Indira Gandhi National Tribal University

Amarkantak (M. P.)-484887

(A Central University Established by an Act of Parliament)

SYLLABUS

For Master of Science (M.Sc)

Department of Mathematics

(Faculty of Science)

Master Program in Mathematics

Course Structure (M.Sc.)

Semester-I

Subject Code	Course	Internal Assessment	Final Exam	Total	Credit
MA-401	Real Analysis	40	60`	100	4
MA-402	Operation Research	40	60	100	4
MA-403	Linear Algebra	40	60	100	4
MA-404	Ordinary Differential Equation	40	60	100	4
-	To be opted outside department	40	60	100	3
	Total Credit				**19**
MA-GE-410 (Generic)	Elementary Mathematics (To be offered for students of other departments)	40	60	100	3

Semester-II

Subject Code	Course	Internal Assessment	Final Exam	Total	Credit
MA-411	Advanced Calculus	40	60`	100	4
MA-412	Numerical Analysis	40	60	100	4
MA-413	Topology	40	60	100	4
MA-414	Partial Differential Equations	40	60	100	4
-	To be opted outside department	40	60	100	3
	Total Credit				**19**
MA-GE-420 (Generic)	Linear Programming Problems (To be offered for students of other departments.)	40	60	100	3
	Total Credit				**19**

Semester-III

Subject Code	Course	Internal Assessment	Final Exam	Total	Credit
MA-501	Complex Analysis	40	60`	100	4
MA-502	Measure Theory	40	60	100	4
MA-503	Differential Geometry	40	60	100	4
MA-504	Abstract Algebra	40	60	100	4
MA-505	Mathematical Methods (Optional)	40	60	100	4
MA-506	Discrete Mathematics (Optional)	40	60	100	4
MA-507	Fluid Mechanics (Optional)	40	60	100	4
	Total Credit				**20**

Remark: Choose any **ONE** optional.

Semester-IV

Subject Code	Course	Internal Assessment	Final Exam	Total	Credit
MA-511	Functional Analysis	40	60`	100	4
MA-512	Special Functions and Integral Transform	40	60	100	4
MA-513	Mathematical Tools and Software’s	40	60	100	2
MA-514	Graph Theory (Optional)	40	60	100	4
MA-515	Optimization Techniques (Optional)	40	60	100	4
MA-516	Number Theory (Optional)	40	60	100	4
MA-517	Advanced Numerical Analysis (Optional)	40	60	100	4
MA-518	Project Work (Optional)	40	60	100	4
	Total Credit				**18**

Remark: Choose any **TWO** optional.

Table of Contents

1. Real Analysis (MA-401)

Unit-1:
Real number system, ordering, bounded set, order completeness axiom, mathematical induction, well ordering principle, supremum and infimum, Archimedian property, Dedekind theorem, complete ordered field, open and closed sets, perfect sets, dense sets, limit point of a set, Bolzano-Weierstrass theorem, countable and uncountable sets, compactness and Heine-Borel theorem. **(Lecture: 9)**

Unit-2:
Sequences, limit of a sequence, bounded and monotonic sequence, limit superior and limit inferior, algebra of sequences, Cauchy sequences, Cauchy criterion for convergence, Cauchy's first and second limit theorems, Euler's constant, subsequence.

Series of real valued numbers, geometric series and its convergence, test for convergence: comparison tests for series of positive terms, Cauchy's root test, D'Alembert ratio test, Raabe's test, logarithmic test, integral test, Gauss test, alternating series, Leibnitz test, absolute convergence, rearrangements of terms in the series, Abel's test and Dirichlet's test, power series, Cauchy product of two series. **(Lecture: 16)**

Unit-3:
Function of single variables, limits, continuity and uniform continuity, monotonic function, functions of bounded variation, differentiability, Darboux's theorem, Rolle's theorem, Lagrange's mean value theorem, Cauchy mean value theorem. **(Lecture: 9)**

Unit-4:
Riemann integration, necessary and sufficient condition for integrability, functions defined by integrals, fundamental theorem of calculus, first and second mean value theorem of integral calculus. **(Lecture: 8)**

Unit-5:
Sequence and series of functions, pointwise, uniform convergence on an interval, test for uniform convergence, properties of uniformly convergent sequence and series, the Weierstrass approximation theorem. **(Lecture: 8)**

Text Books:

1. R. G. Bartle & D. R. Sherbert, Introduction to Real Analysis, Wiley, 2014
2. W. Rudin, Principles of Mathematical Analysis" McGraw-Hill Book Company.
3. S.C. Malik, S. Arora, Mathematical Analysis (4^{th} Edition), New Age International Publishers, 2010.

References:

1. A. H. Smith, W. A. Albrecht, Fundamental Concepts of Analysis, Prentice Hall of India, 1966.
2. N. P. Bali, Real Analysis: Golden Math Series (2011)
3. T. M. Apostol, Mathematical Analysis, Pearson; 2nd edition, 1974.
4. R.R Goldberg, Methods of Real analysis, Oxford & Ibh, 2012.
5. S. Ponnusamy, Foundations of Mathematical Analysis, Birkhäuser; 2012.

2. Operation Research (MA-402)

Unit-1:

Operations research and its scope, necessity of operations research in industry,introductions to Linear programming problems, general linear programming problems (LPP), mathematical formulation of LPP, basic feasible solutions, degenerate and non-degenerate solutions. **(Lecture 8)**

Unit-2:

Solution of LPP by graphical method, Simplex method, revised simplex method, big-M method **(Lecture 14)**

Unit-3:

Primal and dual LPP, dual Simplex Method, sensitivity analysis, transportation and assignment problems. **(Lecture 10)**

Unit-4:

Game theory, competitive game, finite and infinite game, two person zero sum game, rectangular game , solution of game, saddle point, solution of a rectangular game with saddle point. **(Lecture 8)**

Unit-5:

PERT-CPM, product planning control with PERT-CPM.**(Lecture 10)**

Text Books:

1. H. A. Taha, *Operations Research: An Introduction*, Prentice Hall of India, 1997.
2. KantiSwarup, P. K. Gupta and Man Mohan, *Operations Research*, Sultan Chand & Sons, new Delhi, 1991.
3. S. D. Sharma, Operations Research (14th edition), KedarNath Ram Nath& Co. 2004

References:

1. J.C. Pant, Introduction to Optimisation: Operations Research, Jain Brothers Delhi, 2008.
2. N. S. Combo, *Mathematical programming Techniques*, Affiliated East-West Press PVT New Delhi, (1991).

3. Linear Algebra (MA-403)

Unit-1:

Vector space, subspace, sum of subspaces, linear combination, linear dependence and independence, linear span, basis and dimension, examples of infinite dimensional spaces, bases and coordinates. **(Lecture 10)**

Unit-2:

Linear Transformation: Basic definitions, rank-nullity theorem, matrix representation, algebra of linear transformations, change of basis, linear functional, Dual Spaces. **(Lecture 10)**

Unit-3:

Canonical forms, eigen-values of linear transformations, eigen-space, minimal polynomial, diagonalisation, invariant subspaces, Jordan canonical representation, Norm of a matrix. **(Lecture 10)**

Unit-4:

Inner Product Space: Definition of inner product between two vectors, orthogonal and orthonormal vectors, normed space, Cauchy-Schwartz inequality, Gram-Schmidt process for orthogonalisation. **(Lecture 10)**

Unit-5:

Invariant subspaces and annihilators, projection operator, bilinear and quadratic forms, positive definite forms, symmetric, Hermitian, orthogonal, unitary and normal transformations/matrices. **(Lecture 10)**

Text Books:

1. K. Hoffman and R. Kunze, Linear Algebra, 2nd edition, Pearson Education (Asia) Pvt. Ltd/ Prentice Hall of India, 2004.
2. G. Strang, Linear Algebra and its Applications, 3rd edition, Thomson Learning Asia Pvt Ltd, 2003.
3. Krishnamurthy, Linear algebra, Vikas Pub. House, New Delhi, 1976.

References:

1. S.J. Leon, Linear Algebra with Applications, 8th Edition, Pearson, 2009.
2. J.O. Peter, and C. Shakiban, Applied Linear Algebra, 1st Edition, Prentice Hall, 2005.
3. L. Sudan L., Applied Linear Algebra, Prentice Hall, 2001.

4. Ordinary Differential Equation (MA-404)

Unit-1:

Ordinary differential equations, equations with variable separable, exact equations, Lipschitz condition, non-local existence of solutions, uniqueness of solutions, existence and uniqueness theorem for first and higher order equations. **(Lecture 10)**

Unit-2:

Linear differential equations with constant coefficients, initial value problems for second order differential equations, existence and uniqueness theorem, linear dependence and independence of solutions,Wronskian and linear independence.**(Lecture 10)**

Unit-3:

Linear differential equations with variable coefficients, methods of solutions, initial value problems for the homogeneous equations, existence and uniqueness theorem for solution of homogenous differential equations and *n* linearly independent solutions. **(Lecture 10)**

Unit-4:

Regular and singular points, power series and series solutions of Bessel and Legendra differential equations, Frobenius method. **(Lecture 10)**

Unit-5:

Two point boundary value problem, self-adjoint problem and properties, Strum-Liouville problem, solution by Green functions, eigenfunctions and expansion formulae, comparison and separation theorems of BVP. **(Lecture 10)**

Text Books:

1. E. A. Coddington, An Introduction to Ordinary Differential Equations, Prentice-Hall of India Private Ltd. New Delhi, 2001.
2. E. A. Codington and N. Levinson, Theory of Ordinary Differential Equations, Tata McGraw hill publishing co. Ltd. New Delhi, 1999.
3. G. F. Simmons, Differential equations with applications and historical notes (2nd edition), Tata McGraw Hill, 1991.
4. G. F. Simmons and S. G. Krantz, Differential Equations: Theory, Technique, and Practice, Tata McGraw Hill, 2006.

References:

1. W. T. Martain and E. Relssner, Elementary Differential Equations (3rd edition), Addison Wesley Publishing Company, 1995.
2. M.W. Hirsch, S. Smale, and R.L. Devaney, Differential Equations, Dynamical Systems and an Introduction to Chaos, Elsevier, 2004.
3. T. M. Mac Robert, Spherical Harmonics, Pergamon Press, 1967.

5. Elementary Mathematics (MA-GE-410)

Unit-1:

Definition of relation, types of relations- reflexive, symmetric, transitive, antisymmetric and equivalence relations, functions, types of functions- injective, surjective, bijective, many one, inverse functions, composite functions, algebra of functions.

Unit-2: Sequence and series of real numbers

Unit-3:

Limit and continuity of single variables.

Unit-4:

Differentiation, integration, definite integrals and indefinite integrals, higher order differentiation, Taylor series.

Unit-5:

Formation of differential equation, degree and order of differential equation, solution of first order first degree differential equations.

Text Books:

1. NCERT Mathematics text book for 11th and 12th Class.
2. M. R. Spiegel, Vector Analysis and introduction to Tensor Analysis, Schaum Series, McGraw-Hill.
3. N. P. Bali, Differential Equations, Golden Maths Series, published by Firewall Media ,2006.
4. S.C. Malik and S. Arora, Mathematical Analysis, New Age International, 2017.
5. B.S. Grewal, Higher Engineering Mathematics, Khanna Publishers, 2015.

6. Advanced Calculus (MA-411)

Prerequisite: Real Analysis

Unit-1:

Real-valued functions of several variables, limits, continuity, partial derivatives, directional derivatives, total derivatives, chain rule. **(Lectures 10)**

Unit-2:

Vector-valued functions of several variables, derivatives, matrix representation of derivatives, Jacobians, mean value theorem, higher order derivatives, Taylor's theorem. **(Lectures 10)**

Unit-3:

Inverse function theorem, implicit function theorem, maxima and minima of two variables functions, Lagrange method of undetermined multipliers **(Lectures 7)**

Unit-4:

Geometric interpretation of gradient, divergence and curl; parametric representation of curves and surfaces, tangent and normal to surface, line integrals, fundamental theorem of calculus, double integrals, change of variables. **(Lectures 12)**

Unit-5:

Triple integral, applications to surface area and volume, Dirichlet's theorem, Green's theorem, Stoke's theorem, Gauss divergence theorem. **(Lectures 11)**

Text Books:

1. David V. Widder, Advanced Calculus, PHI Learning, 1973.
2. Tom M. Apostol, Mathematical Analysis, Narosa Book Distributor, 2010.
3. J.N. Sharma and A.R. Vashishtha, Real Analysis, Krishna Publications, 2014.

Reference Books:

1. M. Spiegel, D. Spellman and S. Lipschutz, Vector Analysis: Schaum's Outline, McGraw Hill Education, 2009.
2. J.E. Marsden and A.J. Tromba, Vector Calculus, W.H. Freeman and Company, 2003.
3. Walter Rudin, Principles of Mathematical Analysis, McGraw Hill Education, 2017.
4. M. Spivak, Calculus on Manifolds: A Modern Approach To Classical Theorems of Advanced Calculus, Westview Press, 1971.
5. J.R. Munkres, Analysis on Manifolds, Westview Press, 1997.
6. Harold M. Edwards, Advanced Calculus: A Differential Forms Approach, Birkhauser, 2013.
7. E. Kreyszig, Advanced Engineering Mathematics, Wiley, 2011.
8. H. K. Das, Advanced Engineering Mathematics, S. Chand, 2007.

7. Numerical Analysis (MA-412)

Unit-1:

Algebraic and transcendental equations and their roots, direct and iterative methods for determination of roots of these equations, initial approximations; bisection method, secant method, Regula-Falsi method, Newton-Raphson method for determination of roots of algebraic and transcendental equations, error analysis. **(Lecture 10)**

Unit-2:

Systems of linear algebraic equations and their solutions, eigenvalue problem and its solution, direct and iterative methods, ill-conditioned method, forward and backward substitution method, Cramer's rule, Gauss elimination method,Gauss-Jordan elimination method, Gauss-Jacobi iteration method, Gauss-Seidel iteration method, SOR method, power method for eigenvalue problem, iterative method for matrix inversion, error analysis. **Lecture 10)**

Unit-3:

Interpolation, Newtons forward and backward interpolations, Lagrange interpolation, Newton divided differences interpolation, finite difference operators, backward and central differential operator and their relations, shift operator. **(Lecture 10)**

Unit-4:

Numerical differentiation, methods based on linear and quadratic interpolation with error approximation, methods based on finite differences, optimum choice of step length, numerical integration, methods based on interpolation, determination of the error term, Gauss quadrature formula, Trapezoidal rule, Simpson's rule, Weddles rule, Romberg integration, error of integration **(Lecture 10)**

Unit-5:

Numerical solution of ordinary differential equations, Taylors methods, Picard methods, initial value problems; error estimates, Euler-Richardson method, Runge-Kutta methods, Milnes methods, Adam-Basforth method, Predictor-Corrector method, error analysis. **(Lecture 10)**

Text Books:

1. M.K. Jain, S.R.K. Iyenger and R.K. Jain, Numerical Methods for scientific and Engineering computation, New Age international publishers New Delhi, 2003.
2. C. F. Gerald and P. O. Wheatley, Applied Numerical Analysis (5th edition), Addison-Wesley New York, 1998.
3. S. D. Conte and C. de Boor, Elementary Numerical Analysis: An Algorithmic Approach (3rd edition), McGraw Hill New York, 1980.
4. J. B. Scarborough, Numerical Mathematical Analysis, Oxford & IBH Publishing Co., 2001.
5. V. Rajaraman, Computer Oriented Numerical Analysis, Prentice-Hall of India Pvt. Ltd., 2002.

References:

1. M. Friedman and A. Kandel, Fundamental of Computer Numerical Analysis, CRC Press Boca Raton, 1993.
2. K. E. Atkinson, Introduction to Numerical Analysis (2^{nd}edition), John Wiley, 1989.
3. S. S. Sastry, Introductory Methods of Numerical Analysis, Prentice-Hall of India, 2005.

8. Topology (MA-413)

Prerequisite: Set Theory

Unit-1:

Metric spaces, open sets, closed sets, limit points, interior points, exterior points, boundary points, definition of Hausdorff space, convergence of sequence and continuity of functions. **(Lectures 08)**

Unit-2:

Topological spaces, basis and subbasis of topology, subspace topology, order topology, product topology, metric topology, continuous functions, homeomorphisms, pasting lemma, quotient topology. **(Lectures 10)**

Unit-3:

Compact spaces, Lebesgue number lemma, limit point compactness, sequential compactness, local compactness, one-point compactification, product of compact spaces, Tychonoff theorem. **(Lectures 12)**

Unit-4:

Separation, connected spaces, intermediate value theorem, path connectedness, local connectedness. **(Lectures-06)**

Unit-5:

First countable space, second countable space, Lindelof space, separable space, separation axioms: T_0, T_1,T_2, T_3, $T_{3\frac{1}{2}}$, T_4-spaces, Urysohn lemma, Tietze extension theorem, Urysohn metrization theorem. **(Lectures 14)**

Text Books:

1. J.R. Munkres, Topology, Pearson Education, 2015.
2. G.F. Simmons, Introduction to Topology and Modern Analysis, McGraw Hill Education, 2015.

Reference Books:

1. S. Kumaresan, Topology of Metric Spaces, Narosa, 2011.
2. K.D. Joshi, Introduction to General Topology, New Age International, 2017.
3. M.A. Armstrong, Basic Topology, Springer-Verlag, 2004.
4. J.L. Kelley, General Topology, Springer India, 2008.

9. Partial Differential Equations (MA-414)

Unit-1:

Partial differential equation (PDE) of 1st order, method of characteristics, existence and uniqueness theorems, Cauchy problems, Lagrange's, compatible system of first order equations, solutions of nonlinear partial differential equations of 1^{st} order. **(Lecture 10)**

Unit-2:

Special types of first order equations, Charpit's method-examples, Jacobi's method-example, Monge's method-examples. **(Lecture 08)**

Unit-3:

PDE of second and higher orders with constant coefficients, classification of linear PDE of second order, equations with variable coefficients, reduction to canonical form. **(Lecture 10)**

Unit-3:

Methods of separation of variables, solutions of the one-dimensional wave equation, one dimensional heat equation, Laplace equation two and three dimensional. **(Lecture 16)**

Unit-5:

Nonlinear equations of the second-order, Green's functions and integral representations. **(Lecture 06)**

Text Books:

1. T. Amarnath, An Elementary Course in Partial Differential Equations, (2nd edition), Narosa Publishing House, 1997.
2. Phoolan Prasad, Renuka Ravindran, Partial Differential Equations, New Age International Publication, New Delhi, 2009.
3. Ian N. Sneddon, Elements of Partial Differential Equations, McGraw-Hill Company, New York,1957.

References:

1. L.C. Evans, Partial Differential Equations, Graduate studies in Mathematics, Vol 19, AMS,1998.
2. F. John, Partial Differential Equations, 3rd ed. Narosa Publ. Co., New Delhi, 1979.
3. M.D. Raisinghania, Ordinary and partial differential equations, S. Chand Publishing, New Delhi, 2017.
4. R.K. Gupta, Partial Differential Equations, Krishna Prakashan, Meerut, 2014.

10. Linear Programming Problems (MA-GE-420)

Unit-1:

Linear programming problems, statement and formation of general linear programming problems, LPP in matrix notation,graphicalsolution of LPP,basic solutions, degenerate and non-degenerate basic feasible solution, convex set, extreme points, convex functions and concave functions, the hyperplane in convex set,intersection of two convex sets is convex set, the collection of all feasible solution of a LPP constitutes a convex set,a BFS to a LPP corresponds to an extreme point of convex set of feasible solutions.
(Lecture 10)

Unit-2:

Fundamental theorem of linear programming, simplex method. artificial variables, Big-M method, two phase method.**(Lecture 10)**

Unit-3:

Duality in linear programming, sensitivity analysis, dual simplex method, primal-dual method. **(Lecture 10)**

Unit-4:

Solution by minimax principal of 2×2 game theory. **(Lecture 10)**

Unit-5:

Transportation problems, Assignment problems. **(Lecture 10)**

Text Books:

1. B. Kolman, R. E. Beck, *Elementary Linear programming with applications*, Acadmic Press, San Diego, 1995.
2. D. Bertsimas and J. N. Tsitsiklis, *Introduction to linear optimization*, Belmont, Mass.: Athena Scientific, 1997.
3. G. B. Dantzing, M. N. Thapa, *Linear programming*, Springer New York, 1997.
4. H. A. Taha, *Operations Research: An Introduction*, Prentice Hall of India, 1997.
5. KantiSwarup, P. K. Gupta and Man Mohan, *Operations Research,* Sultan Chand & Sons, new Delhi, 1991.
6. S. D. Sharma, Operations Research (14th edition), KedarNath Ram Nath& Co. 2004

References:

1. J.C. Pant, Introduction to Optimisation: Operations Research, Jain Brothers Delhi, 2008.
2. G. Hadley, *Linear Programming*, Narosa Publishing house, 1995.
3. N. S. Combo, *Mathematical programming Techniques*, Affiliated East-West Press PVT New Delhi, (1991).

11. Complex Analysis (MA-501)

Unit-1:

Complex numbers and properties, Continuity, derivatives, Cauchy-Riemaan equations, Analytic functions, harmonic function, reflection principle. **(Lecture 10)**

Unit-2:

Polynomial functions, rational functions, exponential, logarithmic, trigonometric and hyperbolic functions, branch of a logarithm, contours, contours integrals, anti-derivatives, Cauchy-Goursat theorem, simply and multiply-connected domain, Cauchy integral formula, Liouville theorem, fundamental theorem of algebra, maximum modulus principle its applications. **(Lecture 10)**

Unit-3:

Convergence of sequence and series, Taylor's series, Laurent series, isolated singular points, kinds of singularities, residues, Cauchy residue theorem. **(Lecture 10)**

Unit-4:

Evaluation of improper integrals, Jorden's lemma, argument principle, Rouches theorem, Schwarz's Lemma, Schwarz reflection principle. **(Lecture 10)**

Unit-5:

Linear transformations: $w = 1/z, w = sinz, w = z^2, w = z^{\frac{1}{2}}$, conformal mapping and its applications, analytic continuation. **(Lecture 10)**

Text Books:

1. J.B.Conway, Functions of one complex variable (2nd edition), Narosa Publishing House,1996.
2. E.C. Titchmarsh, The Theory of Functions, Oxford University Press London, 1939.
3. S. Ponnusamy, Foundations of Complex Analysis, Narosa Publishing House, 1997.
4. J. W. Brown and R. V. Churchil, Complex varibles and applications (2nd edition), McGraw-Hill, 2008.

References:

1. D. Sarason, Complex Function Theory, Hindustan Book Agency Delhi, 1994.
2. L.V. Ahlfors, Complex Analysis, McGraw-Hill, 1979.
3. W. Rudin, Real and Complex Analysis, McGraw-Hill Book Co., 1966.
4. E. Hille, Analytic Function Theory (2 edition), Gonn& Co., 1959.

12. Measure Theory (MA-502)

Prerequisite: Real Analysis

Unit-1:

Algebra of sets, sigma-algebra, Borel sets, Cantor set, Lebesgue measure, outer measure, measurable sets, existence of non-measurable sets, measurable functions, Littlewood's three principles, Egoroff's theorem, Lusin's theorem. **(Lectures 12)**

Unit-2:

Simple functions, Lebesgue integral of bounded functions, integral of nonnegative functions, Lebesgue monotone convergence theorem, Fatou's lemma, Lebesgue dominated convergence theorem. **(Lectures 12)**

Unit-3:

Riemann integrability versus Lebesgue integrability, functions of bounded variation, absolute continuity, differentiation of an integral. **(Lectures 8)**

Unit-4:

Measurable space, measure space, finite measure, sigma-finite measure, semifinite measure, complete measure space, signed measure, mutually singular measure, absolutely continuous measure, Radon-Nikodym theorem, **(Lectures 10)**

Unit-5:

Product measure, Fubini theorem, Tonelli theorem, introduction to L^p-spaces. **(Lectures 8)**

Text Books:

1. Inder K. Rana, An Introduction to Measure and Integration, Narosa, 2010.
2. G. de Barra, Measure Theory and Integration, New Age International, 2013.
3. H.L. Royden, Real Analysis, PHI Learning, 2011.

Reference Books:

1. P.K. Jain, Lebesgue Measure and Integration, New Age International, 2010.
2. Walter Rudin, Real and Complex Analysis, McGraw Hill Education, 2017.
3. Walter Rudin, Principles of Mathematical Analysis, McGraw Hill Education, 2017.
4. P.R. Halmos, Measure Theory, Springer New York, 1950.
5. Donald L. Cohn, Measure Theory, Birkhauser Advanced Text, 2002.

13. Differential Geometry and Tensors (MA-503)

Unit-1:
Local theory of curves: Space curves, examples, plane curves, tangent, normal and binormal, osculating plane, normal plane and rectifying plane, Serret-Frenet formulae, contact between curve and surfaces, osculating circles and spheres, existence of space curves, Helices, evolutes and involutes of curves. **(Lecture 10)**

Unit-2:
Theory of Surfaces: Parametric curves on surfaces, First and second Fundamental forms, Weingarten equations, direction coefficients, families of curves, principal curvature, Lines of curvature, Rodrigue's equation, Euler's theorem, Dupin's theorem, conjugate and asymptotic lines. **(Lecture 10)**

Unit-3:
Geodesics: Canonical geodesic equations, normal property of geodesics, Geodesic curvature, torsion of a geodesic, geodesic polar coordinates, Gauss-Bonnet theorem, Gaussian and total curvatures. **(Lecture 10)**

Unit-4:
Fundamental equations of surface theory: The equations of Gauss, Mainardi-Codazzi equations, fundamental existence theorem for surfaces. **(Lecture 05)**

Unit-5:
Tensors: Summation convention and indicial notation, Coordinate transformation and Jacobian, Contra-variant and Covariant vectors, Tensors of different type, Algebra of tensors and contraction, Metric tensor and 3-index Christoffel symbols, Parallel propagation of vectors, Covariant and intrinsic derivatives, Curvature tensor and its properties, Bianchi identity, Curl, Divergence and Laplacian operators in tensor form, Physical components. **(Lecture 15)**

Text Books:

1. T. J. Willmore, An Introduction to Differential Geometry, Dover Publications, 2012.
2. S. Lang, Fundamentals of Differential Geometry, Springer, 1999.
3. B. Spain, Tensor Calculus: A concise Course, Dover Publications, 2003.

References:

1. B. O'Neill, Elementary Differential Geometry, Academic press, 2nd Ed., 2006.
2. C.E. Weatherburn, Differential Geometry of Three Dimensions, Cambridge University Press (digital pub), 2003.
3. D.J. Struik, Lectures on Classical Differential Geometry, Dover Publications, 1988.
4. K.K. Dube, Differential Geometry and Tensors, I.K. Int. Publ. house Pvt. Ltd. New Delhi, 2009.
5. B.P. Singh et al., Differential Geometry and Tensor analysis, Krishna Prakashan, Meerut, 2013.

14. Abstract Algebra (MA-504)

Unit-1:

Group Theory: Definition, properties and some examples of groups, abelian group, cyclic group, U(n)-group, Klein-4 group, general linear group, subgroups and its properties, center of group, normalizer, counjugacy, class equation, quaternion's group, permutation and alternating group, the dihedral group, cosets and Lagrange's theorem, Euler's theorem, Fermat's theorem, normal subgroup and quotient subgroup, simple group. **(Lecture 12)**

Unit-2:

Homomorphisms, isomorphism, automorphisms, Cayley's theorem, Sylow's theorems and their applications, direct product of groups, abelian p-groups and their invariants, solvable group and nilpotent group**.** **(Lecture 12)**

Unit-3:

Ring theory: Definition and examples of rings, some special classes of rings, homomorphisms and isomorphism theorems, ideal and quotient rings, prime and maximal ideal. **(Lecture 7)**

Unit-4:

Integral domain, Euclidean domain, principal ideal domain, unique factorization domain, Euclidean rings, polynomial rings. **(Lecture 6)**

Unit-5:

Fields: Definition of field and some examples, extensions of fields, the field of quotients of an integral domain, splitting fields and normal extensions, polynomial over a rational fields and irreducibility of the polynomials, field extension, introduction to Galois theory. **(Lecture 13).**

Text Books:

1. I. N. Herstein, Topics in Algebra (2^{nd} edition) John Wiley & Sons, 2004.
2. Joseph A. Gallian, Contemporary Abstract Algebra, Cengage, 2013.
3. A. K. Vasishtha & A. R. Vasishtha, Modern Algebra, Krishna Publication, 2015.

References:

1. J. B. Fraleigh, A First Course in Abstract Algebra, Narosa Publishing House, 2003.
2. M. Artin, Algebra, Prentice Hall India, 2011.
3. V. K. Khanna, S. K. Bhamri, A Course in Abstract Algebra, Vikas Publishing, 2017.
4. D. S. Dummit, R. M. Foote, Abstract Algebra (3^{rd} Edition), John Wiley & Sons, 2004.

15. Mathematical Methods (MA-505)

Unit-1:

Absolute and conditional extremum of function of several variables, function spaces, functionals, variations of functionals, continuity and differentiability of the functional, necessary and sufficient conditions for strong and weak extrema, Euler's equation, higher derivatives of functionals , invariance of Euler's equations, field of extremals, Legendre's theorem, Weierstrass's theorem, Hilbert invariant, integral theorem, conditional extremum. **(Lecture 10)**

Unit-2:

Initial value problems, Langrange method, application to dynamical problems, variational problems with moving boundaries, discontinuous problems, one-sided variations, solution of boundary value problem by Ritz method. **(Lecture 10)**

Unit-3:

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.

Volterra Integral Equations: solution of Volterra integral equations with the help of successive approximations, Neumann series and resolvent kernel, equations with convolution type kernels, solution of integral equations by transform methods, eigenvalues and eigenfunctions for symmetric kernels. **(Lecture 10)**

***Fredholm Integral Equations:(* Unit-4 & Unit 5)**

Unit-4:

Solution of Fredholm integral equations with separable kernels, eigenvalues and eigenfunctions, fundamentals-iterated kernels, constructing the resolvent kernel with the aid of iterated kernels. **(Lecture 8)**

Unit-5:

Fredholm integral equation with degenerated kernels, solutions of homogeneous Fredholm integral equation with degenerated kernel, solution by the successive approximations, Numann series and resolvent kernel, solution of Fredholm integral equations with symmetric kernels, Hilbert-Schmidt theorem, Green's function approach, Fredholm alternative. **(Lecture 12)**

Text Books:

1. I. M. Gelfand, S. V. Fomin, Calculus of Variations, Dover Books, 2000
2. M. L Krasnov, Problems and Exercices in Integral Equations, MIR publisher, 1971.

3. M. L. Krasnov, Problems and Exercices in the calculus of variations, Central Books Ltd 1975.

References:

1. R. Weinstock, Calculus of Variations with Application to Physics and Engineering, Dover Publication, 1994.
2. A. J. Jerry, Introduction to Integral Equations with Application, Wiley Publishers (2nd Edition), 1999.
3. L. G. Chambers, Integral Equations: A Short Course, International Text Book Company Ltd. 1976
4. H**.** Hochstad, Integral Equations, John Wiley & Sons, 1989.

16. Discrete Mathematics (MA-506)

Unit-1:

Sets and classes, relations and functions, equivalence relations and equivalence classes, principle of mathematical induction, recursive definitions of posets, chains and well-ordered sets, axiom of choice, cardinal and ordinal numbers, Cantor's lemma, set theoretic paradoxes, propositional calculus: well-formed formulae, tautologies, equivalence, normal forms, truth of algebraic systems, calculus of predicates. **(Lecture 10)**

Unit-2:

Principles of addition and multiplication, arrangements, permutations and combinations, multinomial theorem, partitions and allocations, pigeonhole principle, inclusion-exclusion principle, generating functions, recurrence relations.**(Lecture 10)**

Unit-3:

Lattices, distributive and complemented lattices, Boolean lattices and algebra, uniqueness of finite Boolean algebra, Boolean functions and Boolean expressions. **(Lecture 10)**

Unit-4:

Graphs and digraphs, Eulerian and Hamiltonian graphs and cycles, adjacency and incidence matrices, vertex colouring, planarity and duality, trees and binary trees, spanning trees, minimum spanning trees.
(Lecture 10)

Unit-5:

Applications of graph theory to transport networks, matching theory and graphical algorithms, spectra of graphs, colorings of graph, Ramsey theory. **(Lecture 10)**

Text Books:

1. J.P. Tremblay and R.P. Manohar,Discrete Mathematics with Applications to Computer Science, McGraw Hill, 1989.
2. F. Harary, Graph Theory, Narosa, 1995.
3. N. Deo, Graph Theory with Applications to Engineering and Computer Science, Prentice-Hall of India, 2004.
4. S. K. Chakraborty and B. K. Sarkar, Discrete Mathematics, Oxford University Press, 2010

References:

1. V. K. Balakrishnan, Introductory Discrete Mathematics, Dover, 1996
2. BelaBollobas, Graph Theory: An Introductory Course, GTM, Springer Verlag, 1990.
3. C. L. Liu, Elements of discrete mathematics and applications (4^{th} editions), 2012.
4. Kolmaan and N………

17. Fluid Mechanics (MA-507)

Unit-1:

Kinematics of fluid in motion: real and ideal fluids, Lagrangian and Eulerian description, continuity of the mass flow, circulation, rotation and irrotational flows, boundary surface, streamlines, path lines, steak lines, vorticity, Reynolds transport theorem, general equations of motion inviscid case, Bernoulli's theorem, compressible and incompressible flows, Kelvin's circulation theorem. ***(Lecture-12)***

Unit-2:

Stream function, complex potential, sources, sinks and doublets, circle theorem, method of images, theorem of Blasius, stokes stream function, motion of a sphere. ***(Lecture-08)***

Unit-3:

Stress and strain and relation between stress and strain, Stokes hypothesis, derivation of the Navier-Stokes equations, special forms of Navier Stokes equations, Stokes equations and Euler equations, classification of partial differential equations and physical Behaviour, fully developed flows with examples. ***(Lecture-8)***

Unit -4:

Some solvable problem in viscous flow: (i) steady flow between parallel plates, (ii) steady flow in a pipe, (iii) steady flows between concentric cylinders (iii) Couette flow, derivation of energy equation, dissipation of energy, Boussinesq approximation. ***(Lecture-4)***

Unit -5:

Dimensional analysis, Buckingham theorem, physical significance of some non-dimensional parameters: Prandtl, number, Mac number, Reynolds number, Froud number, Reyleigh number, Grashof number, Nusselt number etc., concept of boundary layers, boundary layer thickness, Prantdtls boundary layer, similarity solution, boundary layer on flat plate: Blassius solution, effect of pressure gradient, wall shear stress, separation of the boundary layer. ***(Lecture-10)***

Text Books:

1. G. K. Batchelor, An Introduction to Fluid Dynamics, Cambridge University Press, 2000
2. H. Schlichting, Boundary Layer Theory, McGraw Hill Education, 2014
3. K. Muralidhar, G. Biswas, Advanced Engineering Fluid Mechanics, Narosa Publishing House, 2006
4. R. K. Rathy, An Introduction to Fluid Dynamics, Oxford and IBH publishing Company, New Delhi, 1976

5. F. Chorlton, Text book of Fluid Dynamics, CBS Publisher & Distributors Pvt. Ltd. 1985.

References:

1 P. K. Kundu, I. M. Cohen, D. R. Dowling, Fluid Mechanics (Fifth Edition), Academic Press (Elsevier, 4th Edition).
2 S. W. Yuan, Foundation of Fluid Mechanics (3rd Edition), Prentice Hall of India Private Limited, 1976
3 F. M. White, Fluid Mechanics (Sixth Edition), Tata McGraw-Hill, New Delhi (2008).
4 M. D. Raisinghania, Fluid Dynamics, S Chand & Company, 2010 (5th revised edition)

18. Functional Analysis (MA-511)

Unit-1:
Metric completion, Baire category theorem, contraction mapping, Banach's fixed point theorem, normed linear spaces, inequalities, Banach Spaces, Ssummability in Banach spaces. **(Lecture 12)**

Unit-2:
Linear operators, operator norm, continuity and boundedness of an operator, norm of a bounded operator, Banach limit, Linear functional, reflexivity, Hahn-Banach theorems and its applications, Stone Weierstrass theorem. **(Lecture 10)**

Unit-3:
Pointwise bounded sets, totally bounded sets, equicontinuity, Arzela Ascoli theorem, open mapping and closed graph theorems, uniform boundedness principle, trigonometric polynomial, Fourier series, Carleson-Hunt theorem, convergence and divergence of Fourier series, degree of approximation. **(Lecture 12)**

Unit-4:
Inner product space, orthonormal sets, Gram-Schmidt orthogonalization, Bessel's inequality, orhtonormal basis, Separable Hilbert spaces, projection and Riesz representation theorem . **(Lecture 10)**

Unit-5:
Adjoint operator, normal, unitary, self adjoint operator, compact operator, eigen values, eigen vectors, Banach algebra. **(Lecture 06)**

(Total Contact Time: 50 Hours)

Text Books:

1. Chandrasekhar Rao, Functional Analysis, Alpha Science International Ltd., 7200 The Quorum, Oxford Business Park North Garsington Road, Oxford OX4 2JZ, United Kingdom.
2. Erwin Kreyszig, Functional analysis with applications, John Wiley & Sons, New York, 1978.
3. M. T. Nair, Functional analysis, PHI Learning Pvt. Ltd., Delhi, 2014.

References:

1. J.B. Conway, A Course in Functional Analysis, Springer-Verlag, New York, 1990.
2. C. Goffman and G. Pedrick, First course in Functional Analysis, Prentice Hall of India, New Delhi, 1987.
3. G.F. Simmons, Topology and Modern Analysis, Mc Graw-Hill, New York, 1963.
4. A.E. Taylor, Introduction to Functional Analysis, John Wiley & Sons, New York, 1958
5. W. Rudin, Functional Analysis, Mc Graw-Hill, New York, 1991.
6. B.V. Limaye, Functional Analysis, John Wiley & Sons, 1981

19. Special Functions and Integral Transform (MA-512)

Special Functions:

Unit-1:
Beta and Gamma functions and its elementary properties, hypergeometric functions, Gauss hypergeometric functions and its elementary properties. **(Lecture 07)**

Unit-2:
Bessel functions, Bessel differential equation and it's solution, recurrence relation, generating functions, integral representation, and orthogonality of Bessel functions. Legendre polynomials and functions, solution of Legendre's differential equations, generating functions, Rodrigue's formula, orthogonality of Legendre polynomials, recurrence relations. **(Lecture 16)**

Integral Transforms:

Unit-3:
Laplace Transform, existence theorem, shifting theorems, Laplace transform of derivatives and integrals, inverse Laplace transform and their properties, convolution theorem, initial and final value theorem, Laplace transform of periodic functions, error functions, Heaviside unit step function and Dirac delta function, 2^{nd} shifting theorem, applications of Laplace transform to solve IVP. **(Lecture 10)**

Unit-4:
Trigonometric Fourier series and its convergence, Fourier series of even and odd functions, Gibbs phenomenon, Fourier half-range series, Parseval`s identity, complex form of Fourier series, Fourier integrals, Fourier sine and cosine integrals, complex form of Fourier integral representation, Fourier transform, Fourier transform of derivatives and integrals, Fourier sine and cosine transforms and their properties, convolution theorem, application of Fourier transforms to boundary value problems. **(Lecture 13)**

Unit-5:
Z-Transforms: Z–transform and inverse Z-transform of elementary functions, shifting theorems, convolution theorem, initial and final value theorem, application of Z-transforms to solve difference equations. **(Lecture 05)**

Text Books:

1. E. Kreyszing, Advanced Engineering Mathematics, John Wiley & Sons, 1989.
2. R. K. Jain, S. R. K. Iyengar, Advanced Engineering Mathematics, Alpha Science International Ltd; 3rd Revised edition, 2007.
3. B.S. Grewal, Higher Engineering Mathematics, Khanna Publishers, 43rd edition, 2014.

Reference Book:

20. Mathematical Tools and Software (MA-513)

Unit-1: MS Office:

MS-word documents, MS-excel worksheet, MS-power point presentation (PPT). **(05 Lectures)**

Unit-2: MATLAB:

Basic Introduction: Simple arithmetic calculations, creating and working with arrays, numbers and matrices, creating and printing simple plots, function files, basic 2-D plots and 3-D plots. **(05 Lectures)**

Unit-3: Mathematica:

Basic introduction: Arithmetic operations, functions, graphics: 2-D plots, 3-D plots, plotting the graphs of different functions, matrix operations, finding roots of an equation, finding roots of a system of equations, solving differential equations. **(14 Lectures)**

Unit-4: LATEX:

Basic Introduction: Mathematical symbols and commands, Arrays, formulas, and equations, spacing, borders and colors, using date and time option in LaTeX, to create applications and letters, beamer (PPT in Latex), writing an article, pictures and graphics in LATEX. **(14 Lectures)**

Note: To adopt this course, a personal laptop/computer is compulsory**.**

Reference books:

1. R. Pratap: Getting started with MATLAB, Oxford University Press, 2010.
2. S. Lynch, Dynamical Systems with Applications using MATLAB, Birkhäuser, 2014.
3. M. L. Abell, J.P. Braselton, Differential Equations with Mathematica, Elsevier Academic Press, 2004.
4. I. P. Stavroulakis, S.A. Tersian, An Introduction with Mathematica and MAPLE, World Scientific, 2004.
5. L.W. Lamport, LaTeX: A document Preparation Systems, Addison-Wesley Publishing Company, 1994.
6. H. Kopka, P.W. Daly, Guide to LATEX, Fourth Edition, Addison Wesley, 2004.

21. Graph Theory (MA-514)

Unit-1:

Graph, sub-graphs, degrees of Vertices, paths and connectedness, operations on graphs, directedand undirected graphs,tournaments.**(Lecture 8)**

Unit-2:

Vertex cuts and edge Cuts,connectivity and edge, Trees: definitions, characterization and simple properties, counting the number of spanning trees, Cayley's Formula.**(Lecture 8)**

Unit-3:

Vertex independent sets and vertex Coverings, edge independent sets, matching's and factors, Eulerian Graphs, Hamiltonian Graphs.**(Lecture 10)**

Unit-4:

Vertex colouring, critical graphs, triangle, freegraphs, edge colourings of graphs,chromatic number and polynomials.**(Lecture 10)**

Unit-5:

Planar and nonplanargraphs, Eulerformula and its Consequences, K_5 and $K_{3,3}$ nonplanar graphs, dual of a plane graph, Four-Colour Theorem, Heawood Five-Colour Theorem, Kuratowski's Theorem.**(Lecture 14)**

Text Books:

1. R. Balakrishnan, K. Ranganathan, A Textbook of Graph Theory, Springer International Edition New Delhi, 2008.
2. F. Harary, Graph Theory, Addison - Wesley Reading Mass., 1969.
3. N. Deo, Graph Theory with Applications to Engineering and Computer Science, Prentice-Hall of India, 2004

References:

1. J.A. Bondy, U.S.R. Murty, Graph Theory with Applications, Mac MilanPress Ltd.,1976.
2. Gary Chartrand, Linda Lesniak, Ping Zhang, Graphs and Digraph,CRC press,2010.
3. D. B. West, Introduction to Garph Theory, Prentice Hall India Learning Private, 2002 (2nd edition)

22. Optimization Techniques (MA-515)

Unit-1:

Introduction to optimization, classification of optimization, design vector and constraints, constraint surface, objective function, classification of optimization Problems.

Unit-2:

Classical optimization techniques,single variable optimization, multi-variable optimization, direct substitution method, Lagrange's method of multipliers, Karush-Kuhn-Tucker conditions.

Unit-3:

Linear programming, statement of an LP problem, simplex method, dual simplex method, non-linear programming, one-dimensional minimization, unimodal function, unrestricted search, exhaustive search, dichotomous search, Interval halving method, Fibonacci method, Golden section method, direct root methods, Newton-Raphson and Quasi Newton methods.

Unit-4:

Non-linear programming,unconstrained optimization techniques,direct search method, random search methods, grid search method, univariate method, Hookes and Jeeves' method, Powell's method.

Unit-4:

Modern methods of optimization, Genetic algorithms, Simulated Annealing, Fuzzy optimization, Neural-networkbased methods.

Text Books:

1. R. L. Fox, Optimization Methods for Engineering Design, Addison Wesley, 2001.
2. J. S. Arora, Introduction to Optimum Design (7th edition), Mc-Graw Hill, 2004

References:

1. K. Deb, Multi-objective optimization using evolutionary algorithms, John Wiley, 2001.
2. S. S. Rao, Engineering Optimization: Theory and Practice, John Wiley & Sons, 2009.
3. E. Rich, K. Knight, Artifical Intelligence, Tata McGraw Hill, 1991.
4. M. Negnevitsky, Artificial Intelligence: A Guide to Intelligent Systems, Addison Wesley, 2002.
5. E. Eberhart, Y. Shi, Computational Intelligence: Concepts and Implementations, Morgan Kaufmann San Diego, 2007.
6. S. Rajasekaran, G. A.VijaylakshmiPai, Neural Networks Fuzzy Logic, and Genetic Algorithms, Prentice Hall of India, 2003
7. A. P. Engelbrecht, Computational Intelligence: An Introduction, John Wiley, New York, 2003.
8. A. Konar, Computational Intelligence: Principles, Techniques, and Applications, Springer, Berlin, Germany, 2005.

23. Number Theory (MA-516)

Prerequisites:

Unit-1:

Divisibility, synthetic division, greatest common divisor, Euclidean algorithm, linear Diophantine equation, prime numbers, fundamental theorem of arithmetic. **(Lectures 10)**

Unit-2:

Congruence, linear congruence, chinese remainder theorem, Fermat's theorem, Wilson's theorem, pseudoprimes. **(Lectures 10)**

Unit-3:

Sum and number of divisors, Multiplicative functions, Mobius $\mu -$function, Mobius inversion formula, greatest integer function, Euler's phi-function, Euler's theorem, Lagrange's theorem. **(Lectures 10)**

Unit-4:

Primitive roots for prime and composite numbers, quadratic residue, Euler's criterion, Legendre symbol, Gauss's lemma, laws of quadratic reciprocity, nonlinear Diophantine equation, introduction to Fermat's last theorem. **(Lectures 10)**

Unit-5:

Representation of integers as sum of squares: criterions of Fermat, Euler and Lagrange, introduction to cryptography. **(Lectures 10)**

Text Books:

1. David Burton, Elementary Number Theory, McGraw Hill Education, 2017.
2. I. Niven, H.S. Zuckerman and H.L. Montgomery, An Introduction to the Theory of Numbers, Wiley, 2008.
3. S. Telang, M. Nadkarni and J. Dani, Number Theory, Tata-McGraw Hill, 2001.

Reference Books:

1. T.M. Apostol, Introduction to Analytic Number Theory, Narosa, 1998.
2. Joseph H. Silverman, A Friendly Introduction to Number Theory, Pearson Education, 2014.
3. A.S. Shirali, First Steps in Number Theory, University Press, 2000.
4. G.H. Hardy, E.M. Wright, R.H. Brown and J.H. Silverman, An Introduction to the Theory of Numbers, Oxford University Press, 2008.

24. Advanced Numerical Analysis (MA-517)

Unit-1:
Computations of Eigen Values of a Matrix: Power method for dominant, sub-dominant and smallest eigen-values, Jacobi, Givens and Householder methods for symmetric matrices, LR and QR methods. **(12 Lectures)**

Unit-2:
Solution of ODE: Euler and modified Euler method, Runge-Kutta Method, multistep methods, Predictor-corrector Adam-Bashforth Milne 's method , their error analysis and stability analysis. shooting Method, spline method. (**8 Lectures)**

Unit-3:
Review of finite difference operators, finite difference methods, inverse interpolation, their developments, and applications.
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. **(10 Lectures)**

Unit-4:
Hyperbolic PDE: Solution of hyperbolic equations using FD, method of characteristics, limitations and error analysis.
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, condition of convergence. **(14 Lectures)**

Unit-5:
Weighted residual methods: Galerkins, collocation, least squares, Rayleigh-Ritz methods and their compatibility, application to solve simple problem of ordinary differential equations. **(8 Lectures)**

Text Books:

1. M. K. Jain, S.R.K. Iyenger, R. K. Jain, Numerical Method, New Age International Limited, Publication
2. G. D. Smith, Numerical Solution of Partial Differential Equation, Oxford University Press.
3. J. B. Scarborough, Numerical Mathematical Analysis, Oxford University Press, 1930.

References:

1 C. F. Gerald, P. O. Wheatly, Applied Numerical Analysis, 6th Ed., Addison-Wesley Publishing 2002.
2 M. K. Jain, Numerical Solution of Differential Equations, John Wiley 1991.
3 S.D. Conte, C.D. Boor, Elementary Numerical Analysis (An Algorithmic Approach), 3rd Edition, McGraw-Hill, 1980.