, genetic algorithms, inductive reasoning. | **5** |
| 6 | **Fuzzy Arithmetic and Extension Principle:** Functions of fuzzy sets, extension principle, fuzzy mapping, interval analysis, vertex method and DSW algorithm. | **5** |
| 7 | **Fuzzy Optimization:** One dimensional fuzzy optimization, fuzzy concept variables and casual relations, fuzzy cognitive maps, agent based models. | **5** |
| 8 | **Fuzzy Control Systems:** Fuzzy control system design problems, fuzzy engineering process control, fuzzy statistical process control, industrial applications. | **5** |
| | **Total** | **42** |

11. Suggested Books:

| S. No. | Name of Books/ Authors/ Publishers | Year of publication |
|---|---|---|
| **1** | Ross, T. J., "Fuzzy Logic with Engineering Applications", Wiley India Pvt. Ltd., 3rd Ed. | **2011** |
| **2** | Zimmerman, H. J., "Fuzzy Set Theory and its Applications", Springer India Pvt. Ltd., 4th Ed. | **2006** |
| **3** | Klir, G. and Yuan, B., "Fuzzy Sets and Fuzzy Logic: Theory and Applications", Prentice Hall of India Pvt. Ltd. | **2002** |
| **4** | Klir, G. and Folger, T., "Fuzzy Sets, Uncertainty and Information", Prentice Hall of India Pvt. Ltd. | **2002** |

**INDIAN INSTITUTE OF TECHNOLOGY ROORKEE**

NAME OF DEPTT./CENTRE: **Department of Mathematics**

1. Subject Code: **MAN-532** Course Title:**Graph Theory**

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

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

4. Relative Weightage**:** **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits**:** **3** 6. Semester**: Spring** 7. Subject Area**: PEC**

8. Pre-requisite**:** Nil

9. Objective: To introduce the basic concepts of graph theory and its applications.

10. Details of Course:

| S. No. | Contents | Contact Hours |
|---|---|---|
| 1. | **Introduction to Graphs:** Definition of a graph, finite and infinite graphs, incidence of vertices and edges, types of graphs, subgraphs, walks, trails, paths, cycles, connectivity, components of a graph, Eulerian and Hamiltonian graphs, travelling salesman problem, vertex and edge connectivity, matrix representation of graphs, incidence and adjacency matrices of graphs | **10** |
| 2. | **Trees and Fundamental Circuits:** Definition and properties of trees, rooted and binary trees, counting trees, spanning trees, weighted graphs, minimum spanning tree, fundamental circuit, cut set, separability, network flows | **6** |
| 3 | **Vector Spaces Associated with Graphs:** Galois fields, vector spaces associated with graphs, orthogonal vectors and spaces | **4** |
| 4 | **Planar graphs and Graph Coloring:** Planar graphs, Kuratowski's graphs, detection of planarity, Euler's formula for planar graphs, geometric and combinatorial duals of a planar graphs, coloring of graphs, chromatic numbers, chromatic polynomial, chromatic partitioning, Four color theorem. | **6** |
| 5 | **Directed Graphs:** Types of digraphs, digraphs and binary relations directed paths and connectedness, Euler digraphs, de Brujin sequences, tournaments | **6** |
| 6 | **Ramsey Theory:** Introduction to Ramsey theory, Ramsey numbers, Ramsey theorem | **4** |
| 7 | **Enumerations:** Types of enumerations, Polya theory of enumeration and its applications | **6** |
| | **Total** | **42** |

11. Suggested References/Books:

| S. No. | Authors/Title/Publishers | Year of Publication /Reprint |
|---|---|---|
| **1.** | Deo, N., "Graph Theory with Applications to Engineering and Computer Science", Prentice Hall India | 2004 |
| **2.** | West, D. B., "Introduction to Graph Theory ", Prentice Hall India (2nd Edition | 2009 |
| **3.** | Clark, J. and Holton, J. A.,"A First Look at Graph Theory", World Scientific | 1991 |
| **4.** | Aldous, J. M., Wilson, R. J. and Best S., "Graphs and Applications: An Introductory Approach", Springer | 2003 |
| **5.** | Deistel, R., "Graph Theory", Springer (4th Edition) | 2010 |
| **6.** | Chartrand, G. and Zhang, P., "Introduction to Graph Theory", Tata McGraw Hill | 2007 |
| **7** | Bondy, J. A. and Murty, U. S. R., "Graph Theory", Springer | 2011 |

**INDIAN INSTITUTE OF TECHNOLOGY ROORKEE**

NAME OF DEPTT./CENTRE: **Department of Mathematics**

1. Subject Code: **MAN-533** Course Title: **Integral Equations and Calculus of Variations**

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

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

4. Relative Weightage**: CWS: 25 PRS: 0 MT: 25 ETE: 50 PRE: 0**

5. Credits**: 3** 6. Semester**: Autumn/Spring** 7. Subject Area**: PEC**

8. Pre-requisite**: Nil**

9. Objective: To introduce the methods and concepts to solve integral equations and problems through calculus of variations.

10. Details of Course:

| S. No. | Contents | Contact Hours |
|---|---|---|
| **1.** | **Preliminary Concepts:** Definition and classification of linear integral equations. Conversion of initial and boundary value problems into integral equations. Conversion of integral equations into differential equations. Integro-differential equations. | **4** |
| 2. | **Fredholm Integral Equations:** Solution of integral equations with separable kernels, Eigenvalues and Eigenfunctions. Solution by the successive approximations, Numann series and resolvent kernel. Solution of integral equations with symmetric kernels, Hilbert-Schmidt theorem, Green's function approach. | **8** |
| **3.** | **Classical Fredholm Theory:** Fredholm method of solution and Fredholm theorems. | **4** |
| **4.** | **Volterra Integral Equations:** Successive approximations, Neumann series and resolvent kernel. Equations with convolution type kernels. | **4** |
| **5.** | **Solution of Integral Equations by Transform Methods:** Singular integral equations, Hilbert-transform, Cauchy type integral equations. | **6** |
| **6.** | **Calculus of Variations:** Basic concepts of the calculus of variations such as functionals, extremum, variations, function spaces, the brachistochrone problem. Necessary condition for an extremum, Euler's equation with the cases of one variable and several variables, Variational derivative. Invariance of Euler's equations. Variational problem in parametric form. | **10** |
| **7.** | **General Variation:** Functionals dependent on one or two functions, Derivation of basic formula, Variational problems with moving boundaries, Broken extremals: Weierstrass –Erdmann conditions. | **6** |
| | **Total** | **42** |

11. Suggested References/Books:

| S. No. | Authors/Title/Publishers | Year of Publication /Reprint |
|---|---|---|
| **1.** | Jerry, A. J., Introduction to Integral Equations with Applications, Wiley Publishers ($2^{nd}$ Edition) | **1999** |
| **2.** | Chambers, L. G., Integral Equations: A Short Course, International Text Book Company Ltd. | **1976** |
| **3.** | Kanwal R. P., Linear Integral Equations, Birkhäuser Bosten, ($2^{nd}$ Edition) | **1997** |
| **4.** | Hochstad H., Integral Equations, John Wiley & Sons | **1989** |
| **5.** | Gelfand, I. M., Fomin, S. V., Calculus of Variations, Dover Books | **2000** |
| **6.** | Weinstock R., Calculus of Variations with Applications to Physics and Enginering, Dover Publications. | **1974** |

**INDIAN INSTITUTE OF TECHNOLOGY ROORKEE**

NAME OF DEPTT./CENTRE: **Department of Mathematics**

1. Subject Code: **MAN-534** Course Title:**Mechanics**

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

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

4. Relative Weightage**:** **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits**:** **3** 6. Semester**: Spring** 7. Subject Area**: PEC**

8. Pre-requisite**:** Nil

9. Objective: To introduce the basic concepts of mechanics.

10. Details of Course:

| S. No. | Contents | Contact Hours |
|---|---|---|
| 1 | **Equilibrium of forces in 3D:** Condition of equilibrium for a system of forces in 3D, finite and infinitesimal displacements of a rigid body, work, potential energy virtual work, D'Alembert' s principle. | **6** |
| 2 | **Motion of rigid body:** General motion of a rigid body, momental ellipsoid and principal axes, kinetic energy and angular momentum of a rigid body, principles of energy and momentum, moving frames of reference, Coriolis force. | **12** |
| 3 | **Lagrange's and Hamilton theory:** Generalized forces, Lagrange's equation of motion, Lagrangian function, generalized momentum, deduction of principle of energy from Lagrange's equations (conservative field), Lagrange's equations with impulsive forces, Hamilton formulation, Hamilton to Lagrangian, Ignoration of coordinate and Routh's product procedure, Hamilton principle, Lagrange's equations by variational methods, derivative of Lagrange's equation from Hamilton principle. | **12** |
| 4 | **Small oscillations:** The general theory of small oscillation, stable equilibrium and small oscillation, the approximate forms of T and V, normal modes, orthogonality of normal modes. | **12** |
| | **Total** | **42** |

11. Suggested Books:

| S. No. | Name of Books/ Authors/ Publishers | Year of publication |
|---|---|---|
| **1** | Synge, J.L. and Griffith, B.A., *"*Principles of Mechanics*"*, McGraw-Hill | **1970** |
| **2** | Gregory, R.D., *"*Classical Mechanics*"*, First South Asian Edition, Cambridge Univ. Press | **2008** |
| **3** | Goldstein, H., *"*Classical Mechanics*"*, Addison-Wesley Publishing Company | **1970** |
| **4** | Rana, N.C and Joag, P.S,"Classical Mechanics", Tata McGraw-Hill. | **1991** |
| **5** | Louis, N. Hand and Janet, D. Finch, Analytical Mechanics, Cambridge University Press. | **1998** |
| **6** | Ramsey, A.S., *"*Dynamics Part II*"*, Cambridge Univ. Press | **1961** |

# INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

**NAME OF DEPTT./CENTRE: Department of Mathematics**

1. Subject Code: **MAN-611** Course Title: **Functional Analysis**

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

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

4. Relative Weightage**: CWS: 25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 0**

5. Credits: **3** 6. Semester: **Autumn** 7. Subject Area: **PCC**

8. Pre-requisite: **Nil**

9. Objective: To provide the knowledge of Banach spaces, Hilbert spaces, Linear operators and their properties.

10. Details of Course:

| S. No. | Contents | Contact Hours |
|---|---|---|
| **1.** | Review of Hölder inequality, Minkowski inequality and vector spaces with examples of $\ell_p$ spaces and $L_p$ spaces. | **2** |
| **2.** | Normed linear spaces, Banach spaces with examples, convergence and absolute convergence of series in a normed linear space. | **4** |
| **3.** | Inner product spaces, Hilbert spaces, relation between Banach and Hilbert spaces. Schwarz inequality. | **2** |
| **4.** | 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** |
| **5.** | Continuity of linear maps on normed linear spaces, four equivalent norms on B(N,N′), conjugate and dual spaces, The Riesz Representation Theorem. | **5** |
| **6.** | Adjoint operators, self adjoint operators, normal operators, unitary operators on Hilbert spaces (H) and their properties. Isometric isomorphism of H onto itself under unitary operators and their importance. Projection operators on Banach spaces and Hilbert spaces. Orthogonal projections. | **9** |
| **7.** | Contraction mappings with examples, Banach–fixed point theorems and its applications. | **4** |
| **8.** | Eigenvalues, eigenvectors and eigen-spaces, invariant spaces, spectral theorem on finite dimensional Hilbert spaces. | **4** |
| **9.** | The Closed Graph Theorem, The Uniform Boundedness Principle and its applications, The Hahn – Banach Extension and Separation theorems, Open Mapping Theorem and its applications | **7** |
| | **Total** | **42** |

11. Suggested Books:

| S. No. | Name of Books / Authors/ Publishers | Year of Publication/Reprint |
|---|---|---|
| **1.** | Simmons, G. F., "Introduction to Topology and Modern Analysis", McGraw Hill. | **2004** |
| **2.** | Debnath L. K. and Mikusinski P., "Introduction to Hilbert Spaces with Applications", Academic Press. | **2005** |
| **3.** | Bachman G. and Narici L., "Functional Analysis", Academic Press. | **1972** |
| **4.** | Ponnusamy S., "Foundation of Functional Analysis", Narosa Publication. | **2002** |
| **5.** | Jain P. K. and Ahuja O. P., "Functional Analysis", New Age International Publishers. | **2010** |
| **6.** | Nair, M. T., "Functional Analysis: A First Course", PHI Pvt. Ltd. | **2004** |

# INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

**NAME OF DEPTT./CENTRE: Department of Mathematics**

1. Subject Code: **MAN-613** 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: 25** **PRS: 0** **MTE: 25** **ETE: 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 basic techniques of Operations Research.

10. Details of 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. | **11** |
| 2. | **Duality Theory**: Dual Simplex Method, Sensitivity Analysis, Parametric Linear Programming. | **9** |
| 3. | **Integer Program:** Cutting Plane and Branch and Bound Techniques for all Integer and Mixed Integer Programming Problems | **5** |
| **4.** | **Transportation Problems**: Transportation Problems and Assignment Problems. | **5** |
| **5.** | **Game Theory:** Graphical Method and Linear Programming Method for Rectangular Games, Saddle point, notion of dominance. | **5** |
| **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, Inventory Models. | **7** |
| | **Total** | **42** |

11. Suggested Books:

| S. No. | Name of Books / Authors/ Publishers | Year of Publication/Reprint |
|---|---|---|
| **1.** | Mohan, C. and Deep, K.: "Optimization Techniques", New Age India Pvt. Ltd, New Delhi. | **2009** |
| **2.** | Mittal, K.V. and Mohan, C.: "Optimization Methods in System Analysis and Operations Research", New Age India Pvt. Ltd, New Delhi. | **1996** |
| **3.** | Taha, H.A.: "Operations Research: An Introduction", MacMillan Pub Co., NY, Ninth Edition (Reprint). | **2013** |
| **4.** | Ravindran, A., Phillips, D.T. and Solberg, J.J.: "Operations Research: Principles and Practice", John Wiley and Sons, NY, Second Edition (Reprint). | **2012** |
| **5.** | Pant, J.C.: "Introduction to Optimization/ Operations Research", Jain Brothers, New Delhi, Second Edition. | **2012** |

# INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mathematics**

1. Subject Code: **MAN-641** Course Title: **Abstract Harmonic Analysis**

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

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

4. Relative Weightage**:** **CWS** 25 **PRS** 00 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits**:** 3 6. Semester**: Spring** 7. Subject Area**: PEC**

8. Pre-requisite**:** Knowledge of Topology and Functional Analysis

9. Objective: To introduce the concepts of Harmonic Analysis and representation theory.

10. Details of Course:

| S. No. | *Contents* | Contact Hours |
|---|---|---|
| 1. | **Banach Algebras and Spectral Theory:** Basic Concepts, Gelfand theory, Nonunital Banach algebras, Spectral theorem, Theory of representation. | 9 |
| 2. | **Locally Compact Groups:** Topological groups, Haar measure, Modular functions, Convolutions, Homogenous spaces. | 8 |
| 3. | **Locally Compact Abelian Groups:** Dual Group, Pontragin Duality Theorem, Closed ideals, Spectral synthesis, Bohr compactification, Peter Weyl Theorem, Fourier Analysis. | 8 |
| 4. | **Basic Representation Theory:** Unitary Representation, Representation of a Group and its Group Algebra, Functions of Positive Type, Induced Representations, Frobenius Reciprocity Theorem, Pseudo measures, Imprimitivity. | 9 |
| 5. | **Structures in Representation Theory:** Group C* Algebra, Structure of Dual Space, Tensor products, Direct Integral Decomposition, Planchelar Theorem. | 8 |
| | **Total** | 42 |

11. Suggested Books:

| S. No. | Name of Authors/ Books/Publishers | Year of Publication/Reprint |
|---|---|---|
| 1. | Folland, G. B., A Course in Abstract Harmonic Analysis, CRC Press | 1995 |
| 2. | Fell, J. M. G. and Doran R. S., Representation of C* - Algebras, Locally Compact Groups and Banach Algebra Bundles, Academic Press | 1988 |
| 3. | Hewitt, E. and Ross, K. A., Abstract Harmonic Analysis, Springer. | 1993 |
| 4. | Rudin, W., Fourier Analysis on Groups, Interscience | 1990 |

**INDIAN INSTITUTE OF TECHNOLOGY ROORKEE**

NAME OF DEPTT./CENTR: **Department of Mathematics**

1. Subject Code: **MAN-642** Course Title: **Advanced Numerical Analysis**

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

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

4. Relative Weightage**:** **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits**:** **3** 6. Semester**: Autumn/Spring** 7. Subject Area**: PEC**

8. Pre-requisite**:** Basic knowledge of numerical methods

9. Objective: To impart the knowledge of finite element methods for solving ordinary and partial differential equations.

10. Details of Course:

| S. No. | Contents | Contact Hours |
|---|---|---|
| 1. | **Basic Concepts**: Introduction to finite elements methods, comparison with difference methods. | **2** |
| 2. | **Weighted Residuals Method**: Collocations, least squares and Galerkin's method. | **4** |
| 3. | **Ritz's Method**: Variational formulation of boundary value problems, equivalence of Galerkin and Ritz methods. | **6** |
| 4. | **Applications in ODE**: Application to solve simple problem of ordinary differential equations. | **6** |
| 5. | **One Dimensional Elements**: Linear, quadratic and higher order elements in one dimension and assembly, solution of assembled system | **6** |
| 6. | **Two Dimensional Elements**: Simplex elements in two and three dimensions, quadratic triangular elements, rectangular elements, serendipity elements and isoperimetric elements and their assembly, discretization with curved boundaries | **8** |
| 7. | **Interpolation and Integration**: Interpolation functions, numerical integration, and modeling considerations. | **5** |
| 8. | **Application to PDE**: Solutions of two dimensional partial differential equations under different geometric conditions. | **5** |
| | **Total** | **42** |

11. Suggested References/Books:

| S. No. | Title/Authors/Publishers | Year of Publication |
|---|---|---|
| **1.** | Reddy, J.N.: "Introduction to the Finite Element Methods", Tata McGraw-Hill. | **2003** |
| **2.** | Bathe, K.J.,: "Finite Element Procedures", Prentice-Hall. | **2001** |
| **3.** | Cook, R.D., Malkus, D.S and Plesha, M.E.: "Concepts and Applications of Finite Element Analysis", John Wiley. | **2002** |
| **4.** | Thomas, J.R. Hughes: "The Finite Element Method: Linear Static and Dynamic Finite Element Analysis", Dover Publication. | **2000** |
| **5.** | George, R. Buchanan: "Finite Element Analysis", McGraw-Hill. | **1994** |

**INDIAN INSTITUTE OF TECHNOLOGY ROORKEE**

NAME OF DEPTT./CENTR: **Department of Mathematics**

1. Subject Code: **MAN-643** Course Title: **Algebraic Topology**

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

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

4. Relative Weightage**:** **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits**:** **3** 6. Semester**: Autumn/Spring** 7. Subject Area**: PEC**

8. Pre-requisite**:** Basic knowledge of Group Theory and Topology

9. Objective: To introduce some basic concepts of algebraic topology

10. Details of Course:

| S. No. | Contents | Contact Hours |
|---|---|---|
| **1.** | Homotopy of paths, The Fundamental Group, Introduction to Covering Spaces, The Fundamental Group of the circle, Retractions and fixed points, Brouwer's fixed point theorem, Application to the Fundamental Theorem of Algebra, The Borsuk-Ulam Theorem, Deformation retracts, Homotopy equivalence, Fundamental group of product of spaces, Fundamental groups of the $n$-sphere $S^n$, the torus, the punctured plane, and the real projective n-space $RP^n$. | **14** |
| **2.** | Free Products of groups, Free groups, The Seifert - van Kampen Theorem, Fundamental group of a wedge of circles, Definition and construction of cell complexes, Application of van Kampen Theorem to cell complexes. | **8** |
| **3.** | Triangulations, Simplicial complexes, Barycentric subdivision, Simplicial mappings, homology groups and the simplicial approximation theorem, Calculations for cone complex, $S^n$, The Euler-Poincare formula. The Lefschetz fixed point theorem. Singular homology groups, Topological invariance. The exact homology sequence. The Eilenberg Steenrod axioms. | **12** |
| **4.** | Covering spaces, unique lifting theorem, path-lifting theorem, covering homotopy theorem, Criterion of lifting of maps in terms of fundamental groups, Universal coverings and its existence, Special cases of manifolds and topological groups. | **8** |
| | **Total** | **42** |

11. Suggested Books:

| S. No. | Title/Authors/Publishers | Year of Publication |
|---|---|---|
| **1.** | Munkres, J. R. : "*Topology*", Prentice Hall India (2nd Ed.) | **2000** |
| **2.** | Armstrong, M. A.: "*Basic Topology*", Springer International Edition | **2004** |
| **3.** | Hatcher, A.: "*Algebraic Topology*", Cambridge University Press | **2001** |
| **4.** | Massey, W. S.: "*A Basic Course in Algebraic Topology*", Springer International Edition | **2007** |
| **5.** | Rotman, J. J., "*An Introduction to Algebraic Topology*", Springer International Edition | **2004** |

**INDIAN INSTITUTE OF TECHNOLOGY ROORKEE**

NAME OF DEPTT./CENTRE: **Department of Mathematics**

1. Subject Code: **MAN-644** Course Title: **Approximation Theory**

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

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

4. Relative Weightage**:** **CWS** 25 **PRS** 0 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits**:** 3 6. Semester**: Spring** 7. Subject Area**: PEC**

8. Pre-requisite**:** Real Analysis and Functional Analysis

9. Objective: To provide the concepts of best approximation and various tools of approximation theory.

10. Details of Course:

| S. No. | Contents | Contact Hours |
|---|---|---|
| **1.** | Concept of best approximation in a normed linear space, Existence of the best approximation, Uniqueness problem, Convexity: uniform convexity,strict convexity and their relations, Continuity of the best approximation operator. | **10** |
| **2.** | The Weierstrass theorem, Bernstein polynomials, Korovkin theorem, Algebraic and trigonometric polynomials of the best approximation, Lipschitz class, Modulus of continuity, Integral modulus of continuity and their properties. | **10** |
| **3.** | Bernstein's inequality, Jackson's theorems and their converse theorems, Approximation by means of Fourier series. | **12** |
| **4.** | Positive linear operators, Monotone operators, Simultaneous approximation, $L^p$ - approximation, Approximation of analytic functions. | **10** |
| | **Total** | **42** |

**11. Suggested Books:**

| S. No. | Authors/Title/Publishers | Year of Publication/Reprints |
|---|---|---|
| **1.** | Cheney, E. W., "Introduction to Approximation Theory", AMS Chelsea Publishing Co. | **1981** |
| **2.** | Lorentz, G. G., "Bernstein Polynomials", Chelsea Publishing Co. | **1986** |
| **3.** | Natanson, I. P., "Constructive Function Theory Volume-I", Fredrick Ungar Publishing Co. | **1964** |
| **4.** | Mhaskar, H. M. and Pai, D. V., "Fundamentals of Approximation Theory", Narosa Publishing House | **2000** |
| **5.** | Timan, A. F., "Theory of Approximation of Functions of a Real Variable", Dover Publication Inc. | **1994** |

**INDIAN INSTITUTE OF TECHNOLOGY ROORKEE**

NAME OF DEPTT./CENTR: **Department of Mathematics**

1. Subject Code: **MAN-645** Course Title: **Coding Theory**

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

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

4. Relative Weightage**:** **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits**:** **3** 6. Semester**: Autumn/Spring** 7. Subject Area**: PEC**

8. Pre-requisite**:** Basic Abstract Algebra (Groups, Rings, Fields)

9. Objective: To give an introduction to basic concepts and techniques of coding theory.

10. Details of Course:

| S. No. | Contents | Contact Hours |
|---|---|---|
| **1.** | The communication channel, The coding problem, Block codes, Hamming metric, Nearest neighbour decoding, Linear codes, Generator and Parity-check matrices, Dual code, Standard array decoding, Syndrome decoding. | **8** |
| **2.** | Hamming codes, Golay codes, Reed-Muller codes, Codes derived from Hadamard matrices. | **5** |
| **3.** | Bounds on codes: Sphere packing bound, Perfect codes, Gilbert-Varshamov bound, Singleton bound, MDS codes, Plotkin bound.<br>Weight distributions of codes, MacWilliams identities. | **8** |
| **4.** | Algebra of polynomials, Residue class rings, Finite fields, Cyclic codes, Generator polynomial and check polynomial, Defining set of a cyclic code, BCH bound, Encoding and decoding of cyclic codes | **8** |
| **5.** | Hamming and Golay codes as cyclic codes, BCH codes, Reed-Solomon codes, Quadratic residue codes | **7** |
| **6.** | Graphical codes, Convolutional codes | **6** |
| | **Total** | **42** |

11. Suggested References/Books:

| S. No. | Title/Authors/Publishers | Year of Publication |
|---|---|---|
| **1.** | MacWilliams, F. J. and Sloane, N. J. A.: "*The Theory of Error Correcting Codes*", North Holland | **1977** |
| **2.** | Ling, S. and Xing, C.: "*Coding Theory: A First Course*", Cambridge University Press | **2004** |
| **3.** | Roth, R. M.: "*Introduction to Coding Theory*", Cambridge University Press | **2006** |
| **4.** | Pless, V.: "*Introduction to The Theory of Error Correcting Codes*" John Wiley (3rd Ed.) | **1999** |
| **5.** | Huffman, W. C. and Pless, V.: "*Fundamentals of Error Correcting Codes*", Cambridge University Press | **2003** |
| **6.** | Lint, J. H. van: "*Introduction to Coding Theory*", Springer (3rd ed.) | **1998** |
| **7.** | Moon, T. K.: "*Error Correction Coding*", John Wiley & Sons | **2005** |

**INDIAN INSTITUTE OF TECHNOLOGY ROORKEE**

NAME OF DEPTT./CENTR: **Department of Mathematics**

1. Subject Code: **MAN-646** Course Title: **Combinatorial Mathematics**

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

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

4. Relative Weightage**:** **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits**:** **3** 6. Semester**: Autumn/Spring** 7. Subject Area**: PEC**

8. Pre-requisite**:** Basic knowledge of Group theory

9. Objective: To introduce some basic concepts and techniques in combinatorics.

10. Details of Course:

| S. No. | Contents | Contact Hours |
|---|---|---|
| **1.** | Basic counting principles, Permutations and Combinations (with and without repetitions), Binomial theorem, Multinomial theorem, Counting subsets, Set-partitions, Stirling numbers | **5** |
| **2.** | Principle of Inclusion and Exclusion, Derangements, Inversion formulae | **4** |
| **3.** | Generating functions: Algebra of formal power series, Generating function models, Calculating generating functions, Exponential generating functions.<br>Recurrence relations: Recurrence relation models, Divide and conquer relations, Solution of recurrence relations, Solutions by generating functions. | **9** |
| **4.** | Integer partitions, Systems of distinct representatives. | **6** |
| **5.** | Polya theory of counting: Necklace problem and Burnside's lemma, Cyclic index of a permutation group, Polya's theorems and their immediate applications. | **7** |
| **6.** | Latin squares, Hadamard matrices, Combinatorial designs: *t*-designs, BIBDs, Symmetric designs. | **11** |
| | **Total** | **42** |

11. Suggested Books:

| S. No. | Title/Authors/Publishers | Year of Publication |
|---|---|---|
| **1.** | Lint, J. H. van, and Wilson, R. M.: "*A Course in Combinatorics*", Cambridge University Press (2nd Ed.) | **2001** |
| **2.** | Krishnamurthy, V.: "*Combinatorics: Theory and Applications*", Affiliated East-West Press | **1985** |
| **3.** | Cameron, P. J.: "*Combinatorics: Topics, Techniques, Algorithms*", Cambridge University Press | **1995** |
| **4.** | Hall, M. Jr.: "*Combinatorial Theory*", John Wiley & Sons (2nd Ed.) | **1986** |
| **5.** | Sane, S. S.: "*Combinatorial Techniques*", Hindustan Book Agency | **2013** |
| **6.** | Brualdi, R. A.: "*Introductory Combinatorics*", Pearson Education Inc. (5th Ed.) | **2009** |

**INDIAN INSTITUTE OF TECHNOLOGY ROORKEE**

NAME OF DEPTT./CENTRE: **Department of Mathematics**

1. Subject Code: **MAN-647** Course Title: **Control Theory**

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

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

4. Relative Weightage**:** **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits**:** **3** 6. Semester**: Autumn/Spring** 7. Subject Area**: PEC**

8. Pre-requisite**:** Basic concepts of matrix theory and differential equations

9. Objective: To introduce the basic mathematical concepts of Control Theory such as controllability, observability, stability and optimal control.

10. Details of Course:

| S. No. | Contents | Contact Hours |
|---|---|---|
| **1** | Mathematical models of control systems, State space representation, Autonomous and non autonomous systems, State, transition matrix, Peano series solution of linear dynamical system. | **4** |
| **2** | Block diagram, Transfer function, Realization, Controllability, Kalman theorem, Controllability Grammian, Control computation using Grammian matrix, Observability, Duality theorems, Discrete control systems, Controllability and Observability results for discrete systems. | **10** |
| **3** | Companion form, Feedback control, State observer, Realization | **6** |
| **4** | Liapunov stability, Stability analysis for linear systems, Liapunov theorems for stability and instability for nonlinear systems, Stability analysis through Linearization, Routh criterion, Nyquist criterion, Stabilizability and detachability, | **8** |
| **5** | State feedback of multivariable system, Riccatti equation, Calculus of variation, Euler- Hamiltonian equations, Optimal control for nonlinear control systems, Computation of optimal control for linear systems. | **8** |
| **6** | Control systems on Hilbert spaces, Semi group theory, Mild solution, Control of a linear system | **6** |
| | **Total** | **42** |

11. Suggested Books:

| S. No. | Name of Books/Authors/Publishers | Year of Publications / Reprints |
|---|---|---|
| **1.** | Barnett, S. "*Introduction to Mathematical Control Theory*" Clarendon press Oxford | **1975** |
| **2.** | Dukkipati, R. V.,"*Control Systems*", Narosa | **2005** |
| **3.** | Nagrath I. J. and Gopal M., *"Control System Engineering"*, New Age international | **2001** |
| **4.** | Datta, B., "*Numerical Methods for Linear Control Systems*", Academic press Elsevier | **2005** |
| **5.** | Kho , B. C.,*"Automatic Control System"*, Prentice hall | **2001** |

**INDIAN INSTITUTE OF TECHNOLOGY ROORKEE**

NAME OF DEPTT./CENTRE: **Department of Mathematics**

1. Subject Code: **MAN-648** Course Title: **Dynamical Systems**

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

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

4. Relative Weightage**:** **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits**:** **3** 6. Semester**: Autumn/Spring** 7. Subject Area**: PEC**

8. Pre-requisite**:** **Nil**

9. Objective: To provide basic knowledge of the dynamical systems.

10. Details of Course:

| S. No. | *Contents* | Contact Hours |
|---|---|---|
| 1. | **Linear Dynamical Continuous Systems:** First order equations, existence uniqueness theorem, growth equation, logistic growth, constant harvesting, Planar linear systems, equilibrium points, stability, phase space, n-dimensional linear systems, stable, unstable and center spaces | 8 |
| 2. | **Nonlinear Autonomous Systems:** Motion of pendulum, local and global stability, Liapunov method, periodic solution, Bendixson's criterion, Poincare Bendixson theorem, limit cycle, attractors, index theory, Hartman Grobman theorem, non-hyperbolic critical points, center manifolds, normal forms, Gradient and Hamiltonian systems. | 14 |
| 3. | **Local Bifurcation:** Fixed points, saddle node, pitchfork trans-critical bifurcation, Hopf bifurcation, co-dimension. | 6 |
| 4. | **Discrete Systems:** Logistic maps, equilibrium points and their local stability, cycles, period doubling, chaos, tent map, horse shoe map. | 6 |
| 5. | **Deterministic Chaos:** Duffing's oscillator, Lorenz System, Liapunov exponents, routes to chaos, necessary conditions for chaos. | 8 |
| | **Total** | 42 |

11. Suggested Books:

| S. No. | Name of Authors/ Books/Publishers | Year of Publication/Reprint |
|---|---|---|
| **1.** | Hirsch, M.W., Smale, S., Devaney, R.L. "Differential Equations, Dynamical Systems and an Introduction to Chaos", Academic Press | **2008** |
| **2.** | Strogatz, S. H., "Nonlinear Dynamics and Chaos", Westview Press | **2008** |
| **3.** | Lakshmanan, M, Rajseeker, S., "Nonlinear Dynamics", Springer | **2003** |
| **4.** | Perko,L., "Differential Equations and Dynamical Systems", Springer | **1996** |
| **5.** | Hubbard J. H., West, B. H., "Differential Equations: A Dynamical Systems Approach", Springer-Verlag | **1995** |
| **6.** | Kaplan D. , Gloss L., "Understanding Nonlinear Dynamics", Springer | **1995** |
| **7.** | Wiggins, S. "Introduction to Applied Nonlinear Dynamical Systems and Chaos", Springer-Verlag | **1990** |

**INDIAN INSTITUTE OF TECHNOLOGY ROORKEE**

NAME OF DEPTT./CENTRE: **Department of Mathematics**

1. Subject Code: **MAN-649** Course Title:**Financial Mathematics**

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

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

4. Relative Weightage**:** **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits**:** **3** 6. Semester**: Autumn/Spring** 7. Subject Area**: PEC**

8. Pre-requisite**:** Basic knowledge of probability and statistics

9. Objective: To introduce the applications of mathematics and statistics in finance.

10. Details of Course:

| S. No. | Contents | Contact Hours |
|---|---|---|
| **1** | Introduction- a simple market model : basic notions and assumptions, no– arbitrage principle. | **2** |
| **2** | Risk-free assets: time value of money, future and present values of a single amount, future and present values of an annuity, Intra-year compounding and discounting, continuous compounding. | **5** |
| **3** | Valuation of bonds and stocks: bond valuation, bond yields, equity valuation by dividend discount model and the P/E ratio approach. | **5** |
| **4** | Risky assets: risk of a single asset, dynamics of stock prices, binomial tree model, other models, geometrical interpretations of these models, martingale property. | **6** |
| **5** | Portfolio management: risk of a portfolio with two securities and several securities, capital asset pricing model, minimum variance portfolio, some results on minimum variance portfolio. | **8** |
| **6** | Options: call and put option, put-call parity, European options, American options, bounds on options, variables determining option prices, time value of options. | **6** |
| **7** | Option valuation: binomial model (European option, American option), Black-Scholes model (Analysis, Black-Scholes equation, Boundary and final conditions, Black-Scholes formulae etc). | **10** |
| | **Total** | **42** |

11. Suggested Books:

| S. No. | Name of Books/ Authors/ Publishers | Year of publication |
|---|---|---|
| **1** | Capinski M. and Zastawniak T., "Mathematics for Finance- An introduction to Financial Engineering" , Springer | **2003** |
| **2** | Teall J. L. and Hasan I., "Quantitative Methods for Finance and Investments", Blackwell Publishing | **2002** |
| **3** | Hull J.C., "Options, Futures and other Derivatives", Pearson education | **2005** |
| **4** | Chandra P., "Financial Management – Theory and Practice", Tata McGraw Hill | **2004** |
| **5** | Wilmott P.,Howison S. and Dewynne J., "The Mathematics of Financial Derivatives- A Student Introduction", Cambridge University Press | **1999** |

# INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mathematics**

1. Subject Code: **MAN-650** Course Title: **Fluid Dynamics**

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

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

4. Relative Weightage**: CWS: 25** **PRS: 0** **MTE: 25** **ETE: 50** **PRE: 0**

5. Credits**: 3** 6. Semester**: Autumn** 7. Subject Area**: PEC**

8. Pre-requisite**: Nil**

9. Objective: To introduce basic concepts of fluid dynamics.

10. Details of Course:

| S. No. | Contents | Contact Hours |
|---|---|---|
| **1.** | Lagrangian and Eulerian descriptions, Continuity of mass flow, circulation, rotational and irrotational flows, boundary surface, streamlines, path lines, streak lines, vorticity | **6** |
| **2.** | General equations of motion: inviscid case, Bernoulli's theorem, compressible and incompressible flows, Kelvin's theorem, constancy of circulation | **4** |
| **3.** | Stream function, Complex-potential, source, sink and doublets, circle theorem, method of images, Theorem of Blasius, Strokes stream function, Motion of a sphere. | **5** |
| **4.** | Helmholtz's vorticity equation, vortex filaments, vortex pair. | **2** |
| **5.** | Navier-Stokes equations, dissipation of energy, diffusion of vorticity, Steady flow between two infinite parallel plates through a circular pipe (Hagen-Poiseuille flow), Flow between two co-axial cylinders, Energy equation, Dynamical similarity | **9** |
| **6.** | Dimensional analysis, large Reynold's numbers; Laminar boundary layer equations, Similar solutions; Flow past a flat plate, Momentum integral equations, Solution by Karman-Pohlhausen methods, impulsive flow, Reyleigh problem, dynamical similarity, Thermal boundary layer equation for incompressible flow; Temperature distribution in Coutte flow and in flow past a flat plate. | **5** |
| **7.** | Mathematical formulation of the stability problem of incompressible flow, Stability of flows under different cases, Prandtl's momentum transfer theory. | **7** |
| **8** | Introduction to Complex fluids. | **4** |
| | **TOTAL** | **42** |

11. Suggested Books:

| S.No. | Title/Authors/Publishers | 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, "Laminar Boundary Layers", Dover Publications | 1963 |
| 4. | Drazin, P.G., Reid W. H., "Hydrodynamic Stability", Cambridge Press | 2004 |

**INDIAN INSTITUTE OF TECHNOLOGY ROORKEE**

NAME OF DEPTT./CENTRE: **Department of Mathematics**

1. Subject Code: **MAN-651** Course Title: **Measure Theory**

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

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

4. Relative Weightage**:** **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits**:** **3** 6. Semester**: Autumn/Spring** 7. Subject Area**: PEC**

8. Pre-requisite**:** A first course on Real Analysis

9. Objective: To provide the knowledge of Lebesgue Measure and $L^p$ spaces.

10. Details of Course:

| S. No. | Contents | Contact Hours |
|---|---|---|
| 1 | **Measure on the real line:** Introduction, Lebesgue outer measure, Measurable sets, Borel sets, Regular measure, Measurable functions, Borel and Lebesgue measurable functions. | **5** |
| 2 | **Integration of functions of a real variable:** Integration of non-negative functions, Lebesgue integral, Fatou's Lemma, Lebesgue Monotone Convergence Theorem, the general integral, Lebesgue dominated convergence theorem, integration of series, Riemann and Lebesgue integrals. | **10** |
| 3 | **Abstract measure spaces:** Measures and outer measures, extensions of measure, uniqueness of the extension, completion of a measure, measure spaces, integration with respect to a measure. | **10** |
| 4 | **Inequalities and the Lp-spaces :** Lp spaces, convex functions, Jensen's inequality, inequalities of Holder and Minkowski, convergence in measure, almost uniform convergence. | **6** |
| 5 | **Signed Measures and their Derivatives:** Signed measures and the Hahn decomposition, the Jordan decomposition, The Radon Nikodym Theorem and some applications. | **6** |
| 6 | **Complex Measures:** Total variation, absolute continuity, consequences of Radon Nikodym Theorem, Riesz Representation Theorem. | **5** |
| | **Total** | **42** |

11. Suggested Books:

| S. No. | Name of Books/Authors/Publishers | Year of publications / reprints |
|---|---|---|
| **1.** | Barra, G.D., Measure theory and Integration. Woodhead Publishing. | **2003** |
| **2.** | Natanson, I.P., Hewitt E., Boron L.F., Theory of Functions of a Real Variable, Vol. I & II, Literary Licensing, LLC | **2013** |
| **3.** | Rana, I.K., An Introduction to Measure and Integration, Narosa Publishing House. | **2007** |
| **4.** | Rudin, W., Real and Complex Analysis, 3rd Ed., McGraw Hill | **1987** |
| **5.** | Royden, H.L., "Real Analysis", The Macmillan Company. | **2010** |
| **6.** | Munroe, M.E., Introduction to Measure and Integration, Addison Wesley. | **1953** |

**INDIAN INSTITUTE OF TECHNOLOGY ROORKEE**

NAME OF DEPTT./CENTR: **Department of Mathematics**

1. Subject Code: **MAN-652** Course Title: **Number Theory**

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

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

4. Relative Weightage**:** **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits**:** **3** 6. Semester**: Spring** 7. Subject Area**: PEC**

8. Pre-requisite**: Nil**

9. Objective: To introduce basic concepts of Number Theory.

10. Details of Course:

| S. No. | Contents | Contact Hours |
|---|---|---|
| **1.** | **Divisibility and prime numbers**: Divisibility, Euclidean algorithm, linear Diophantine equations, prime numbers, fundamental theorem of arithmetic, discussion on the prime number theorem. | **6** |
| **2.** | **Congruences:** Introduction to 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. | **10** |
| **3.** | **Public key cryptography**: Introduction to public key cryptography, the RSA cryptosystem. | **3** |
| **4.** | **Quadratic residues and quadratic reciprocity**: Quadratic residues, quadratic reciprocity, the Jacobi symbols. | **6** |
| **5.** | **Some functions of number theory**: The greatest integer function, arithmetic functions, Mobius function and Mobius inversion formula. | **6** |
| **6.** | **Continued fractions**: Finite continued fractions, infinite continued fractions, approximation to irrational numbers. | **5** |
| **7.** | **Algebraic numbers**: Introduction to algebraic numbers, algebraic number fields, algebraic integers, quadratic fields, units in quadratic fields, primes in quadratic fields, unique factorization, primes in quadratic fields having the unique factorization property. | **6** |
| | **Total** | **42** |

11. Suggested Books:

| S. No. | Title/Authors/Publishers | Year of Publication |
|---|---|---|
| **1.** | Niven I., Zuckerman H. S., and Montgomery H. L., An Introduction to the Theory of Numbers, John Wiley & Sons ($5^{th}$ Ed.) | **1991** |
| **2.** | Hardy, G., H. and Wright, E. M, An Introduction to the Theory of Numbers, Oxford University Press ($6^{th}$ Ed.) | **2008** |
| **3.** | Burton D. M., Elementary Number Theory, McGraw Hill ($7^{th}$ Ed.) | **2010** |
| **4.** | Apostol T. M., Introduction to Analytic Number Theory, Springer | **1998** |
| **5.** | Baker A., A Comprehensive Course in Number Theory, Cambridge University Press | **2012** |
| **6.** | Koblitz N., A Course in Number Theory and Cryptography, Springer ($2^{nd}$ Ed.) | **1994** |

**INDIAN INSTITUTE OF TECHNOLOGY ROORKEE**

NAME OF DEPTT./CENTRE: **Department of Mathematics**

1. Subject Code: **MAN-653** Course Title: **Numerical Optimization**

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

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

4. Relative Weightage: CWS **25** PRS **0** MTE **25** ETE **50** PRE **0**

5. Credits: **3** 6. Semester: **Autumn/Spring** 7. Subject Area: **PEC**

8. Pre-requisite: Nil

9. Objective: To acquaint the students with the basic concepts of Numerical Optimization.

10. Details of Course:

| S.No. | Contents | Contact Hours |
|---|---|---|
| **1.** | **Linear Programming:** Review of various methods of linear programming | **5** |
| **2.** | **Nonlinear Programming:** 1-D Unconstrained Minimization Methods, Golden Section, Fibonnacci Search, Bisection, Newton's Methods. | **6** |
| **3.** | **Multi-dimensional Unconstrained Minimization Methods:** Cyclic Co-ordinate Method, Hookes & Jeeves continuous and discrete methods, Rosenbrock method, Nelder & Mead method, Box's Complex method, Powell method, Steepest descent method, Newton's method, conjugate gradient method. | **10** |
| **4.** | **Constrained Minimization:** Rosen's gradient projection method for linear constraints, Zoutendijk method of feasible directions for nonlinear constraints, generalized reduced gradient method for nonlinear constraints. | **6** |
| **5.** | **Penalty function methods:** Exterior point penalty, Interior point penalty. | **4** |
| **6.** | **Computer Programs of above methods**: Case studies from Engineering and Industry, Use of software packages such as LINDO, LINGO, EXCEL, TORA, MATLAB | **11** |
| | Total | **42** |

11. Suggested Books

| S. No. | Title/Authors/Publishers | Year of Publication |
|---|---|---|
| **1.** | Bazaraa, M. S., Sherali, H. D. and Shetty, C. M.:"Nonlinear Programming Theory and Algorithms", 3rd Edition, John Wiley and Sons. | **2006** |
| **2.** | Belegundu, A. D. and Chandrupatla, T. R. :"Optimization Concepts and Applications in Engineering", Pearson Education Pvt. Ltd. | **2002** |
| **3.** | Deb, K.: "Optimization for Engineering Design: Algorithms and Examples", Prentice Hall of India. | **2004** |
| **4.** | Mohan, C. and Deep, K.: "Optimization Techniques", New Age India Pvt. Ltd. | **2009** |
| **5.** | Nocedal, J. and Wright, S. J.: "Numerical Optimization", Springer Series in Operations Research, Springer-Verlag. | **2000** |

# INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mathematics**

1. Subject Code: **MAN-654** Course Title: **Orthogonal Polynomials and Special Functions**

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

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

4. Relative Weightage**:** **CWS** 25 **PRS** 0 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits**:** 3 6. Semester**: Autumn/Spring** 7. Subject Area**: PEC**

8. Pre-requisite**:** Basic knowledge of Real and Complex Analysis

9. Objective: To give in-depth knowledge of various special functions and the concepts of orthogonal polynomials.

10. Details of Course:

| S. No. | *Contents* | Contact Hours |
|---|---|---|
| 1. | **Hypergeometric functions:** Solution of homogeneous linear differential equations of second order near an ordinary and regular singular point, their convergence and solutions for large values. Differential equations with three regular singularities, hypergeometric differential equations. Gauss hypergeometric function, elementary properties, contiguous relations, integral representation, linear and quadratic transformation and summation formulae. | 8 |
| 2. | **Analytic continuation:** Barnes' contour integral representation. Confluent hypergeometric function and its elementary properties. | 4 |
| 3. | Generalized hypergeometric function $p\ q\ F$ and its elementary properties – linear and quadratic transformations, summation formula. | 4 |
| 4. | **Asymptotic series:** Definition, elementary properties, term by term differentiation and integration, theorem of uniqueness, Watson's lemma. Asymptotic expansion of 1F1 and 2F1 hypergeometric series. | 6 |
| 5. | **Orthogonal polynomials**: Definition, zeros of orthogonal polynomials, expansion in terms of orthogonal polynomials, three term recurrence relation, Christofel-Darboux formula, Bessel's inequality. Hermite, Laguerre, Jacobi and Ultraspherical polynomials: Definition and elementary properties. | 12 |

| | | |
|---|---|---|
| **6.** | Generating functions of some standard forms including Boas and Buck type. Sister Celine's techniques for finding pure recurrence relation. Characterization: Appell, Sheffes and s-type characterization of polynomial sets. | **8** |
| | **Total** | **42** |

11. Suggested Books:

| **S. No.** | **Name of Authors/ Books/Publishers** | **Year of Publication/Reprint** |
|---|---|---|
| 1. | T.S, Chihara, An Introduction to Orthogonal Polynomials, Dover Publications | 2011 |
| 2. | M.E.H. Ismail, Classical and Quantum Orthogonal Polynomials in One Variable, Cambridge University Press. | 2005 |
| 3. | F. Marcellan and W.Van Assche , Orthogonal Polynomials and Special Functions: Computation and Applications, Lecture Notes in Mathematics, Springer | 2006 |
| 4. | E.D. Rainville, Special Functions, MacMillan | 1960 |
| 5. | G. Szego, Orthogonal Polynomials, Memoirs of AMS | 1939 |

**INDIAN INSTITUTE OF TECHNOLOGY ROORKEE**

NAME OF DEPTT./CENTRE: **Department of Mathematics**

1. Subject Code: **MAN-655** Course Title:**Stochastic Processes**

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

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

4. Relative Weightage**:** **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits**:** **3** 6. Semester**: Autumn/Spring** 7. Subject Area**: PEC**

8. Pre-requisite**:** Basic concepts probability and statistics

9. Objective: To introduce the basic concepts of stochastic processes.

10. Details of Course:

| S. No. | Contents | Contact Hours |
|---|---|---|
| 1 | Introduction to stochastic processes | 2 |
| 2 | **Poisson Process:** Interarrival and waiting time distributions, conditional distributions of the arrival times, nonhomogeneous Poisson process, compound Poisson random variables and Poisson processes, conditional Poisson processes. | 8 |
| 4 | **Markov Chains:** Introduction and examples, Chapman-Kolmogorov equations and classification of states, limit theorems, transitions among classes, the Gambler's ruin problem, mean time in transient states, branching processes, applications of Markov chains, time reversible Markov chains, semi Markov processes. | 8 |
| 5 | **Continuous-Time Markov Chains:** Introduction, continuous time Markov chains, birth and death processes, The Kolmogorov differential equations, limiting probabilities, time reversibility, applications of reversed chain to queueing theory. | 8 |
| 6 | **Martingales:** Introduction, stopping times, Azuma's inequality for martingales, submartingales, supermartingles, martingale convergence theorem. | 6 |
| 7 | **Brownian Motion and other Markov Processes:** Introduction, hitting time, maximum variable, Arc sine laws, variations on Brownian motion, Brownian motion with drift, backward and forward diffusion equations. | 10 |
| | **Total** | 42 |

11. Suggested Books:

| S. No. | Name of Books/Authors/Publishers | Year of publications/ reprints |
|---|---|---|
| **1.** | Ross, S. M., "Stochastic Processes" Wiley India Pvt. Ltd., 2nd Ed. | **2008** |
| **2.** | Brzezniak, Z. and Zastawniak, T., "Basic Stochastic Processes: A Course through Exercises", Springer | **1992** |
| **3.** | Medhi, J., "Stochastic Processes", New Age Science | **2009** |
| **4.** | Resnick, S.I., "Adventures in Stochastic Processes", Birkhauser | **1999** |
| **5.** | Hoel, P.G. and Stone, C.J., "Introduction to Stochastic Processes", Waveland Press | **1986** |

## INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Mathematics**

1. Subject Code: **MAN-656** Course Title: **Wavelet Theory**

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

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

4. Relative Weightage**: CWS** 25 **PRS** 0 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits**:** 3 6. Semester**: Autumn/Spring** 7. Subject Area**: PEC**

8. Pre-requisite**:** Basic knowledge of Lebesgue theory and functional analysis.

9. Objective: To provide basic knowledge of Fourier analysis, time frequency analysis and wavelet transform.

10. Details of Course:

| S. No. | Contents | Contact Hours |
|---|---|---|
| 1. | Review of basic concepts and theorems of functional analysis and Lebesgue theory. | 4 |
| 2. | **Advanced Fourier Analysis:** Fourier transform (F.T.) of functions in $L_1(R)$. Basic properties of F.T. of functions in $L_\infty(R)$. Inverse Fourier transform, Convolution, Approximate identity. Auto correlation of functions in $L_2(R)$, F.T. of functions in $L_1(R)\cap L_2(R)$. Various versions of Parseval`s identity (P. I.) of functions in $L_1(R)\cap L_2(R)$. Evaluation of improper integrals using P.I., Plancheral theorem. | 12 |
| 3. | Trigonometric Fourier Series (TFS) of functions of $L_1[0, 2\pi]$ and its complex form. Dirichlet conditions, Gibbs phenomenon, modulus of continuity, integral modulus of continuity. Convergence of TFS in $L_1[0, 2\pi]$, Bessel`s inequality for functions of $L_2[0, 2\pi]$. Summability of TFS. The Poisson`s summation formula and its applications. | 6 |
| 4. | **Time Frequency Analysis:** Window functions and their examples. Windowed functions. The Gabor transform STFS, the uncertainty principle, the classical Shanon sampling theorem, frames, exact and tight frames. | 10 |
| 5. | **Wavelet Transform:** Isometric isomorphism between $\ell_2$ and $L_2[0, 2\pi]$, wavelet transform, wavelet series. Basic wavelets (Haar/Shannon/Daubechies), integral wavelet, orthogonal wavelets, multi-resolution analysis, reconstruction of wavelets and applications. | 10 |
| | **Total** | 42 |

11. Suggested Books:

| S. No. | Authors/Title/Publishers | Year of Publication/ Reprint |
|---|---|---|
| **1.** | Chui, C. K., An Introduction to Wavelets, Academic Press | **1992** |
| **2.** | Bachman, G. Narici, L., Beckenstein, E., Fourier and Wavelet Analysis, Springer | **2005** |
| **3.** | Chan, A. K., Peng C., Wavelets for Sensing Technology, Artech House | **2003** |
| **4.** | Daubechies, I., Ten Lectures in Wavelets, SIAM | **1992** |
| **5.** | Koorniwinder, T.H., Wavelet: An Elementary Treatment of Theory and Applications, World Scientific Publication. | **1993** |