Draft Syllabus Mathematics (Hons)

1. Introduction

The syllabus for Mathematics at undergraduate level using the Choice Based Credit system has been framed in compliance with model syllabus given by UGC.

The main objective of framing this new syllabus is to give the students a holistic understanding of the subject giving substantial weightage to both the core content and techniques used in Mathematics. Keeping in mind and in tune with the changing nature of the subject, adequate emphasis has been given on new techniques of mapping and understanding of the subject.

The syllabus has given equal importance to the three main branches of mathematics – Algebra, Calculus and Geometry.

The syllabus has also been framed in such a way that the basic skills of subject are taught to the students, and everyone might not need to go for higher studies and the scope of securing a job after graduation will increase.

It is essential that Mathematics students select their general electives courses from Physics, Chemistry and/or any branch of Life Sciences disciplines.

While the syllabus is in compliance with UGC model curriculum, some changes have been made to ensure all topics are covered and any of the subjects don't become difficult to be completed in one semester. For example, Core course 1 on "Calculus" now also has introductory concepts on Geometry and Differential equations and has been renamed accordingly.

Similarly, Discipline Electives have been grouped where in student can chose 1 elective from a group of 3 papers. This has been done to help students learn across the semesters in their interest areas

Project Work may be introduced instead of the 4th Elective with a credit of 6 split into 2+4, where 2 credits will be for continuous evaluation and 4 credits reserved for the merit of the dissertation.

2. Scheme for CBCS Curriculum

2.1 Credit Distribution across Courses

		Credits	
Course Type	Total Papers	Theory + Practical	Theory*
Core Courses	14	14*4 =56 14*2 =28	14*5 =70 14*1=14
Discipline Specific Electives	4	4*4=16 4*2=8	4*5=20 4*1=4
Generic Electives	4	4*4=16 4*2=8	4*5=20 4*1=4
Ability Enhancement Language Courses	2	2*2=4	2*2=4
Skill Enhancement Courses	2	2*2=4	2*2=4
Totals	26	140	140

*Tutorials of 1 Credit will be conducted in case there is no practical component

2.2 Scheme for CBCS Curriculum

Semester	Course Name	Course Detail	Credits
I	Ability Enhancement Compulsory Course - I	English communication / Environmental Science	2
	Core course - I	Calculus, Geometry and Differential Equation	6
	Core course - I Practical	-	-
	Core course - II	Algebra	6
	Core course - II Practical	-	-
	Genetic Elective - 1	TBD	4
	Generic Elective - 1 Practical	TBD	2
II	Ability Enhancement Compulsory Course - II	English communication / Environmental Science	2
	Core course - III	Real Analysis	6
	Core course - III Practical	-	-
	Core course - IV	Differential Equations and Vector Calculus	6
	Core course - IV Practical	-	-
	Generic Elective - 2	TBD	4
	Generic Elective - 2 Practical	TBD	2
III	Core course - V	Theory of Real Functions & Introduction to Metric Spaces	6
	Core course - V Practical	-	-
	Core course - VI	Group Theory I	6
	Core course - VI Practical	-	-
	Core course - VII	Numerical Methods	4
	Core course - VII Practical	Numerical Methods Lab	2
	Skill Enhancement Course - 1	TBD	2

	Generic Elective – 3	TBD	4
	Generic Elective – 3 Practical	TBD	2
IV	Core course – VIII	Riemann Integration and Series of Functions	6
	Core course – VIII Practical	-	-
	Core course – IX	Multivariate Calculus	6
	Core course – IX Practical	-	-
	Core course – X	Ring Theory and Linear Algebra I	6
	Core course – X Practical	-	-
	Skill Enhancement Course-2	TBD	2
	Generic Elective – 4	TBD	4
	Generic Elective – 4 Practical	TBD	2
V	Core course – XI	Partial Differential Equations and Applications	6
	Core course – XI Practical	-	-
	Core course – XII	Group Theory II	6
	Core course – XII Practical	-	-
	Discipline Specific Elective – 1	TBD	4
	Discipline Specific Elective – 1 Practical	TBD	2
	Discipline Specific Elective – 2	TBD	4
	Discipline Specific Elective – 2 Practical	TBD	2
VI	Core course – XIII	Metric Spaces and Complex Analysis	6
	Core course – XIII Practical	-	-
	Core course – XIV	Ring Theory and Linear Algebra II	6
	Core course – XIV Practical	-	-
	Discipline Specific Elective – 3	TBD	4

	Discipline Specific Elective - 3 Practical	TBD	2
	Discipline Specific Elective - 4	TBD	4
	Discipline Specific Elective - 4 Practical	TBD	2

2.3 Choices for Discipline Specific Electives

Discipline Specific Elective - 1	Discipline Specific Elective - 2	Discipline Specific Elective - 3	Discipline Specific Elective - 4
Linear Programming	Probability and Statistics	Number Theory	Bio Mathematics
Theory of Equations	Portfolio Optimization	Industrial Mathematics	Differential Geometry
Point Set Topology	Boolean Algebra & Automata	Mechanics	Mathematical Modeling

- Optional Dissertation or project work in place of one Discipline Specific Elective Paper (6 credits) in 6th Semester

2.4 Choices for Skill Enhancement Courses

Skill Enhancement Course-1	Skill Enhancement Course-2
Logic and Sets	Graph Theory
Computer Graphics	Operating System: Linux
Object Oriented Programming	

3. Core Subjects Syllabus

3.1 Core T1 – Calculus, Geometry & Differential Equation

Calculus, Geometry & Differential Equation	
	6 Credits
Unit 1	
Hyperbolic functions, higher order derivatives, Leibnitz rule and its applications to problems of type eax+bsinx, eax+bcosx, (ax+b)nsinx, (ax+b)ncosx, concavity and inflection points, envelopes, asymptotes, curve tracing in Cartesian coordinates, tracing in polar coordinates of standard curves, L'Hospital's rule, applications in business, economics and life sciences.	
Unit 2	
Reduction formulae, derivations and illustrations of reduction formulae of the type f sin nx dx, f cos nx dx, f tan nx dx, f sec nx dx, f (log x)n dx, f sinn x sinm x dx, parametric equations, parameterizing a curve, arc length, arc length of parametric curves, area of surface of revolution. Techniques of sketching conics.	
Unit 3	
Reflection properties of conics, rotation of axes and second degree equations, classification of conics using the discriminant, polar equations of conics. Spheres. Cylindrical surfaces. Central conicoids, paraboloids, plane sections of conicoids, Generating lines, classification of quadrics, Illustrations of graphing standard quadric surfaces like cone, ellipsoid.	
Unit 4	
Differential equations and mathematical models. General, particular, explicit, implicit and singular solutions of a differential equation. Exact differential equations and integrating factors, separable equations and equations reducible to this form, linear equation and Bernoulli equations, special integrating factors and transformations.	

Graphical Demonstration (Teaching Aid)

1. Plotting of graphs of function eax + b, log(ax + b), 1/(ax + b), sin(ax + b), cos(ax + b), |ax + b| and to illustrate the effect of a and b on the graph.
2. Plotting the graphs of polynomial of degree 4 and 5, the derivative graph, the second derivative graph and comparing them.
3. Sketching parametric curves (Eg. Trochoid, cycloid, epicycloids, hypocycloid).
4. Obtaining surface of revolution of curves.
5. Tracing of conics in cartesian coordinates/ polar coordinates.
6. Sketching ellipsoid, hyperboloid of one and two sheets, elliptic cone, elliptic, paraboloid, and hyperbolic paraboloid using Cartesian coordinates.

Reference Books

- G.B. Thomas and R.L. Finney, Calculus, 9th Ed., Pearson Education, Delhi, 2005.
- M.J. Strauss, G.L. Bradley and K. J. Smith, Calculus, 3rd Ed., Dorling Kindersley (India) P. Ltd. (Pearson Education), Delhi, 2007.
- H. Anton, I. Bivens and S. Davis, Calculus, 7th Ed., John Wiley and Sons (Asia) P. Ltd., Singapore, 2002.
- R. Courant and F. John, Introduction to Calculus and Analysis (Volumes I & II), Springer-Verlag, New York, Inc., 1989.
- S.L. Ross, Differential Equations, 3rd Ed., John Wiley and Sons, India, 2004.
- Murray, D., Introductory Course in Differential Equations, Longmans Green and Co.
- G.F.Simmons, Differential Equations, Tata Mcgraw Hill.
- T. Apostol, Calculus, Volumes I and II.
- S. Goldberg, Calculus and mathematical analysis.

3.3 Core T2 - Algebra

Algebra	
	6 Credits
Unit 1	
Polar representation of complex numbers, nth roots of unity, De Moivre's theorem for rational indices and its applications. Theory of equations: Relation between roots and coefficients, Transformation of equation, Descartes rule of signs, Cubic and biquadratic equation. Inequality: The inequality involving AM≥GM≥HM, Cauchy-Schwartz inequality.	
Unit 2	
Equivalence relations. Functions, Composition of functions, Invertible functions, One to one correspondence and cardinality of a set. Well-ordering property of positive integers, Division algorithm, Divisibility and Euclidean algorithm. Congruence relation between integers. Principles of Mathematical Induction, statement of Fundamental Theorem of Arithmetic.	
Unit 3	
Systems of linear equations, row reduction and echelon forms, vector equations, the matrix equation Ax=b, solution sets of linear systems, applications of linear systems, linear independence.	
Unit 4	
Introduction to linear transformations, matrix of a linear transformation, inverse of a matrix, characterizations of invertible matrices. Subspaces of Rn, dimension of subspaces of Rn, rank of a matrix, Eigen values, Eigen Vectors and Characteristic Equation of a matrix. Cayley-Hamilton theorem and its use in finding the inverse of a matrix.	
Reference Books	

- Titu Andreescu and Dorin Andrica, Complex Numbers from A to Z, Birkhauser, 2006.
- Edgar G. Goodaire and Michael M. Parmenter, Discrete Mathematics with Graph Theory, 3rd Ed., Pearson Education (Singapore) P. Ltd., Indian Reprint, 2005.

- David C. Lay, Linear Algebra and its Applications, 3rd Ed., Pearson Education Asia, Indian Reprint, 2007.
- K.B. Dutta, Matrix and linear algebra.
- K. Hoffman, R. Kunze, Linear algebra.
- W.S. Burnstine and A.W. Panton, Theory of equations.

3.4 Core T3 – Real Analysis

Real Analysis	
	6 Credits
Unit 1	
Review of Algebraic and Order Properties of R, ε-neighbourhood of a point in R. Idea of countable sets, uncountable sets and uncountability of R. Bounded above sets, Bounded below sets, Bounded Sets, Unbounded sets. Suprema and Infima. Completeness Property of R and its equivalent properties. The Archimedean Property, Density of Rational (and Irrational) numbers in R, Intervals. Limit points of a set, Isolated points, Open set, closed set, derived set, Illustrations of Bolzano-Weierstrass theorem for sets, compact sets in R, Heine-Borel Theorem.	
Unit 2	
Sequences, Bounded sequence, Convergent sequence, Limit of a sequence, lim inf, lim sup. Limit Theorems. Monotone Sequences, Monotone Convergence Theorem. Subsequences, Divergence Criteria. Monotone Subsequence Theorem (statement only), Bolzano Weierstrass Theorem for Sequences. Cauchy sequence, Cauchy's Convergence Criterion.	
Unit 3	
Infinite series, convergence and divergence of infinite series, Cauchy Criterion, Tests for convergence: Comparison test, Limit Comparison test, Ratio Test, Cauchy's nth root test, Integral test. Alternating series, Leibniz test. Absolute and Conditional convergence.	
Graphical Demonstration (Teaching Aid)	
1. Plotting of recursive sequences. 2. Study the convergence of sequences through plotting. 3. Verify Bolzano-Weierstrass theorem through plotting of sequences and hence identify convergent subsequences from the plot. 4. Study the convergence/divergence of infinite series by plotting their sequences of partial sum. 5. Cauchy's root test by plotting nth roots. 6. Ratio test by plotting the ratio of nth and (n+1)th term.	

Reference Books

- R.G. Bartle and D. R. Sherbert, Introduction to Real Analysis, 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.
- Gerald G. Bilodeau , Paul R. Thie, G.E. Keough, An Introduction to Analysis, 2nd Ed., Jones & Bartlett, 2010.
- Brian S. Thomson, Andrew. M. Bruckner and Judith B. Bruckner, Elementary Real Analysis, Prentice Hall, 2001.
- S.K. Berberian, a First Course in Real Analysis, Springer Verlag, New York, 1994.
- Tom M. Apostol, Mathematical Analysis, Narosa Publishing House
- Courant and John, Introduction to Calculus and Analysis, Vol I, Springer
- W. Rudin, Principles of Mathematical Analysis, Tata McGraw-Hill
- Terence Tao, Analysis I, Hindustan Book Agency, 2006
- S. Goldberg, Calculus and mathematical analysis.

3.5 Core T4 – Differential Equations and Vector Calculus

Differential Equations and Vector Calculus	
	6 Credits
Unit 1	
Lipschitz condition and Picard's Theorem (Statement only). General solution of homogeneous equation of second order, principle of super position for homogeneous equation, Wronskian: its properties and applications, Linear homogeneous and non-homogeneous equations of higher order with constant coefficients, Euler's equation, method of undetermined coefficients, method of variation of parameters.	
Unit 2	
Systems of linear differential equations, types of linear systems, differential operators, an operator method for linear systems with constant coefficients, Basic Theory of linear systems in normal form, homogeneous linear systems with constant coefficients: Two Equations in two unknown functions.	
Unit 3	
Equilibrium points, Interpretation of the phase plane Power series solution of a differential equation about an ordinary point, solution about a regular singular point.	
Unit 4	
Triple product, introduction to vector functions, operations with vector-valued functions, limits and continuity of vector functions, differentiation and integration of vector functions.	
Graphical Demonstration (Teaching Aid)	
1. Plotting of family of curves which are solutions of second order differential equation. 2. Plotting of family of curves which are solutions of third order differential equation.	
Reference Books	

- Belinda Barnes and Glenn R. Fulford, Mathematical Modeling with Case Studies, A Differential Equation Approach using Maple and Matlab, 2nd Ed., Taylor and Francis group, London and New York, 2009.
- C.H. Edwards and D.E. Penny, Differential Equations and Boundary Value problems Computing and Modeling, Pearson Education India, 2005.
- S.L. Ross, Differential Equations, 3rd Ed., John Wiley and Sons, India, 2004.
- Martha L Abell, James P Braselton, Differential Equations with MATHEMATICA, 3rd Ed., Elsevier Academic Press, 2004.
- Murray, D., Introductory Course in Differential Equations, Longmans Green and Co.
- Boyce and Diprima, Elementary Differential Equations and Boundary Value Problems, Wiley.
- G.F.Simmons, Differential Equations, Tata Mc Graw Hill
- Marsden, J., and Tromba, Vector Calculus, McGraw Hill.
- Maity, K.C. and Ghosh, R.K. Vector Analysis, New Central Book Agency (P) Ltd. Kolkata (India).
- M.R. Speigel, Schaum's outline of Vector Analysis

3.6 Core T5 - Theory of Real Functions & Introduction to Metric Space

Theory of Real Functions & Introduction to Metric Space	
	6 Credits

Unit 1

Limits of functions (ε - δ approach), sequential criterion for limits, divergence criteria. Limit theorems, one sided limits. Infinite limits and limits at infinity. Continuous functions, sequential criterion for continuity and discontinuity. Algebra of continuous functions. Continuous functions on an interval, intermediate value theorem, location of roots theorem, preservation of intervals theorem. Uniform continuity, non-uniform continuity criteria, uniform continuity theorem.

Unit 2

Differentiability of a function at a point and in an interval, Caratheodory's theorem, algebra of differentiable functions. Relative extrema, interior extremum theorem. Rolle's theorem. Mean value theorem, intermediate value property of derivatives, Darboux's theorem. Applications of mean value theorem to inequalities and approximation of polynomials.

Unit 3

Cauchy's mean value theorem. Taylor's theorem with Lagrange's form of remainder, Taylor's theorem with Cauchy's form of remainder, application of Taylor's theorem to convex functions, relative extrema. Taylor's series and Maclaurin's series expansions of exponential and trigonometric functions, ln(1 + x), 1/ax+b and (1 +x)n. Application of Taylor's theorem to inequalities.

Unit 4

Metric spaces: Definition and examples. Open and closed balls, neighbourhood, open set, interior of a set. Limit point of a set, closed set, diameter of a set, subspaces, dense sets, separable spaces.

Reference Books

- R. Bartle and D.R. Sherbert, Introduction to Real Analysis, John Wiley and Sons, 2003.
- K.A. Ross, Elementary Analysis: The Theory of Calculus, Springer, 2004.

- A. Mattuck, Introduction to Analysis, Prentice Hall, 1999.
- S.R. Ghorpade and B.V. Limaye, a Course in Calculus and Real Analysis, Springer, 2006.
- Tom M. Apostol, Mathematical Analysis, Narosa Publishing House
- Courant and John, Introduction to Calculus and Analysis, Vol II, Springer
- W. Rudin, Principles of Mathematical Analysis, Tata McGraw-Hill
- Terence Tao, Analysis II, Hindustan Book Agency, 2006
- Satish Shirali and Harikishan L. Vasudeva, Metric Spaces, Springer Verlag, London, 2006
- S. Kumaresan, Topology of Metric Spaces, 2nd Ed., Narosa Publishing House, 2011.
- G.F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, 2004.

3.7 Core T6 – Group Theory 1

Group Theory 1	
	6 Credits
Unit 1	
Symmetries of a square, Dihedral groups, definition and examples of groups including permutation groups and quaternion groups (through matrices), elementary properties of groups.	
Unit 2	
Subgroups and examples of subgroups, centralizer, normalizer, center of a group, product of two subgroups.	
Unit 3	
Properties of cyclic groups, classification of subgroups of cyclic groups. Cycle notation for permutations, properties of permutations, even and odd permutations, alternating group, properties of cosets, Lagrange's theorem and consequences including Fermat's Little theorem.	
Unit 4	
External direct product of a finite number of groups, normal subgroups, factor groups, Cauchy's theorem for finite abelian groups.	
Unit 5	
Group homomorphisms, properties of homomorphisms, Cayley's theorem, properties of isomorphisms. First, Second and Third isomorphism theorems.	

Reference Books

- John B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.
- M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.
- Joseph A. Gallian, Contemporary Abstract Algebra, 4th Ed., 1999.
- Joseph J. Rotman, An Introduction to the Theory of Groups, 4th Ed., 1995.
- I.N. Herstein, Topics in Algebra, Wiley Eastern Limited, India, 1975.
- D.S. Malik, John M. Mordeson and M.K. Sen, Fundamentals of abstract algebra.

3.8 Core T7 – Numerical Models

Numerical Models	
	4 Credits
Unit 1	
Algorithms. Convergence. Errors: Relative, Absolute. Round off. Truncation.	
Unit 2	
Transcendental and Polynomial equations: Bisection method, Newton's method, Secant method, Regula-falsi method, fixed point iteration, Newton-Raphson method. Rate of convergence of these methods.	
Unit 3	
System of linear algebraic equations: Gaussian Elimination and Gauss Jordan methods. Gauss Jacobi method, Gauss Seidel method and their convergence analysis. LU Decomposition	
Unit 4	
Interpolation: Lagrange and Newton's methods. Error bounds. Finite difference operators. Gregory forward and backward difference interpolation. Numerical differentiation: Methods based on interpolations, methods based on finite differences.	
Unit 5	
Numerical Integration: Newton Cotes formula, Trapezoidal rule, Simpson's $1/3^{rd}$ rule, Simpsons $3/8^{th}$ rule, Weddle's rule, Boole's Rule. Midpoint rule, Composite Trapezoidal rule, Composite Simpson's $1/3^{rd}$ rule, Gauss quadrature formula. The algebraic eigenvalue problem: Power method. Approximation: Least square polynomial approximation.	
Unit 6	

Ordinary Differential Equations: The method of successive approximations, Euler's method, the modified Euler method, Runge-Kutta methods of orders two and four.

Reference Books

- Brian Bradie, A Friendly Introduction to Numerical Analysis, Pearson Education, India, 2007.
- M.K. Jain, S.R.K. Iyengar and R.K. Jain, Numerical Methods for Scientific and Engineering
- Computation, 6th Ed., New age International Publisher, India, 2007.
- C.F. Gerald and P.O. Wheatley, Applied Numerical Analysis, Pearson Education, India, 2008.
- Uri M. Ascher and Chen Greif, A First Course in Numerical Methods, 7th Ed., PHI Learning Private Limited, 2013.
- John H. Mathews and Kurtis D. Fink, Numerical Methods using Matlab, 4th Ed., PHI Learning Private Limited, 2012.
- Scarborough, James B., Numerical Mathematical Analysis, Oxford and IBH publishing co.
- Atkinson, K. E., An Introduction to Numerical Analysis, John Wiley and Sons, 1978.
- YashavantKanetkar, Let Us C , BPB Publications.

3.9 Core P7 - Numerical Models Lab

Numerical Models	
	2 Credits
List of practical (using any software)	

1. Calculate the sum 1/1 + 1/2 + 1/3 + 1/4 + ----------+ 1/ N.
2. Enter 100 integers into an array and sort them in an ascending order.
3. Solution of transcendental and algebraic equations by
    a. Bisection method
    b. Newton Raphson method.
    c. Secant method.
    d. Regula Falsi method.
4. Solution of system of linear equations
    a. LU decomposition method
    b. Gaussian elimination method
    c. Gauss-Jacobi method
    d. Gauss-Seidel method
5. Interpolation
    a. Lagrange Interpolation
    b. Newton Interpolation
6. Numerical Integration
    a. Trapezoidal Rule
    b. Simpson's one third rule
    c. Weddle's Rule
    d. Gauss Quadrature
7. Method of finding Eigenvalue by Power method
8. Fitting a Polynomial Function
9. Solution of ordinary differential equations
    a. Euler method
    b. Modified Euler method
    c. Runge Kutta method

Note: For any of the CAS (Computer aided software) Data types-simple data types, floating data types, character data types, arithmetic operators and operator precedence, variables and constant declarations, expressions, input/output, relational operators, logical operators and logical expressions, control statements and loop statements, Arrays should be introduced to the students.

3.10 Core T8 – Riemann Integration and Series of Functions

Riemann Integration and Series of Functions	
	6 Credits
Unit 1	
Riemann integration: inequalities of upper and lower sums, Darbaux integration, Darbaux theorem, Riemann conditions of integrability, Riemann sum and definition of Riemann integral through Riemann sums, equivalence of two Definitions. Riemann integrability of monotone and continuous functions, Properties of the Riemann integral; definition and integrability of piecewise continuous and monotone functions. Intermediate Value theorem for Integrals. Fundamental theorem of Integral Calculus.	
Unit 2	
Improper integrals. Convergence of Beta and Gamma functions.	
Unit 3	
Pointwise and uniform convergence of sequence of functions. Theorems on continuity, derivability and integrability of the limit function of a sequence of functions. Series of functions; Theorems on the continuity and derivability of the sum function of a series of functions; Cauchy criterion for uniform convergence and Weierstrass M-Test.	
Unit 4	
Fourier series: Definition of Fourier coefficients and series, Reimann Lebesgue lemma, Bessel's inequality, Parseval's identity, Dirichlet's condition. Examples of Fourier expansions and summation results for series.	
Unit 5	
Power series, radius of convergence, Cauchy Hadamard Theorem. Differentiation and integration of power series; Abel's Theorem; Weierstrass Approximation Theorem.	

Reference Books

- K.A. Ross, Elementary Analysis, The Theory of Calculus, Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.
- R.G. Bartle D.R. Sherbert, Introduction to Real Analysis, 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.
- Charles G. Denlinger, Elements of Real Analysis, Jones & Bartlett (Student Edition), 2011.
- S. Goldberg, Calculus and mathematical analysis.
- Santi Narayan, Integral calculus.
- T. Apostol, Calculus I, II.

3.11 Core T9 – Multivariate Calculus

Multivariate Calculus	
	6 Credits
Unit 1	
Functions of several variables, limit and continuity of functions of two or more variables Partial differentiation, total differentiability and differentiability, sufficient condition for differentiability. Chain rule for one and two independent parameters, directional derivatives, the gradient, maximal and normal property of the gradient, tangent planes, Extrema of functions of two variables, method of Lagrange multipliers, constrained optimization problems	
Unit 2	
Double integration over rectangular region, double integration over non-rectangular region, Double integrals in polar co-ordinates, Triple integrals, Triple integral over a parallelepiped and solid regions. Volume by triple integrals, cylindrical and spherical co-ordinates. Change of variables in double integrals and triple integrals.	
Unit 3	
Definition of vector field, divergence and curl. Line integrals, Applications of line integrals: Mass and Work. Fundamental theorem for line integrals, conservative vector fields, independence of path.	
Unit 4	
Green's theorem, surface integrals, integrals over parametrically defined surfaces. Stoke's theorem, The Divergence theorem.	
Reference Books	

- G.B. Thomas and R.L. Finney, Calculus, 9th Ed., Pearson Education, Delhi, 2005.
- M.J. Strauss, G.L. Bradley and K. J. Smith, Calculus, 3rd Ed., Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2007.
- E. Marsden, A.J. Tromba and A. Weinstein, Basic Multivariable Calculus, Springer (SIE), Indian reprint, 2005.

- James Stewart, Multivariable Calculus, Concepts and Contexts, 2nd Ed., Brooks /Cole, Thomson Learning, USA, 2001
- Tom M. Apostol, Mathematical Analysis, Narosa Publishing House
- Courant and John, Introduction to Calculus and Analysis, Vol II, Springer
- W. Rudin, Principles of Mathematical Analysis, Tata McGraw-Hill
- Marsden, J., and Tromba, Vector Calculus, McGraw Hill.
- Maity, K.C. and Ghosh, R.K. Vector Analysis, New Central Book Agency (P) Ltd. Kolkata (India).
- Terence Tao, Analysis II, Hindustan Book Agency, 2006
- M.R. Speigel, Schaum's outline of Vector Analysis.

3.12 Core T10 – Ring Theory and Linear Algebra I

Ring Theory and Linear Algebra 1	
	6 Credits
Unit 1	
Definition and examples of rings, properties of rings, subrings, integral domains and fields, characteristic of a ring. Ideal, ideal generated by a subset of a ring, factor rings, operations on ideals, prime and maximal ideals.	
Unit 2	
Ring homomorphisms, properties of ring homomorphisms. Isomorphism theorems I, II and III, field of quotients.	
Unit 3	
Vector spaces, subspaces, algebra of subspaces, quotient spaces, linear combination of vectors, linear span, linear independence, basis and dimension, dimension of subspaces.	
Unit 4	
Linear transformations, null space, range, rank and nullity of a linear transformation, matrix representation of a linear transformation, algebra of linear transformations. Isomorphisms. Isomorphism theorems, invertibility and isomorphisms, change of coordinate matrix.	

Reference Books

- John B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.
- M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.
- Stephen H. Friedberg, Arnold J. Insel, Lawrence E. Spence, Linear Algebra, 4th Ed., Prentice- Hall of India Pvt. Ltd., New Delhi, 2004.
- Joseph A. Gallian, Contemporary Abstract Algebra, 4th Ed., Narosa Publishing House, New Delhi, 1999.
- S. Lang, Introduction to Linear Algebra, 2nd Ed., Springer, 2005.
- Gilbert Strang, Linear Algebra and its Applications, Thomson, 2007.
- S. Kumaresan, Linear Algebra- A Geometric Approach, Prentice Hall of India, 1999.

- Kenneth Hoffman, Ray Alden Kunze, Linear Algebra, 2nd Ed., Prentice-Hall of India Pvt. Ltd., 1971.
- D.A.R. Wallace, Groups, Rings and Fields, Springer Verlag London Ltd., 1998.
- D.S. Malik, John M. Mordeson and M.K. Sen, Fundamentals of abstract algebra.

3.13 Core T11 – Partial Differential Equations and Applications

Partial Differential Equations and Applications	
	6 Credits
Unit 1	
Partial Differential Equations – Basic concepts and Definitions. Mathematical Problems. First-Order Equations: Classification, Construction and Geometrical Interpretation. Method of Characteristics for obtaining General Solution of Quasi Linear Equations. Canonical Forms of First-order Linear Equations. Method of Separation of Variables for solving first order partial differential equations.	
Unit 2	
Derivation of Heat equation, Wave equation and Laplace equation. Classification of second order linear equations as hyperbolic, parabolic or elliptic. Reduction of second order Linear Equations to canonical forms.	
Unit 3	
The Cauchy problem, Cauchy-Kowalewskaya theorem, Cauchy problem of an infinite string. Initial Boundary Value Problems. Semi-Infinite String with a fixed end, Semi-Infinite String with a Free end. Equations with non-homogeneous boundary conditions. Non- Homogeneous Wave Equation. Method of separation of variables, Solving the Vibrating String Problem. Solving the Heat Conduction problem	
Unit 4	
Central force. Constrained motion, varying mass, tangent and normal components of acceleration, modelling ballistics and planetary motion, Kepler's second law.	
Graphical Demonstration (Teaching Aid)	
1. Solution of Cauchy problem for first order PDE. 2. Finding the characteristics for the first order PDE. 3. Plot the integral surfaces of a given first order PDE with initial data.	

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

(a) $u(x,0) = \phi(x),\ u_t(x,0) = \psi(x),\ x \in R,\ t > 0.$

(b) $u(x,0) = \phi(x),\ u_t(x,0) = \psi(x), u(0,t) = 0\ \ x \in (0,\infty),\ t > 0$

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

(a) $u(x,0) = \phi(x),\ u\ \ (o,t) = a, u\ \ (l,t) = b,\ \ 0 < x < l, t > 0.$

$u(x,0) = \phi(x),\ x \in R,\ \ 0 < t < T.$

Reference Books

- Tyn Myint-U and Lokenath Debnath, Linear Partial Differential Equations for Scientists and Engineers, 4th edition, Springer, Indian reprint, 2006.
- S.L. Ross, Differential equations, 3rd Ed., John Wiley and Sons, India, 2004.
- Martha L Abell, James P Braselton, Differential equations with MATHEMATICA, 3rd Ed., Elsevier Academic Press, 2004.
- Sneddon, I. N., Elements of Partial Differential Equations, McGraw Hill.
- Miller, F. H., Partial Differential Equations, John Wiley and Sons.
- Loney, S. L., An Elementary Treatise on the Dynamics of particle and of Rigid Bodies, Loney Press

3.14 Core T12 – Group Theory II

Group Theory II	
	6 Credits
Unit 1	
Automorphism, inner automorphism, automorphism groups, automorphism groups of finite and infinite cyclic groups, applications of factor groups to automorphism groups, Characteristic subgroups, Commutator subgroup and its properties.	
Unit 2	
Properties of external direct products, the group of units modulo n as an external direct product, internal direct products, Fundamental Theorem of finite abelian groups.	
Unit 3	
Group actions, stabilizers and kernels, permutation representation associated with a given group action. Applications of group actions. Generalized Cayley's theorem. Index theorem.	
Unit 4	
Groups acting on themselves by conjugation, class equation and consequences, conjugacy in Sn, p-groups, Sylow's theorems and consequences, Cauchy's theorem, Simplicity of An for n ≥ 5, non-simplicity tests.	

Reference Books

- John B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.
- M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.
- Joseph A. Gallian, Contemporary Abstract Algebra, 4th Ed., 1999.
- David S. Dummit and Richard M. Foote, Abstract Algebra, 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2004.
- J.R. Durbin, Modern Algebra, John Wiley & Sons, New York Inc., 2000.
- D. A. R. Wallace, Groups, Rings and Fields, Springer Verlag London Ltd., 1998
- D.S. Malik, John M. Mordeson and M.K. Sen, Fundamentals of abstract algebra.
- I.N. Herstein, Topics in Algebra, Wiley Eastern Limited, India, 1975.

3.15 Core T13 – Metric Spaces and Complex Analysis

Metric Spaces and Complex Analysis	
	6 Credits
Unit 1	
Metric spaces: Sequences in metric spaces, Cauchy sequences. Complete Metric Spaces, Cantor's theorem.	
Unit 2	
Continuous mappings, sequential criterion and other characterizations of continuity. Uniform continuity. Connectedness, connected subsets of R. Compactness: Sequential compactness, Heine-Borel property, Totally bounded spaces, finite intersection property, and continuous functions on compact sets. Homeomorphism. Contraction mappings. Banach Fixed point Theorem and its application to ordinary differential equation.	
Unit 3	
Limits, Limits involving the point at infinity, continuity. Properties of complex numbers, regions in the complex plane, functions of complex variable, mappings. Derivatives, differentiation formulas, Cauchy-Riemann equations, sufficient conditions for differentiability.	
Unit 4	
Analytic functions, examples of analytic functions, exponential function, Logarithmic function, trigonometric function, derivatives of functions, and definite integrals of functions. Contours, Contour integrals and its examples, upper bounds for moduli of contour integrals. Cauchy- Goursat theorem, Cauchy integral formula.	
Unit 5	
Liouville's theorem and the fundamental theorem of algebra. Convergence of sequences and series, Taylor series and its examples.	

Unit 6
Laurent series and its examples, absolute and uniform convergence of power series.

Reference Books

- Satish Shirali and Harikishan L. Vasudeva, Metric Spaces, Springer Verlag, London, 2006.
- S. Kumaresan, Topology of Metric Spaces, 2nd Ed., Narosa Publishing House, 2011.
- G.F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, 2004.
- James Ward Brown and Ruel V. Churchill, Complex Variables and Applications, 8th Ed., McGraw – Hill International Edition, 2009.
- Joseph Bak and Donald J. Newman, Complex Analysis, 2nd Ed., Undergraduate Texts in Mathematics, Springer-Verlag New York, Inc., NewYork, 1997.
- S. Ponnusamy, Foundations of complex analysis.
- E.M.Stein and R. Shakrachi, Complex Analysis, Princeton University Press.

3.16 Core T14 – Ring Theory and Linear Algebra II

Ring Theory and Linear Algebra II	
	6 Credits
Unit 1	
Polynomial rings over commutative rings, division algorithm and consequences, principal ideal domains, factorization of polynomials, reducibility tests, irreducibility tests, Eisenstein criterion, and unique factorization in Z [x]. Divisibility in integral domains, irreducible, primes, unique factorization domains, Euclidean domains.	
Unit 2	
Dual spaces, dual basis, double dual, transpose of a linear transformation and its matrix in the dual basis, annihilators. Eigen spaces of a linear operator, diagonalizability, invariant subspaces and Cayley-Hamilton theorem, the minimal polynomial for a linear operator, canonical forms.	
Unit 3	
Inner product spaces and norms, Gram-Schmidt orthogonalisation process, orthogonal complements, Bessel's inequality, the adjoint of a linear operator. Least Squares Approximation, minimal solutions to systems of linear equations. Normal and self-adjoint operators. Orthogonal projections and Spectral theorem.	

Reference Books

- John B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.
- M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.
- Joseph A. Gallian, Contemporary Abstract Algebra, 4th Ed., Narosa Publishing House, 1999.
- Stephen H. Friedberg, Arnold J. Insel, Lawrence E. Spence, Linear Algebra, 4th Ed., Prentice- Hall of India Pvt. Ltd., New Delhi, 2004.
- S. Lang, Introduction to Linear Algebra, 2nd Ed., Springer, 2005.
- Gilbert Strang, Linear Algebra and its Applications, Thomson, 2007.
- S. Kumaresan, Linear Algebra- A Geometric Approach, Prentice Hall of India, 1999.
- Kenneth Hoffman, Ray Alden Kunze, Linear Algebra, 2nd Ed., Prentice-Hall of India Pvt. Ltd., 1971.

- S.H. Friedberg, A.L. Insel and L.E. Spence, Linear Algebra, Prentice Hall of India Pvt. Ltd., 2004

4. Department Specific Electives Subjects Syllabus

4.1 DSE T1 – Linear Programming

Linear Programming	
	6 Credits

Unit 1

Introduction to linear programming problem. Theory of simplex method, graphical solution, convex sets, optimality and unboundedness, the simplex algorithm, simplex method in tableau format, introduction to artificial variables, two-phase method. Big-M method and their comparison.

Unit 2

Duality, formulation of the dual problem, primal-dual relationships, economic interpretation of the dual.

Transportation problem and its mathematical formulation, northwest-corner method, least cost method and Vogel approximation method for determination of starting basic solution, algorithm for solving transportation problem, assignment problem and its mathematical formulation, Hungarian method for solving assignment problem.

Unit 3

Game theory: formulation of two person zero sum games, solving two person zero sum games, games with mixed strategies, graphical solution procedure, linear programming solution of games.

Reference Books

- Mokhtar S. Bazaraa, John J. Jarvis and Hanif D. Sherali, Linear Programming and Network Flows, 2nd Ed., John Wiley and Sons, India, 2004.
- F.S. Hillier and G.J. Lieberman, Introduction to Operations Research, 9th Ed., Tata McGraw Hill, Singapore, 2009.
- Hamdy A. Taha, Operations Research, An Introduction, 8th Ed., Prentice-Hall India, 2006.
- G. Hadley, Linear Programming, Narosa Publishing House, New Delhi, 2002.

4.2 DSE T2 – Theory of Equations

Theory of Equations	
	6 Credits
Unit 1	
General properties of polynomials, Graphical representation of a polynomial, maximum and minimum values of a polynomials, General properties of equations, Descarte's rule of signs positive and negative rule, Relation between the roots and the coefficients of equations.	
Unit 2	
Symmetric functions. Applications of symmetric function of the roots. Transformation of equations. Solutions of reciprocal and binomial equations. Algebraic solutions of the cubic and biquadratic. Properties of the derived functions.	
Unit 3	
Symmetric functions of the roots, Newton's theorem on the sums of powers of roots, homogeneous products, limits of the roots of equations.	
Unit 4	
Separation of the roots of equations, Strums theorem. Applications of Strum's theorem, Conditions for reality of the roots of an equation. Solution of numerical equations.	
Reference Books	

- W.S. Burnside and A.W. Panton, The Theory of Equations, Dublin University Press, 1954.
- C. C. MacDuffee, Theory of Equations, John Wiley & Sons Inc., 1954.

4.3 DSE T3 – Point Set Topology

Point Set Topology	
	6 Credits
Unit 1	
Countable and Uncountable Sets, Schroeder-Bernstein Theorem, Cantor's Theorem. Cardinal Numbers and Cardinal Arithmetic. Continuum Hypothesis, Zorns Lemma, Axiom of Choice. Well-Ordered Sets, Hausdorff's Maximal Principle. Ordinal Numbers.	
Unit 2	
Topological spaces, Basis and Subbasis for a topology, subspace Topology, Interior Points, Limit Points, Derived Set, Boundary of a set, Closed Sets, Closure and Interior of a set. Continuous Functions, Open maps, Closed maps and Homeomorphisms. Product Topology, Quotient Topology, Metric Topology, Baire Category Theorem.	
Unit 3	
Connected and Path Connected Spaces, Connected Sets in R, Components and Path Components, Local Connectedness. Compact Spaces, Compact Sets in R. Compactness in Metric Spaces. Totally Bounded Spaces, Ascoli-Arzela Theorem, The Lebesgue Number Lemma. Local Compactness.	
Reference Books	

- Munkres, J.R., Topology, A First Course, Prentice Hall of India Pvt. Ltd., New Delhi, 2000.
- Dugundji, J., Topology, Allyn and Bacon, 1966.
- Simmons, G.F., Introduction to Topology and Modern Analysis, McGraw Hill, 1963.
- Kelley, J.L., General Topology, Van Nostrand Reinhold Co., New York, 1995.
- Hocking, J., Young, G., Topology, Addison-Wesley Reading, 1961.
- Steen, L., Seebach, J., Counter Examples in Topology, Holt, Reinhart and Winston, New York, 1970.
- Abhijit Dasgupta, Set Theory, Birkhäuser.

4.4 DSE T4 - Probability and Statistics

Probability and Statistics	
	6 Credits
Unit 1	
Sample space, probability axioms, real random variables (discrete and continuous), cumulative distribution function, probability mass/density functions, mathematical expectation, moments, moment generating function, characteristic function, discrete distributions: uniform, binomial, Poisson, geometric, negative binomial, continuous distributions: uniform, normal, exponential.	
Unit 2	
Joint cumulative distribution function and its properties, joint probability density functions, marginal and conditional distributions, expectation of function of two random variables, conditional expectations, independent random variables, bivariate normal distribution, correlation coefficient, joint moment generating function (jmgf) and calculation of covariance (from jmgf), linear regression for two variables.	
Unit 3	
Chebyshev's inequality, statement and interpretation of (weak) law of large numbers and strong law of large numbers. Central Limit theorem for independent and identically distributed random variables with finite variance, Markov Chains, Chapman-Kolmogorov equations, classification of states.	
Unit 4	
Random Samples, Sampling Distributions, Estimation of parameters, Testing of hypothesis.	

Reference Books

- Robert V. Hogg, Joseph W. McKean and Allen T. Craig, Introduction to Mathematical Statistics, Pearson Education, Asia, 2007.
- Irwin Miller and Marylees Miller, John E. Freund, Mathematical Statistics with Applications, 7th Ed., Pearson Education, Asia, 2006.
- Sheldon Ross, Introduction to Probability Models, 9th Ed., Academic Press, Indian Reprint, 2007.

- Alexander M. Mood, Franklin A. Graybill and Duane C. Boes, Introduction to the Theory of Statistics, 3rd Ed., Tata McGraw- Hill, Reprint 2007
- A. Gupta, Ground work of Mathematical Probability and Statistics, Academic publishers.

4.5 DSE T5 - Portfolio Optimization

Portfolio Optimization	
	6 Credits
Unit 1	
Financial markets. Investment objectives. Measures of return and risk. Types of risks. Risk free assets. Mutual funds. Portfolio of assets. Expected risk and return of portfolio. Diversification.	
Unit 2	
Mean-variance portfolio optimization- the Markowitz model and the two-fund theorem, risk-free assets and one fund theorem, efficient frontier. Portfolios with short sales. Capital market theory.	
Unit 3	
Capital assets pricing model- the capital market line, beta of an asset, beta of a portfolio, security market line. Index tracking optimization models. Portfolio performance evaluation measures.	
Reference Books	

- F. K. Reilly, Keith C. Brown, Investment Analysis and Portfolio Management, 10th Ed., South-Western Publishers, 2011.
- H.M. Markowitz, Mean-Variance Analysis in Portfolio Choice and Capital Markets, Blackwell, New York, 1987.
- M.J. Best, Portfolio Optimization, Chapman and Hall, CRC Press, 2010.
- D.G. Luenberger, Investment Science, 2nd Ed., Oxford University Press, 2013.

4.6 DSE T6 – Boolean Algebra and Automata Theory

Boolean Algebra and Automata Theory	
	6 Credits
Unit 1	
Definition, examples and basic properties of ordered sets, maps between ordered sets, duality principle, lattices as ordered sets, lattices as algebraic structures, sublattices, products and homomorphisms.	
Unit 2	
Definition, examples and properties of modular and distributive lattices, Boolean algebras, Boolean polynomials, minimal and maximal forms of Boolean polynomials, Quinn-McCluskey method, Karnaugh diagrams, Logic Gates, switching circuits and applications of switching circuits.	
Unit 3	
Introduction: Alphabets, strings, and languages. Finite Automata and Regular Languages: deterministic and non-deterministic finite automata, regular expressions, regular languages and their relationship with finite automata, pumping lemma and closure properties of regular languages.	
Unit 4	
Context Free Grammars and Pushdown Automata: Context free grammars (CFG), parse trees, ambiguities in grammars and languages, pushdown automaton (PDA) and the language accepted by PDA, deterministic PDA, Non- deterministic PDA, properties of context free languages; normal forms, pumping lemma, closure properties, decision properties.	
Unit 5	
Turing Machines: Turing machine as a model of computation, programming with a Turing machine, variants of Turing machine and their equivalence.	
Unit 6	

Undecidability: Recursively enumerable and recursive languages, undecidable problems about Turing machines: halting problem. Post Correspondence Problem, and undecidability problems About CFGs.

Reference Books

- B A. Davey and H. A. Priestley, Introduction to Lattices and Order, Cambridge University Press, Cambridge, 1990.
- Edgar G. Goodaire and Michael M. Parmenter, Discrete Mathematics with Graph Theory,
- (2nd Ed.), Pearson Education (Singapore) P.Ltd., Indian Reprint 2003.
- Rudolf Lidl and Günter Pilz, Applied Abstract Algebra, 2nd Ed., Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.
- J. E. Hopcroft, R. Motwani and J. D. Ullman, Introduction to Automata Theory, Languages, and Computation, 2nd Ed., Addison-Wesley, 2001.
- H.R. Lewis, C.H. Papadimitriou, C. Papadimitriou, Elements of the Theory of Computation, 2nd Ed., Prentice-Hall, NJ, 1997.
- J.A. Anderson, Automata Theory with Modern Applications, Cambridge University Press, 2006

4.7 DSE T7 - Number Theory

Number Theory	
	6 Credits
Unit 1	
Linear Diophantine equation, prime counting function, statement of prime number theorem, Goldbach conjecture, linear congruences, complete set of residues, Chinese Remainder theorem, Fermat's Little theorem, Wilson's theorem.	
Unit 2	
Number theoretic functions, sum and number of divisors, totally multiplicative functions, definition and properties of the Dirichlet product, the Mobius Inversion formula, the greatest integer function, Euler's phi-function, Euler's theorem, reduced set of residues. some properties of Euler's phi-function.	
Unit 3	
Order of an integer modulo n, primitive roots for primes, composite numbers having primitive roots, Euler's criterion, the Legendre symbol and its properties, quadratic reciprocity, quadratic congruences with composite moduli. Public key encryption, RSA encryption and decryption, the equation x2 + y2= z2, Fermat's Last theorem.	
Reference Books	
► David M. Burton, Elementary Number Theory, 6th Ed., Tata McGraw-Hill, Indian reprint, 2007. ► Neville Robinns, Beginning Number Theory, 2nd Ed., Narosa Publishing House Pvt. Ltd., Delhi, 2007	

4.8 DSE T8 – Industrial Mathematics

Industry Mathematics	
	6 Credits
Unit 1	
Medical Imaging and Inverse Problems. The content is based on Mathematics of X-ray and CT scan based on the knowledge of calculus, elementary differential equations, complex numbers and matrices.	
Unit 2	
Introduction to Inverse problems: Why should we teach Inverse Problems? Illustration of Inverse problems through problems taught in Pre-Calculus, Calculus, Matrices and differential equations. Geological anomalies in Earth's interior from measurements at its surface (Inverse problems for Natural disaster) and Tomography.	
Unit 3	
X-ray: Introduction, X-ray behavior and Beers Law (The fundamental question of image construction) Lines in the place.	
Unit 4	
Radon Transform: Definition and Examples, Linearity, Phantom (Shepp - Logan Phantom - Mathematical phantoms).	
Unit 5	
Back Projection: Definition, properties and examples.	
Unit 6	
CT Scan: Revision of properties of Fourier and inverse Fourier transforms and applications of their properties in image reconstruction. Algorithms of CT scan machine. Algebraic reconstruction techniques abbreviated as ART with application to CT scan.	
Reference Books	

- Timothy G. Feeman, The Mathematics of Medical Imaging, A Beginners Guide, Springer Under graduate Text in Mathematics and Technology, Springer, 2010.
- C.W. Groetsch, Inverse Problems, Activities for Undergraduates, The Mathematical Association of America, 1999.
- Andreas Kirsch, An Introduction to the Mathematical Theory of Inverse Problems, 2nd Ed., Springer, 2011

4.9 DSE T9 – Mechanics

Mechanics	
	6 Credits
Unit 1	
Co-planar forces. Astatic equilibrium. Friction. Equilibrium of a particle on a rough curve. Virtual work. Forces in three dimensions. General conditions of equilibrium. Centre of gravity for different bodies. Stable and unstable equilibrium.	
Unit 2	
Equations of motion referred to a set of rotating axes. Motion of a projectile in a resisting medium. Stability of nearly circular orbits. Motion under the inverse square law. Slightly disturbed orbits. Motion of artificial satellites. Motion of a particle in three dimensions. Motion on a smooth sphere, cone, and on any surface of revolution.	
Unit 3	
Degrees of freedom. Moments and products of inertia. Momental Ellipsoid. Principal axes. D'Alembert's Principle. Motion about a fixed axis. Compound pendulum. Motion of a rigid body in two dimensions under finite and impulsive forces. Conservation of momentum and energy.	

Reference Books

- I.H. Shames and G. Krishna Mohan Rao, Engineering Mechanics: Statics and Dynamics, (4th Ed.), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2009.
- R.C. Hibbeler and Ashok Gupta, Engineering Mechanics: Statics and Dynamics, 11th Ed., Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi.
- Chorlton, F., Textbook of Dynamics.
- Loney, S. L., An Elementary Treatise on the Dynamics of particle and of Rigid Bodies
- Loney, S. L., Elements of Statics and Dynamics I and II.
- Ghosh, M. C, Analytical Statics.
- Verma, R. S., A Textbook on Statics, Pothishala, 1962 .
- Matiur Rahman, Md., Statics.
- Ramsey, A. S., Dynamics (Part I).

4.10 DSE T10 – Bio Mathematics

Bio Mathematics	
	6 Credits
Unit 1	
Mathematical Biology and the modeling process: an overview. Continuous models: Malthus model, logistic growth, Allee effect, Gompertz growth, Michaelis-Menten Kinetics, Holling type growth, Bacterial growth in a Chemostat, Harvesting a single natural population, Prey predator systems and Lotka Volterra equations, Populations in competitions, Epidemic Models (SI, SIR, SIRS, SIC)	
Unit 2	
Activator-Inhibitor system, Insect Outbreak Model: Spruce Budworm, Numerical solution of the models and its graphical representation. Qualitative analysis of continuous models: Steady state solutions, stability and linearization, multiple species communities and Routh-Hurwitz Criteria, Phase plane methods and qualitative solutions, bifurcations and limit cycles with examples in the context of biological scenario. Spatial Models: One species model with diffusion, Two species model with diffusion. Conditions for diffusive instability, Spreading colonies of microorganisms, Blood flow in circulatory system, Travelling wave solutions, Spread of genes in a population.	
Unit 3	
Discrete Models: Overview of difference equations, steady state solution and linear stability analysis. Introduction to Discrete Models, Linear Models, Growth models, Decay models, Drug Delivery Problem, Discrete Prey-Predator models, Density dependent growth models with harvesting, Host-Parasitoid systems (Nicholson-Bailey model), Numerical solution of the models and its graphical representation. Case Studies: Optimal Exploitation models, Models in Genetics, Stage Structure Models, Age Structure Models.	
Graphical Demonstration (Teaching Aid)	
1. Growth model (exponential case only). 2. Decay model (exponential case only). 3. Lake pollution model (with constant/seasonal flow and pollution concentration).	

4. Case of single cold pill and a course of cold pills.
5. Limited growth of population (with and without harvesting).
6. Predatory-prey model (basic volterra model, with density dependence, effect of DDT, two prey one predator).
7. Epidemic model of infuenza (basic epidemic model, contagious for life, disease with carriers).
8. Battle model (basic battle model, jungle warfare, long range weapons).

Reference Books

- 1. L.E. Keshet, Mathematical Models in Biology, SIAM, 1988.
- 2. J. D. Murray, Mathematical Biology, Springer, 1993.
- 3. Y.C. Fung, Biomechanics, Springer-Verlag, 1990.
- 4. F. Brauer, P.V.D. Driessche and J. Wu, Mathematical Epidemiology, Springer, 2008.
- 5. M. Kot, Elements of Mathematical Ecology, Cambridge University Press, 2001.

4.11 DSE T11 – Differential Geometry

Differential Geometry	
	6 Credits
Unit 1	
Theory of Space Curves: Space curves. Planer curves, Curvature, torsion and Serret-Frenet formula. Osculating circles, Osculating circles and spheres. Existence of space curves. Evolutes and involutes of curves.	
Unit 2	
Theory of Surfaces: Parametric curves on surfaces. Direction coefficients. First and second Fundamental forms. Principal and Gaussian curvatures. Lines of curvature, Euler's theorem. Rodrigue's formula. Conjugate and Asymptotic lines.	
Unit 3	
Developables: Developable associated with space curves and curves on surfaces, Minimal surfaces. Geodesics: Canonical geodesic equations. Nature of geodesics on a surface of revolution. Clairaut's theorem. Normal property of geodesics. Torsion of a geodesic. Geodesic curvature. Gauss-Bonnet theorem.	

Reference Books

- T.J. Willmore, An Introduction to Differential Geometry, Dover Publications, 2012.
- B. O'Neill, Elementary Differential Geometry, 2nd Ed., Academic Press, 2006.
- C.E. Weatherburn, Differential Geometry of Three Dimensions, Cambridge University Press 2003.
- D.J. Struik, Lectures on Classical Differential Geometry, Dover Publications, 1988.
- S. Lang, Fundamentals of Differential Geometry, Springer, 1999.
- B. Spain, Tensor Calculus: A Concise Course, Dover Publications, 2003

4.12 DSE T12 – Mathematical Modelling

Mathematical Modelling	
	6 Credits
Unit 1	
Power series solution of Bessel's equation and Legendre's equation, Laplace transform and inverse transform, application to initial value problem up to second order.	
Unit 2	
Monte Carlo Simulation Modeling: simulating deterministic behavior (area under a curve, volume under a surface), Generating Random Numbers: middle square method, linear congruence, Queuing Models: harbor system, morning rush hour, Overview of optimization modelling. Linear Programming Model: geometric solution algebraic solution, simplex method, sensitivity analysis	

Graphical Demonstration (Teaching Aid)

1. Plotting of Legendre polynomial for n = 1 to 5 in the interval [0,1]. Verifying graphically that all the roots of Pn (x) lie in the interval [0,1].
2. Automatic computation of coefficients in the series solution near ordinary points.
3. Plotting of the Bessel's function of first kind of order 0 to 3.
4. Automating the Frobenius Series Method.
5. Random number generation and then use it for one of the following (a) Simulate area under a curve (b) Simulate volume under a surface.
6. Programming of either one of the queuing model (a) Single server queue (e.g. Harbor system) (b) Multiple server queue (e.g. Rush hour).
7. Programming of the Simplex method for 2/3 variables.

Reference Books

- Tyn Myint-U and Lokenath Debnath, Linear Partial Differential Equation for Scientists and Engineers, Springer, Indian reprint, 2006.
- Frank R. Giordano, Maurice D. Weir and William P. Fox, A First Course in Mathematical Modeling, Thomson Learning, London and New York, 2003.

5. Skill Enhancement Subjects Syllabus

5.1 SEC T1 – Logic and Sets

Logic and Sets	
	2 Credits
Unit 1	
Introduction, propositions, truth table, negation, conjunction and disjunction. Implications, biconditional propositions, converse, contra positive and inverse propositions and precedence of logical operators. Propositional equivalence: Logical equivalences. Predicates and quantifiers: Introduction, Quantifiers, Binding variables and Negations.	
Unit 2	
Sets, subsets, Set operations and the laws of set theory and Venn diagrams. Examples of finite and infinite sets. Finite sets and counting principle. Empty set, properties of empty set. Standard set operations. Classes of sets. Power set of a set.	
Unit 3	
Difference and Symmetric difference of two sets. Set identities, Generalized union and intersections. Relation: Product set. Composition of relations, Types of relations, Partitions, Equivalence Relations with example of congruence modulo relation. Partial ordering relations, n-ary relations.	
Reference Books	

- R.P. Grimaldi, Discrete Mathematics and Combinatorial Mathematics, Pearson Education, 1998.
- P.R. Halmos, Naive Set Theory, Springer, 1974.
- E. Kamke, Theory of Sets, Dover Publishers, 1950.

5.2 SEC T2 – Computer Graphics

Computer Graphics	
	2 Credits
Unit 1	
Development of computer Graphics: Raster Scan and Random Scan graphics storages, displays processors and character generators, colour display techniques, interactive input/output devices.	
Unit 2	
Points, lines and curves: Scan conversion, line-drawing algorithms, circle and ellipse generation, conic-section generation, polygon filling anti-aliasing.	
Unit 3	
Two-dimensional viewing: Coordinate systems, linear transformations, line and polygon clipping algorithms.	
Reference Books	

- D. Hearn and M.P. Baker, Computer Graphics, 2nd Ed., Prentice–Hall of India, 2004.
- J.D. Foley, A van Dam, S.K. Feiner and J.F. Hughes, Computer Graphics: Principals and Practices, 2nd Ed., Addison-Wesley, MA, 1990.
- D.F. Rogers, Procedural Elements in Computer Graphics, 2nd Ed., McGraw Hill Book Company, 2001.
- D.F. Rogers and A.J. Admas, Mathematical Elements in Computer Graphics, 2nd Ed., McGraw Hill Book Company, 1990.

5.3 SEC T3 – Object Oriented Programming in C++

Object Oriented Programming in C++	
	2 Credits
Unit 1	
Programming paradigms, characteristics of object oriented programming languages, brief history of C++, structure of C++ program, differences between C and C++, basic C++ operators, Comments, working with variables, enumeration, arrays and pointer.	
Unit 2	
Objects, classes, constructor and destructors, friend function, inline function, encapsulation, data abstraction, inheritance, polymorphism, dynamic binding, operator overloading, method overloading, overloading arithmetic operator and comparison operators.	
Unit 3	
Template class in C++, copy constructor, subscript and function call operator, concept of namespace and exception handling.	
Reference Books	

- A. R. Venugopal, Rajkumar, and T. Ravishanker, Mastering C++, TMH, 1997.
- S. B. Lippman and J. Lajoie, C++ Primer, 3rd Ed., Addison Wesley, 2000.
- Bruce Eckel, Thinking in C++, 2nd Ed., President, Mindview Inc., Prentice Hall.
- D. Parasons, Object Oriented Programming with C++, BPB Publication.
- Bjarne Stroustrup, The C++ Programming Language, 3rd Ed., Addison Welsley.
- E. Balaguruswami, Object Oriented Programming In C++, Tata McGrawHill
- Herbert Scildt, C++, The Complete Reference, Tata McGrawHill.

5.4 SEC T4 - Graph Theory

Graph Theory	
	2 Credits
Unit 1	
Definition, examples and basic properties of graphs, pseudo graphs, complete graphs, bi - partite graphs isomorphism of graphs.	
Unit 2	
Eulerian circuits, Eulerian graph, semi-Eulerian graph, theorems, Hamiltonian cycles,theorems Representation of a graph by matrix, the adjacency matrix, incidence matrix, weighted graph,	
Unit 3	
Travelling salesman's problem, shortest path, Tree and their properties, spanning tree, Dijkstra's algorithm, Warshall algorithm.	
Reference Books	

- B.A. Davey and H.A. Priestley, Introduction to Lattices and Order, Cambridge University Press, Cambridge, 1990.
- Edgar G. Goodaire and Michael M. Parmenter, Discrete Mathematics with Graph Theory, 2nd Edition, Pearson Education (Singapore) P. Ltd., Indian Reprint 2003.
- Rudolf Lidl and Gunter Pilz, Applied Abstract Algebra, 2nd Ed., Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.

5.5 SEC T5 – Operating System: Linux

Operating Systems: Linux	
	2 Credits
Unit 1	
Linux – The Operating System: Linux history, Linux features, Linux distributions, Linux's relationship to Unix, Overview of Linux architecture, Installation, Start up scripts, system processes (an overview), Linux Security.	
Unit 2	
The Ext2 and Ext3 File systems: General Characteristics of The Ext3 File system, file permissions. User Management: Types of users, the powers of Root, managing users (adding and deleting): using the command line and GUI tools.	
Unit 3	
Resource Management in Linux: file and directory management, system calls for files Process Management, Signals, IPC: Pipes, FIFOs, System V IPC, Message Queues, system calls for processes, Memory Management, library and system calls for memory.	
Reference Books	

- Arnold Robbins, Linux Programming by Examples The Fundamentals, 2nd Ed., Pearson Education, 2008.
- Cox K, Red Hat Linux Administrator's Guide, PHI, 2009.
- R. Stevens, UNIX Network Programming, 3rd Ed., PHI, 2008.
- Sumitabha Das, UNIX Concepts and Applications, 4th Ed., TMH, 2009.
- Ellen Siever, Stephen Figgins, Robert Love, Arnold Robbins, Linux in a Nutshell, 6th Ed., O'Reilly Media, 2009.
- Neil Matthew, Richard Stones, Alan Cox, Beginning Linux Programming, 3rd Ed., 2004.

6. General Elective Subjects Syllabus

6.1 GE T1 – Calculus, Geometry & Differential Equation

Calculus, Geometry & Differential Equation	
	6 Credits
Unit 1	
Hyperbolic functions, higher order derivatives, Leibnitz rule and its applications to problems of type eax+bsinx, eax+bcosx, (ax+b)nsinx, (ax+b)ncosx, concavity and inflection points, envelopes, asymptotes, curve tracing in Cartesian coordinates, tracing in polar coordinates of standard curves, L'Hospital's rule, applications in business, economics and life sciences.	
Unit 2	
Reduction formulae, derivations and illustrations of reduction formulae of the type f sin nx dx, f cos nx dx, f tan nx dx, f sec nx dx, f (log x)n dx, f sinn x sinm x dx, parametric equations, parameterizing a curve, arc length, arc length of parametric curves, area of surface of revolution. Techniques of sketching conics.	
Unit 3	
Reflection properties of conics, rotation of axes and second degree equations, classification of conics using the discriminant, polar equations of conics. Spheres. Cylindrical surfaces. Central conicoids, paraboloids, plane sections of conicoids, Generating lines, classification of quadrics, Illustrations of graphing standard quadric surfaces like cone, ellipsoid.	
Unit 4	
Differential equations and mathematical models. General, particular, explicit, implicit and singular solutions of a differential equation. Exact differential equations and integrating factors, separable equations and equations reducible to this form, linear equation and Bernoulli equations, special integrating factors and transformations.	

Graphical Demonstration (Teaching Aid)

1. Plotting of graphs of function eax + b, log(ax + b), 1/(ax + b), sin(ax + b), cos(ax + b), |ax + b| and to illustrate the effect of a and b on the graph.
2. Plotting the graphs of polynomial of degree 4 and 5, the derivative graph, the second derivative graph and comparing them.
3. Sketching parametric curves (Eg. Trochoid, cycloid, epicycloids, hypocycloid).
4. Obtaining surface of revolution of curves.
5. Tracing of conics in cartesian coordinates/ polar coordinates.
6. Sketching ellipsoid, hyperboloid of one and two sheets, elliptic cone, elliptic, paraboloid, and hyperbolic paraboloid using Cartesian coordinates.

Reference Books

- G.B. Thomas and R.L. Finney, Calculus, 9th Ed., Pearson Education, Delhi, 2005.
- M.J. Strauss, G.L. Bradley and K. J. Smith, Calculus, 3rd Ed., Dorling Kindersley (India) P. Ltd. (Pearson Education), Delhi, 2007.
- H. Anton, I. Bivens and S. Davis, Calculus, 7th Ed., John Wiley and Sons (Asia) P. Ltd., Singapore, 2002.
- R. Courant and F. John, Introduction to Calculus and Analysis (Volumes I & II), Springer-Verlag, New York, Inc., 1989.
- S.L. Ross, Differential Equations, 3rd Ed., John Wiley and Sons, India, 2004.
- Murray, D., Introductory Course in Differential Equations, Longmans Green and Co.
- G.F.Simmons, Differential Equations, Tata Mcgraw Hill.
- T. Apostol, Calculus, Volumes I and II.
- S. Goldberg, Calculus and mathematical analysis.

6.2 GE T2 - Algebra

Algebra	
	6 Credits
Unit 1	
Polar representation of complex numbers, nth roots of unity, De Moivre's theorem for rational indices and its applications. Theory of equations: Relation between roots and coefficients, Transformation of equation, Descartes rule of signs, Cubic and biquadratic equation. Inequality: The inequality involving AM≥GM≥HM, Cauchy-Schwartz inequality.	
Unit 2	
Equivalence relations. Functions, Composition of functions, Invertible functions, One to one correspondence and cardinality of a set. Well-ordering property of positive integers, Division algorithm, Divisibility and Euclidean algorithm. Congruence relation between integers. Principles of Mathematical Induction, statement of Fundamental Theorem of Arithmetic.	
Unit 3	
Systems of linear equations, row reduction and echelon forms, vector equations, the matrix equation Ax=b, solution sets of linear systems, applications of linear systems, linear independence.	
Unit 4	
Introduction to linear transformations, matrix of a linear transformation, inverse of a matrix, characterizations of invertible matrices. Subspaces of Rn, dimension of subspaces of Rn, rank of a matrix, Eigen values, Eigen Vectors and Characteristic Equation of a matrix. Cayley-Hamilton theorem and its use in finding the inverse of a matrix.	
Reference Books	
▸ Titu Andreescu and Dorin Andrica, Complex Numbers from A to Z, Birkhauser, 2006. ▸ Edgar G. Goodaire and Michael M. Parmenter, Discrete Mathematics with Graph Theory, 3rd Ed., Pearson Education (Singapore) P. Ltd., Indian Reprint, 2005.	

- David C. Lay, Linear Algebra and its Applications, 3rd Ed., Pearson Education Asia, Indian Reprint, 2007.
- K.B. Dutta, Matrix and linear algebra.
- K. Hoffman, R. Kunze, Linear algebra.
- W.S. Burnstine and A.W. Panton, Theory of equations.

6.3 GE T3 - Real Analysis

Real Analysis	
	6 Credits

Unit 1

Review of Algebraic and Order Properties of R, ε-neighbourhood of a point in R. Idea of countable sets, uncountable sets and uncountability of R. Bounded above sets, Bounded below sets, Bounded Sets, Unbounded sets. Suprema and Infima. Completeness Property of R and its equivalent properties. The Archimedean Property, Density of Rational (and Irrational) numbers in R, Intervals. Limit points of a set, Isolated points, Open set, closed set, derived set, Illustrations of Bolzano-Weierstrass theorem for sets, compact sets in R, Heine-Borel Theorem.

Unit 2

Sequences, Bounded sequence, Convergent sequence, Limit of a sequence, lim inf, lim sup. Limit Theorems. Monotone Sequences, Monotone Convergence Theorem. Subsequences, Divergence Criteria. Monotone Subsequence Theorem (statement only), Bolzano Weierstrass Theorem for Sequences. Cauchy sequence, Cauchy's Convergence Criterion.

Unit 3

Infinite series, convergence and divergence of infinite series, Cauchy Criterion, Tests for convergence: Comparison test, Limit Comparison test, Ratio Test, Cauchy's nth root test, Integral test. Alternating series, Leibniz test. Absolute and Conditional convergence.

Graphical Demonstration (Teaching Aid)

1. Plotting of recursive sequences.
2. Study the convergence of sequences through plotting.
3. Verify Bolzano-Weierstrass theorem through plotting of sequences and hence identify convergent subsequences from the plot.
4. Study the convergence/divergence of infinite series by plotting their sequences of partial sum.
5. Cauchy's root test by plotting nth roots.
6. Ratio test by plotting the ratio of nth and (n+1)th term.

Reference Books

- R.G. Bartle and D. R. Sherbert, Introduction to Real Analysis, 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.
- Gerald G. Bilodeau , Paul R. Thie, G.E. Keough, An Introduction to Analysis, 2nd Ed., Jones & Bartlett, 2010.
- Brian S. Thomson, Andrew. M. Bruckner and Judith B. Bruckner, Elementary Real Analysis, Prentice Hall, 2001.
- S.K. Berberian, a First Course in Real Analysis, Springer Verlag, New York, 1994.
- Tom M. Apostol, Mathematical Analysis, Narosa Publishing House
- Courant and John, Introduction to Calculus and Analysis, Vol I, Springer
- W. Rudin, Principles of Mathematical Analysis, Tata McGraw-Hill
- Terence Tao, Analysis I, Hindustan Book Agency, 2006
- S. Goldberg, Calculus and mathematical analysis.

6.4 GE T4 - Differential Equations and Vector Calculus

Differential Equations and Vector Calculus	
	6 Credits
Unit 1	
Lipschitz condition and Picard's Theorem (Statement only). General solution of homogeneous equation of second order, principle of super position for homogeneous equation, Wronskian: its properties and applications, Linear homogeneous and non-homogeneous equations of higher order with constant coefficients, Euler's equation, method of undetermined coefficients, method of variation of parameters.	
Unit 2	
Systems of linear differential equations, types of linear systems, differential operators, an operator method for linear systems with constant coefficients, Basic Theory of linear systems in normal form, homogeneous linear systems with constant coefficients: Two Equations in two unknown functions.	
Unit 3	
Equilibrium points, Interpretation of the phase plane Power series solution of a differential equation about an ordinary point, solution about a regular singular point.	
Unit 4	
Triple product, introduction to vector functions, operations with vector-valued functions, limits and continuity of vector functions, differentiation and integration of vector functions.	
Graphical Demonstration (Teaching Aid)	
1. Plotting of family of curves which are solutions of second order differential equation. 2. Plotting of family of curves which are solutions of third order differential equation.	
Reference Books	

- Belinda Barnes and Glenn R. Fulford, Mathematical Modeling with Case Studies, A Differential Equation Approach using Maple and Matlab, 2nd Ed., Taylor and Francis group, London and New York, 2009.
- C.H. Edwards and D.E. Penny, Differential Equations and Boundary Value problems Computing and Modeling, Pearson Education India, 2005.
- S.L. Ross, Differential Equations, 3rd Ed., John Wiley and Sons, India, 2004.
- Martha L Abell, James P Braselton, Differential Equations with MATHEMATICA, 3rd Ed., Elsevier Academic Press, 2004.
- Murray, D., Introductory Course in Differential Equations, Longmans Green and Co.
- Boyce and Diprima, Elementary Differential Equations and Boundary Value Problems, Wiley.
- G.F.Simmons, Differential Equations, Tata Mc Graw Hill
- Marsden, J., and Tromba, Vector Calculus, McGraw Hill.
- Maity, K.C. and Ghosh, R.K. Vector Analysis, New Central Book Agency (P) Ltd. Kolkata (India).
- M.R. Speigel, Schaum's outline of Vector Analysis

6.5 GE T5 - Theory of Real Functions & Introduction to Metric Space

Theory of Real Functions & Introduction to Metric Space	
	6 Credits
Unit 1	
Limits of functions (ε - δ approach), sequential criterion for limits, divergence criteria. Limit theorems, one sided limits. Infinite limits and limits at infinity. Continuous functions, sequential criterion for continuity and discontinuity. Algebra of continuous functions. Continuous functions on an interval, intermediate value theorem, location of roots theorem, preservation of intervals theorem. Uniform continuity, non-uniform continuity criteria, uniform continuity theorem.	
Unit 2	
Differentiability of a function at a point and in an interval, Caratheodory's theorem, algebra of differentiable functions. Relative extrema, interior extremum theorem. Rolle's theorem. Mean value theorem, intermediate value property of derivatives, Darboux's theorem. Applications of mean value theorem to inequalities and approximation of polynomials.	
Unit 3	
Cauchy's mean value theorem. Taylor's theorem with Lagrange's form of remainder, Taylor's theorem with Cauchy's form of remainder, application of Taylor's theorem to convex functions, relative extrema. Taylor's series and Maclaurin's series expansions of exponential and trigonometric functions, ln(1 + x), 1/ax+b and (1 +x)n. Application of Taylor's theorem to inequalities.	
Unit 4	
Metric spaces: Definition and examples. Open and closed balls, neighbourhood, open set, interior of a set. Limit point of a set, closed set, diameter of a set, subspaces, dense sets, separable spaces.	
Reference Books	
► R. Bartle and D.R. Sherbert, Introduction to Real Analysis, John Wiley and Sons, 2003. ► K.A. Ross, Elementary Analysis: The Theory of Calculus, Springer, 2004.	

- A. Mattuck, Introduction to Analysis, Prentice Hall, 1999.
- S.R. Ghorpade and B.V. Limaye, a Course in Calculus and Real Analysis, Springer, 2006.
- Tom M. Apostol, Mathematical Analysis, Narosa Publishing House
- Courant and John, Introduction to Calculus and Analysis, Vol II, Springer
- W. Rudin, Principles of Mathematical Analysis, Tata McGraw-Hill
- Terence Tao, Analysis II, Hindustan Book Agency, 2006
- Satish Shirali and Harikishan L. Vasudeva, Metric Spaces, Springer Verlag, London, 2006
- S. Kumaresan, Topology of Metric Spaces, 2nd Ed., Narosa Publishing House, 2011.
- G.F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, 2004.

6.6 GE T6 - Group Theory 1

Group Theory 1	
	6 Credits
Unit 1	
Symmetries of a square, Dihedral groups, definition and examples of groups including permutation groups and quaternion groups (through matrices), elementary properties of groups.	
Unit 2	
Subgroups and examples of subgroups, centralizer, normalizer, center of a group, product of two subgroups.	
Unit 3	
Properties of cyclic groups, classification of subgroups of cyclic groups. Cycle notation for permutations, properties of permutations, even and odd permutations, alternating group, properties of cosets, Lagrange's theorem and consequences including Fermat's Little theorem.	
Unit 4	
External direct product of a finite number of groups, normal subgroups, factor groups, Cauchy's theorem for finite abelian groups.	
Unit 5	
Group homomorphisms, properties of homomorphisms, Cayley's theorem, properties of isomorphisms. First, Second and Third isomorphism theorems.	
Reference Books	

- John B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.
- M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.
- Joseph A. Gallian, Contemporary Abstract Algebra, 4th Ed., 1999.
- Joseph J. Rotman, An Introduction to the Theory of Groups, 4th Ed., 1995.
- I.N. Herstein, Topics in Algebra, Wiley Eastern Limited, India, 1975.
- D.S. Malik, John M. Mordeson and M.K. Sen, Fundamentals of abstract algebra.

6.7 GE T7 – Partial Differential Equations and Applications

Partial Differential Equations and Applications	
	6 Credits
Unit 1	
Partial Differential Equations – Basic concepts and Definitions. Mathematical Problems. First-Order Equations: Classification, Construction and Geometrical Interpretation. Method of Characteristics for obtaining General Solution of Quasi Linear Equations. Canonical Forms of First-order Linear Equations. Method of Separation of Variables for solving first order partial differential equations.	
Unit 2	
Derivation of Heat equation, Wave equation and Laplace equation. Classification of second order linear equations as hyperbolic, parabolic or elliptic. Reduction of second order Linear Equations to canonical forms.	
Unit 3	
The Cauchy problem, Cauchy-Kowalewskaya theorem, Cauchy problem of an infinite string. Initial Boundary Value Problems. Semi-Infinite String with a fixed end, Semi-Infinite String with a Free end. Equations with non-homogeneous boundary conditions. Non- Homogeneous Wave Equation. Method of separation of variables, Solving the Vibrating String Problem. Solving the Heat Conduction problem	
Unit 4	
Central force. Constrained motion, varying mass, tangent and normal components of acceleration, modelling ballistics and planetary motion, Kepler's second law.	
Graphical Demonstration (Teaching Aid)	
1. Solution of Cauchy problem for first order PDE. 2. Finding the characteristics for the first order PDE. 3. Plot the integral surfaces of a given first order PDE with initial data.	

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

(c) $u(x,0) = \phi(x),\ u_t(x,0) = \psi(x),\ x \in R,\ t > 0.$

(d) $u(x,0) = \phi(x),\ u_t(x,0) = \psi(x), u(0,t) = 0\ x \in (0,\infty),\ t > 0$

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

(b) $u(x,0) = \phi(x),\ u\ \ (o,t) = a, u\ \ (l,t) = b,\ \ 0 < x < l, t > 0.$

$u(x,0) = \phi(x),\ x \in R,\ \ 0 < t < T.$

Reference Books

- Tyn Myint-U and Lokenath Debnath, Linear Partial Differential Equations for Scientists and Engineers, 4th edition, Springer, Indian reprint, 2006.
- S.L. Ross, Differential equations, 3rd Ed., John Wiley and Sons, India, 2004.
- Martha L Abell, James P Braselton, Differential equations with MATHEMATICA, 3rd Ed., Elsevier Academic Press, 2004.
- Sneddon, I. N., Elements of Partial Differential Equations, McGraw Hill.
- Miller, F. H., Partial Differential Equations, John Wiley and Sons.
- Loney, S. L., An Elementary Treatise on the Dynamics of particle and of Rigid Bodies, Loney Press

6.8 GE T8 - Numerical Models

Numerical Models	
	4 Credits
Unit 1	
Algorithms. Convergence. Errors: Relative, Absolute. Round off. Truncation.	
Unit 2	
Transcendental and Polynomial equations: Bisection method, Newton's method, Secant method, Regula-falsi method, fixed point iteration, Newton-Raphson method. Rate of convergence of these methods.	
Unit 3	
System of linear algebraic equations: Gaussian Elimination and Gauss Jordan methods. Gauss Jacobi method, Gauss Seidel method and their convergence analysis. LU Decomposition	
Unit 4	
Interpolation: Lagrange and Newton's methods. Error bounds. Finite difference operators. Gregory forward and backward difference interpolation. Numerical differentiation: Methods based on interpolations, methods based on finite differences.	
Unit 5	
Numerical Integration: Newton Cotes formula, Trapezoidal rule, Simpson's $1/3^{rd}$ rule, Simpsons $3/8^{th}$ rule, Weddle's rule, Boole's Rule. Midpoint rule, Composite Trapezoidal rule, Composite Simpson's $1/3^{rd}$ rule, Gauss quadrature formula. The algebraic eigenvalue problem: Power method. Approximation: Least square polynomial approximation.	
Unit 6	

Ordinary Differential Equations: The method of successive approximations, Euler's method, the modified Euler method, Runge-Kutta methods of orders two and four.

Reference Books

- Brian Bradie, A Friendly Introduction to Numerical Analysis, Pearson Education, India, 2007.
- M.K. Jain, S.R.K. Iyengar and R.K. Jain, Numerical Methods for Scientific and Engineering
- Computation, 6th Ed., New age International Publisher, India, 2007.
- C.F. Gerald and P.O. Wheatley, Applied Numerical Analysis, Pearson Education, India, 2008.
- Uri M. Ascher and Chen Greif, A First Course in Numerical Methods, 7th Ed., PHI Learning Private Limited, 2013.
- John H. Mathews and Kurtis D. Fink, Numerical Methods using Matlab, 4th Ed., PHI Learning Private Limited, 2012.
- Scarborough, James B., Numerical Mathematical Analysis, Oxford and IBH publishing co.
- Atkinson, K. E., An Introduction to Numerical Analysis, John Wiley and Sons, 1978.
- YashavantKanetkar, Let Us C , BPB Publications.

6.9 GE P8 - Numerical Models Lab

Numerical Models	
	2 Credits
List of practical (using any software)	

10. Calculate the sum 1/1 + 1/2 + 1/3 + 1/4 + ----------+ 1/ N.
11. Enter 100 integers into an array and sort them in an ascending order.
12. Solution of transcendental and algebraic equations by
    a. Bisection method
    b. Newton Raphson method.
    c. Secant method.
    d. Regula Falsi method.
13. Solution of system of linear equations
    a. LU decomposition method
    b. Gaussian elimination method
    c. Gauss-Jacobi method
    d. Gauss-Seidel method
14. Interpolation
    a. Lagrange Interpolation
    b. Newton Interpolation
15. Numerical Integration
    a. Trapezoidal Rule
    b. Simpson's one third rule
    c. Weddle's Rule
    d. Gauss Quadrature
16. Method of finding Eigenvalue by Power method
17. Fitting a Polynomial Function
18. Solution of ordinary differential equations
    a. Euler method
    b. Modified Euler method
    c. Runge Kutta method

Note: For any of the CAS (Computer aided software) Data types-simple data types, floating data types, character data types, arithmetic operators and operator precedence, variables and constant declarations, expressions, input/output, relational operators, logical operators and logical expressions, control statements and loop statements, Arrays should be introduced to the students.

6.10 GE T9 - Riemann Integration and Series Functions

Riemann Integration and Series of Functions	
	6 Credits
Unit 1	
Riemann integration: inequalities of upper and lower sums, Darbaux integration, Darbaux theorem, Riemann conditions of integrability, Riemann sum and definition of Riemann integral through Riemann sums, equivalence of two Definitions. Riemann integrability of monotone and continuous functions, Properties of the Riemann integral; definition and integrability of piecewise continuous and monotone functions. Intermediate Value theorem for Integrals. Fundamental theorem of Integral Calculus.	
Unit 2	
Improper integrals. Convergence of Beta and Gamma functions.	
Unit 3	
Pointwise and uniform convergence of sequence of functions. Theorems on continuity, derivability and integrability of the limit function of a sequence of functions. Series of functions; Theorems on the continuity and derivability of the sum function of a series of functions; Cauchy criterion for uniform convergence and Weierstrass M-Test.	
Unit 4	
Fourier series: Definition of Fourier coefficients and series, Reimann Lebesgue lemma, Bessel's inequality, Parseval's identity, Dirichlet's condition. Examples of Fourier expansions and summation results for series.	
Unit 5	
Power series, radius of convergence, Cauchy Hadamard Theorem. Differentiation and integration of power series; Abel’s Theorem; Weierstrass Approximation Theorem.	

Reference Books

- K.A. Ross, Elementary Analysis, The Theory of Calculus, Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.
- R.G. Bartle D.R. Sherbert, Introduction to Real Analysis, 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.
- Charles G. Denlinger, Elements of Real Analysis, Jones & Bartlett (Student Edition), 2011.
- S. Goldberg, Calculus and mathematical analysis.
- Santi Narayan, Integral calculus.
- T. Apostol, Calculus I, II.

6.12 GE T10 – Ring Theory and Linear Algebra I

Ring Theory and Linear Algebra 1	
	6 Credits
Unit 1	
Definition and examples of rings, properties of rings, subrings, integral domains and fields, characteristic of a ring. Ideal, ideal generated by a subset of a ring, factor rings, operations on ideals, prime and maximal ideals.	
Unit 2	
Ring homomorphisms, properties of ring homomorphisms. Isomorphism theorems I, II and III, field of quotients.	
Unit 3	
Vector spaces, subspaces, algebra of subspaces, quotient spaces, linear combination of vectors, linear span, linear independence, basis and dimension, dimension of subspaces.	
Unit 4	
Linear transformations, null space, range, rank and nullity of a linear transformation, matrix representation of a linear transformation, algebra of linear transformations. Isomorphisms. Isomorphism theorems, invertibility and isomorphisms, change of coordinate matrix.	

Reference Books

- John B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.
- M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.
- Stephen H. Friedberg, Arnold J. Insel, Lawrence E. Spence, Linear Algebra, 4th Ed., Prentice- Hall of India Pvt. Ltd., New Delhi, 2004.
- Joseph A. Gallian, Contemporary Abstract Algebra, 4th Ed., Narosa Publishing House, New Delhi, 1999.
- S. Lang, Introduction to Linear Algebra, 2nd Ed., Springer, 2005.
- Gilbert Strang, Linear Algebra and its Applications, Thomson, 2007.
- S. Kumaresan, Linear Algebra- A Geometric Approach, Prentice Hall of India, 1999.

- Kenneth Hoffman, Ray Alden Kunze, Linear Algebra, 2nd Ed., Prentice-Hall of India Pvt. Ltd., 1971.
- D.A.R. Wallace, Groups, Rings and Fields, Springer Verlag London Ltd., 1998.
- D.S. Malik, John M. Mordeson and M.K. Sen, Fundamentals of abstract algebra.

6.13 GE T11 – Multivariate Calculus

Multivariate Calculus	
	6 Credits
Unit 1	
Functions of several variables, limit and continuity of functions of two or more variables Partial differentiation, total differentiability and differentiability, sufficient condition for differentiability. Chain rule for one and two independent parameters, directional derivatives, the gradient, maximal and normal property of the gradient, tangent planes, Extrema of functions of two variables, method of Lagrange multipliers, constrained optimization problems	
Unit 2	
Double integration over rectangular region, double integration over non-rectangular region, Double integrals in polar co-ordinates, Triple integrals, Triple integral over a parallelepiped and solid regions. Volume by triple integrals, cylindrical and spherical co-ordinates. Change of variables in double integrals and triple integrals.	
Unit 3	
Definition of vector field, divergence and curl. Line integrals, Applications of line integrals: Mass and Work. Fundamental theorem for line integrals, conservative vector fields, independence of path.	
Unit 4	
Green's theorem, surface integrals, integrals over parametrically defined surfaces. Stoke's theorem, The Divergence theorem.	
Reference Books	
▸ G.B. Thomas and R.L. Finney, Calculus, 9th Ed., Pearson Education, Delhi, 2005. ▸ M.J. Strauss, G.L. Bradley and K. J. Smith, Calculus, 3rd Ed., Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2007. ▸ E. Marsden, A.J. Tromba and A. Weinstein, Basic Multivariable Calculus, Springer (SIE), Indian reprint, 2005.	

- James Stewart, Multivariable Calculus, Concepts and Contexts, 2nd Ed., Brooks /Cole, Thomson Learning, USA, 2001
- Tom M. Apostol, Mathematical Analysis, Narosa Publishing House
- Courant and John, Introduction to Calculus and Analysis, Vol II, Springer
- W. Rudin, Principles of Mathematical Analysis, Tata McGraw-Hill
- Marsden, J., and Tromba, Vector Calculus, McGraw Hill.
- Maity, K.C. and Ghosh, R.K. Vector Analysis, New Central Book Agency (P) Ltd. Kolkata (India).
- Terence Tao, Analysis II, Hindustan Book Agency, 2006
- M.R. Speigel, Schaum's outline of Vector Analysis.

7. Appendix I - Scheme for CBCS Curriculum for Pass Course

7.1 Credit Distribution across Courses

			Credits	
Course Type		Total Papers	Theory + Practical	Theory*+Tutorials
Core Courses	4 papers each from 3 disciplines of choice	12	12*4 =48 12*2 =24	12*5 =60 12*1=12
Elective Courses	2 papers each from 3 discipline of choice including interdisciplinary papers	6	6*4=24 6*2=12	6*5=30 6*1=6
Ability Enhancement Language Courses		2	2*2=4	2*2=4
Skill Enhancement Courses		4	4*2=8	4*2=8
Totals		24	120	120

*Tutorials of 1 Credit will be conducted in case there is no practical component

- All Pass courses will have 3 subjects/disciplines of interest. Student will select 4 core courses each from discipline of choice including Mathematics as one of the disciplines. The details for core courses available in Mathematics have been detailed in Section 3 of this document
- Student will select 2 core courses each from discipline of choice including Mathematics as one of the disciplines. The details for elective courses available in Mathematics have been detailed in Section 4 and 6 of this document
- Student may also chose Skill Enhancement courses in Mathematics. The details for skill enhancement courses available in Mathematics have been detailed in Section 5 of this document

7.2 Scheme for CBCS Curriculum

Semester	Course Name	Course Detail	Credits
I	Ability Enhancement Compulsory Course-I	English communication / Environmental Science	2
	Core course-I	Core Course 1A from Mathematics	4
	Core course-IPractical	Core Course 1A Practical from Mathematics	2
	Core course-II	Core Course 2A from other chosen discipline	4
	Core course-II Practical	Core Course 2A Practical from other chosen discipline	2
	Core course - III	Core Course 3A from other chosen discipline	4
	Core course - III Practical	Core Course 3A Practical from other chosen discipline	2
II	Ability Enhancement Compulsory Course-II	English communication / Environmental Science	2
	Core course-IV	Core Course 1B from Mathematics	4
	Core course-IV Practical	Core Course 1B Practical from Mathematics	2
	Core course-V	Core Course 2B from other chosen discipline	4
	Core course- V Practical	Core Course 2B Practical from other chosen discipline	2
	Core course - VI	Core Course 3B from other chosen discipline	4
	Core course - VI Practical	Core Course 3B Practical from other chosen discipline	2
III	Core course VII	Core Course 1C from Mathematics	4
	Core course-VII Practical	Core Course 1C Practical from Mathematics	2
	Core course - VIII	Core Course 2C from other chosen discipline	4
	Core course - VIII Practical	Core Course 2C Practical from other chosen discipline	2
	Core course-IX	Core Course 3C from other chosen discipline	4
	Core course-IX Practical	Core Course 3C Practical from other chosen discipline	2
	Skill Enhancement Course-1	TBD	2

IV	Core course-X	Core Course 1D from Mathematics	4
	Core course – X Practical	Core Course 1D Practical from Mathematics	2
	Core course-XI	Core Course 2D from other chosen discipline	4
	Core course-XI Practical	Core Course 2D Practical from other chosen discipline	2
	Core course-XII	Core Course 3D from other chosen discipline	4
	Core course-XII Practical	Core Course 3D Practical from other chosen discipline	2
	Skill Enhancement Course-2	TBD	2
V	Skill Enhancement Course – 3	TBD	2
	Discipline Specific Elective 1	DSE 1A from Mathematics	4
	Discipline Specific Elective 1 Practical	DSE 1A Practical from Mathematics	2
	Discipline Specific Elective 2	DSE 2A from other chosen discipline	4
	Discipline Specific Elective 2 Practical	DSE 2A Practical from other chosen discipline	2
	Discipline Specific Elective 3	DSE 3A from other chosen discipline	4
	Discipline Specific Elective 3 Practical	DSE 3A Practical from other chosen discipline	2
VI	Skill Enhancement Course – 4	TBD	2
	Discipline Specific Elective 4	DSE 1B from Mathematics	4
	Discipline Specific Elective 4 Practical	DSE 1B Practical from Mathematics	2
	Discipline Specific Elective 5	DSE 2B from other chosen discipline	4
	Discipline Specific Elective 5 Practical	DSE 2B Practical from other chosen discipline	2
	Discipline Specific Elective 6	DSE 3B from other chosen discipline	4
	Discipline Specific Elective 6 Practical	DSE 3B Practical from other chosen discipline	2