

Proposed Syllabus of Mathematics (Hons.) on
Choice Based Credit System: Submitted to
Coochbehar Panchanan Barma University

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1. Scheme for CBCS Curriculum

1.1 Credit Distribution across Courses

Course Type	Total Papers	Credits	
		Theory + Practical	Theory*+Tutorial
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

1.2 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 & Differential Equation	6
	Core course-I Practical	-	
	Core course-II	Algebra	6
	Core course-II Practical	-	-
	Generic Elective-1	TBD	6
	Generic Elective-1 Practical		-
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 & Vector Calculus	6
	Core course-IV Practical	-	-
	Generic Elective-2	TBD	6
	Generic Elective-2 Practical	-	-
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	6

	Generic Elective–3 Practical	-	-
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	6
	Discipline Specific Elective– 1 Practical	-	-
	Discipline Specific Elective–2	TBD	6
	Discipline Specific Elective– 2 Practical	-	-
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	6
	Discipline Specific Elective– 3 Practical	-	-
	Discipline Specific Elective–4	TBD	6

	DisciplineSpecificElective– 4 Practical		-
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- TBD: To be decided

1.3 Choices for Discipline Specific Electives

DisciplineSpecificElective–1	DisciplineSpecificElective–2	DisciplineSpecificElective–3	DisciplineSpecificElective–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

1.4 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 in C++	

1.5 Choices for Generic Elective Courses

Skill Enhancement Course-1	Skill Enhancement Course-2

2. Core Subjects Syllabus

2.1 Core T1 –Calculus, Geometry & Differential Equation

Calculus, Geometry & Differential Equation	
	6 Credits
Unit 1	
<p>Hyperbolic functions, higher order derivatives, Leibnitz rule and its applications to problems of type $e^{ax+b}\sin x$, $e^{ax+b}\cos x$, $(ax+b)^n\sin x$, $(ax+b)^n\cos x$, 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.</p>	
Unit 2	
<p>Reduction formulae, derivations and illustrations of reduction formulae of the type $\int \sin nx \, dx$, $\int \cos nx \, dx$, $\int \tan nx \, dx$, $\int \sec nx \, dx$, $\int (\log x)^n \, dx$, $\int \sin^n x \cos^m x \, dx$, parametric equations, parameterizing a curve, arc length of a curve, arc length of parametric curves, area under a curve, area and volume of surface of revolution, techniques of sketching conics.</p>	
Unit 3	
<p>Reflection properties of conics, rotation of axes and second degree equations, classification of conics using the discriminant, polar equations of conics.</p> <p>Spheres. Cylindrical surfaces. Central conicoids, paraboloids, plane sections of conicoids, generating lines, classification of quadrics, illustrations of graphing standard quadric surfaces like cone, ellipsoid.</p>	
Unit 4	
<p>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.</p>	
Graphical Demonstration (Teaching Aid)	

1. Plotting of graphs of function e^{ax+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.
- ▶

2.2 Core T2- Algebra

Algebra	
	6 Credits
Unit 1	
<p>Polar representation of complex numbers, nth roots of unity, De Moivre's theorem for rational indices and its applications.</p> <p>Theory of equations: Relation between roots and coefficients, transformation of equation, Descartes rule of signs, cubic and biquadratic equation.</p> <p>Inequality: The inequality involving $AM \geq GM \geq HM$, Cauchy-Schwartz inequality.</p>	
Unit 2	
<p>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.</p>	
Unit 3	
<p>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.</p>	
Unit 4	
<p>Introduction to linear transformations, matrix of a linear transformation, inverse of a matrix, characterizations of invertible matrices. Subspaces of R^n, dimension of subspaces of R^n, 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.</p>	
Reference Books	
<ul style="list-style-type: none"> ▶ 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. Hoffman, R. Kunze, Linear algebra.
- ▶ W.S. Burnstine and A.W. Panton, Theory of equations.

2.3 Core T3 –Real Analysis

Real Analysis	
	6 Credits
Unit 1	
Review of algebraic and order properties of \mathbb{R} , ε -neighborhood of a point in \mathbb{R} . Idea of countable sets, uncountable sets and uncountability of \mathbb{R} . Bounded above sets, bounded below sets, bounded sets, unbounded sets. Suprema and infima. Completeness property of \mathbb{R} and its equivalent properties. The Archimedean property, density of rational (and Irrational) numbers in \mathbb{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 \mathbb{R} , Heine-Borel Theorem.	
Unit 2	
Sequences, bounded sequence, convergent sequence, limit of a sequence, \liminf , \limsup . 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 n th root test, integral test. Alternating series, Leibniz test. Absolute and conditional convergence.	
Unit 4	
Graphical Demonstration (Teaching aid)	
<ol style="list-style-type: none"> 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.
- ▶ T. 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.

2.4 Core T4–Differential Equations & Vector Calculus

Differential Equations & 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.	
Unit 5	
Graphical demonstration (Teaching aid) <ol style="list-style-type: none"> 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. Spiegel, Schaum's outline of Vector Analysis.
- ▶

2.5 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 ($\epsilon - \delta$ 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 $(x+1)^n$. 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	
<ul style="list-style-type: none"> ▶ 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. ▶ T. 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
- ▶ SatishShirali 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.

2.6 Core T6 –Group Theory I

Group Theory I	
	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	
<ul style="list-style-type: none"> ▶ 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, New Delhi, 1999. ▶ Joseph J. Rotman, An Introduction to the Theory of Groups, 4th Ed., Springer Verlag, 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. 	

2.7 Core T7 – Numerical Methods

Numerical Methods	
	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 $1/3^{\text{rd}}$ rule, Simpsons $3/8^{\text{th}}$ rule, Weddle's rule, Boole's Rule. midpoint rule, Composite trapezoidal rule, composite Simpson's $1/3^{\text{rd}}$ rule, Gauss quadrature formula.	
The algebraic eigen value 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	
<ul style="list-style-type: none"> ▶ 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.
- ▶ Yashavant Kanetkar, Let Us C , BPB Publications.

2.8 Core P7 – Numerical Methods Lab

Numerical Methods Lab	
	2 Credits
List of practical (using any software)	
<ol style="list-style-type: none"> 1. Calculate the sum $1/1 + 1/2 + 1/3 + 1/4 + \dots + 1/N$. 2. Enter 100 integers into an array and sort them in an ascending order. 3. Solution of transcendental and algebraic equations by <ul style="list-style-type: none"> • Bisection method • Newton Raphson method. • Secant method. • Regula Falsi method. 4. Solution of system of linear equations <ol style="list-style-type: none"> i) LU decomposition method ii) Gaussian elimination method iii) Gauss-Jacobi method iv) Gauss-Seidel method 5. Interpolation <ol style="list-style-type: none"> i) Lagrange Interpolation ii) Newton Interpolation 6. Numerical Integration <ol style="list-style-type: none"> i) Trapezoidal Rule ii) Simpson's one third rule iii) Weddle's Rule 	

- iv) Gauss Quadrature
- 7. Method of finding Eigenvalue by Power method
- 8. Fitting a Polynomial Function
- 9. Solution of ordinary differential equations
 - i) Euler method
 - ii) Modified Euler method
 - iii) 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.

2.9 Core T8 –Riemann Integration and Series of Functions

Riemann Integration and Series of Functions	
	6 Credits
Unit 1	
<p>Riemann integration: inequalities of upper and lower sums, Darboux integration, Darboux 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.</p> <p>Intermediate Value theorem for Integrals; Fundamental theorem of Integral Calculus.</p>	
Unit 2	
Improper integrals. Convergence of Beta and Gamma functions.	
Unit 3	
<p>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;</p> <p>Theorems on the continuity and derivability of the sum function of a series of functions; Cauchy criterion for uniform convergence and Weierstrass M-Test.</p>	

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
<ul style="list-style-type: none"> ▶ 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.

2.10Core T9– Multivariate Calculus

Multivariate Calculus	
	6 Credits
Unit 1	
<p>Functions of several variables, limit and continuity of functions of two or more variables</p> <p>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</p>	
Unit 2	
<p>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</p>	

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
- ▶ T. 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. Spiegel, Schaum's outline of Vector Analysis.

2.11 Core T10–Ring Theory and Linear Algebra I

Ring Theory and Linear Algebra I

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.

2.12Core T11– Partial Differential Equations & Applications

Partial Differential Equations & 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.

Unit 5

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

2.13 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 S_n , p -groups, Sylow's theorems and consequences, Cauchy's theorem, Simplicity of A_n for $n \geq 5$, non-simplicity tests.	
Reference Books	
<ul style="list-style-type: none"> ▶ 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. ▶ 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. 	

2.14 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	
<p>Continuous mappings, sequential criterion and other characterizations of continuity. Uniform continuity. Connectedness, connected subsets of \mathbb{R}.</p> <p>Compactness: Sequential compactness, Heine-Borel property, totally bounded spaces, finite intersection property, and continuous functions on compact sets.</p> <p>Homeomorphism. Contraction mappings. Banach fixed point theorem and its application to ordinary differential equation.</p>	
Unit 3	
<p>Limits, limits involving the point at infinity, continuity. Properties of complex numbers, regions in the complex plane, functions of complex variable, mappings.</p> <p>Derivatives, differentiation formulas, Cauchy-Riemann equations, sufficient conditions for differentiability.</p>	
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	
▶ SatishShirali 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., New York, 1997.
- ▶ S. Ponnusamy, Foundations of complex analysis.
- ▶ E.M.Stein and R. Shakrachi, Complex Analysis, Princeton University Press.

2.15Core 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 $\mathbb{Z}[x]$. 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	
<ul style="list-style-type: none"> ▶ 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

Department Specific Electives Subjects Syllabus

2.16DSE 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	
<ul style="list-style-type: none"> ▶ 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. 	

2.17DSE 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	
<ul style="list-style-type: none"> ▶ 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. 	

DSE T3 – Point Set Topology

Point Set Topology	
	6 Credits
Unit 1	
<p>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.</p>	
Unit 2	
<p>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.</p>	
Unit 3	
<p>Connected and path connected spaces, connected sets in \mathbb{R}, components and path components, local connectedness. Compact spaces, compact sets in \mathbb{R}. Compactness in metric spaces. Totally bounded spaces, Ascoli-Arzela theorem, the Lebesgue number lemma. Local compactness.</p>	
Reference Books	
<ul style="list-style-type: none"> ▶ 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 andWinston, New York, 1970. ▶ Abhijit Dasgupta, Set Theory, Birkhäuser. 	

2.18DSE 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	
<ul style="list-style-type: none"> ▶ 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. 	

2.19DSE 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	
<ul style="list-style-type: none"> ▶ 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. 	

2.20DSE 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

2.21DSE 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 $x^2 + y^2 = z^2$, Fermat's Last theorem.	
Reference Books	
<ul style="list-style-type: none"> ▶ 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 	

2.22DSE 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 plane.	
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	
<ul style="list-style-type: none"> ▶ Timothy G. Feeman, The Mathematics of Medical Imaging, A Beginners Guide, Springer Undergraduate 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

2.23DSE 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	
<ul style="list-style-type: none"> ▶ ▶ 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 Press . ▶ Loney, S. L., Elements of Staticsand 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).

2.24DSE 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	
<ul style="list-style-type: none"> ▶ 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 	

2.25DSE 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 modelling: 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	
Reference Books	
<ul style="list-style-type: none"> ▶ TynMyint-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. 	
Graphical demonstration as Teaching aid using any software)	
<ol style="list-style-type: none"> 1. Plotting of Legendre polynomial for $n = 1$ to 5 in the interval $[0,1]$. Verifying graphically that all the roots of $P_n(x)$ 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. 	

3. Skill Enhancement Subjects Syllabus

3.1 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	
<ul style="list-style-type: none"> ▶ 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. 	

3.2 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	
<ul style="list-style-type: none"> ▶ 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. 	

3.3 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. Parsons, Object Oriented Programming with C++, BPB Publication.
▶	Bjarne Stroustrup, The C++ Programming Language, 3rd Ed., Addison Wesley.
▶	E. Balaguruswami, Object Oriented Programming In C++, Tata McGrawHill
▶	Herbert Schildt, C++, The Complete Reference, Tata McGrawHill.

EC T4–Graph Theory

Graph Theory	
	2 Credits
Unit 1	
Definition, examples and basic properties of graphs, pseudo graphs, complete graphs, bipartite 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.
- ▶ Narsingh Deo, Graph Theory with Applications to Engineering and Computer Science, Prentice-Hall of India Pvt. Ltd., New Delhi.

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.

GE1: Mathematical Finance

Basic principles: Comparison, arbitrage and risk aversion, Interest (simple and compound, discrete and continuous), time value of money, inflation, net present value, internal rate of return (calculation by bisection and Newton-Raphson methods), comparison of NPV and IRR. Bonds, bond prices and yields, Macaulay and modified duration, term structure of interest rates: spot and forward rates, explanations of term structure, running present value, floating-rate bonds, immunization, convexity, puttable and callable bonds.

Asset return, short selling, portfolio return, (brief introduction to expectation, variance, covariance and correlation), random returns, portfolio mean return and variance, diversification, portfolio diagram, feasible set, Markowitz model (review of Lagrange multipliers for 1 and 2 constraints), Two fund theorem, risk free assets, One fund theorem, capital market line, Sharpe index. Capital Asset Pricing Model (CAPM), betas of stocks and portfolios, security market line, use of CAPM in investment analysis and as a pricing formula, Jensen's index.

Books Recommended

1. David G. Luenberger, *Investment Science*, Oxford University Press, Delhi, 1998.
2. John C. Hull, *Options, Futures and Other Derivatives*, 6th Ed., Prentice-Hall India, Indian reprint, 2006.
3. Sheldon Ross, *An Elementary Introduction to Mathematical Finance*, 2nd Ed., Cambridge University Press, USA, 2003.

GE 2 Bio Mathematics

Bio Mathematics

6Credits

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 LotkaVolterra 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.

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.

Graphical demonstration as Teaching aid using any software)

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 influenza (basic epidemic model, contagious for life,disease with carriers).
8. Battle model (basic battle model, jungle warfare, long range weapons).

GE 3 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
<ul style="list-style-type: none"> ▶ 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

GE 4

3.4 – 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. Parsons, Object Oriented Programming with C++, BPB Publication.
- ▶ Bjarne Stroustrup, The C++ Programming Language, 3rd Ed., Addison Wesley.
- ▶ E. Balaguruswami, Object Oriented Programming In C++, Tata McGrawHill
- ▶ Herbert Schildt, C++, The Complete Reference, Tata McGrawHill.

3.5 SEC T4–Graph Theory

Graph Theory	
	2 Credits
Unit 1	
Definition, examples and basic properties of graphs, pseudo graphs, complete graphs, bipartite 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.
▶	Narsingh Deo, Graph Theory with Applications to Engineering and Computer Science, Prentice-Hall of India Pvt. Ltd., New Delhi.

GE 5

Applications of Algebra	
	6 Credits
Unit 1	
Balanced incomplete block designs (BIBD): definitions and results, incidence matrix of a BIBD, construction of BIBD from difference sets, construction of BIBD using quadratic residues, difference set families, construction of BIBD from finite fields.	
Unit 2	
Coding Theory: introduction to error correcting codes, linear codes, generator and parity check matrices, minimum distance, Hamming Codes, decoding and cyclic codes. Symmetry groups and color patterns: review of permutation groups, groups of symmetry and action of a group on a set; colouring and colouring patterns, Polya theorem and pattern inventory, generating functions for non-isomorphic graphs.	
Unit 3	
Special types of matrices: idempotent, nilpotent, involution, and projection tri diagonal matrices, circulant matrices, Vandermonde matrices, Hadamard matrices, permutation and doubly stochastic matrices, Frobenius- König theorem, Birkhoff theorem. Positive Semi-definite matrices: positive semi-definite matrices, square root of a positive semi-definite matrix, a pair of positive semi-definite matrices, and their simultaneous diagonalization.	
Unit 4	
Symmetric matrices and quadratic forms: diagonalization of symmetric matrices, quadratic forms, constrained optimization, singular value decomposition, and applications to image processing and statistics.	
Unit 5	
Applications of linear transformations: Fibonacci numbers, incidence models, and differential equations. Least squares methods: Approximate solutions of system of linear equations, approximate inverse of an $m \times n$ matrix, solving a matrix equation using its normal equation, finding functions that approximate data.	
Unit 6	
Linear algorithms: LDU factorization, the row reduction algorithm and its inverse, backward and forward substitution, approximate inverse and projection algorithms.	
Reference Books	
<ol style="list-style-type: none"> 1. I. N. Herstein and D. J. Winter, <i>Primer on Linear Algebra</i>, Macmillan Publishing Company, New York, 1990. 2. S. R. Nagpaul and S. K. Jain, <i>Topics in Applied Abstract Algebra</i>, Thomson Brooks and Cole, Belmont, 2005. 3. Richard E. Klima, Neil Sigmon, Ernest Stitzinger, <i>Applications of Abstract Algebra with Maple</i>, CRC Press LLC, Boca Raton, 2000. 4. David C. Lay, <i>Linear Algebra and its Applications</i>. 3rd Ed., Pearson Education Asia, Indian Reprint, 2007. 5. Fuzhen Zhang, <i>Matrix theory</i>, Springer-Verlag New York, Inc., New York, 1999. 	



GE.6

Astronomy

6 Credits

Unit 1: The Celestial sphere, Geometry of the sphere, Spherical triangle, System of Co-ordinates,

Unit 2: time The Sun's annual motion in the Ecliptic. Sidereal day and sidereal. Dip of the Horizon.

Unit 3: General description of Sun, The seasons, Twilight. The Sundial, Equation of time, Effect of Longitude. Mean solar time and sidereal time. The Solar System,

Unit 4: Astronomical Refraction

Unit 5 Parallax, Abrration

Unit 6 Precession and Nutation, The moon, Eclipses

Reference Books

Proposed Syllabus of Mathematics (Pass) on Choice Based Credit System: Submitted to Coochbehar Panchanan Barma University

February, 2017.

Proposed Scheme for Choice Based Credit System in B.Sc. with Mathematics

Semester	Core Course (12)	Ability Enhancement Compulsory Course (AECC) (2)	Skill Enhancement Course (SEC) (2)	Discipline Specific Elective (DSE) (6)
1	Differential Calculus	AECC1		
	Descriptive Statistics and Probability Theory			
	Linear Programming			
2	Differential Equations	AECC1		
	Statistical Methods			
	Mathematical Programming			
3	Real Analysis		SEC 1	
	Statistical Inference			
	Inventory Systems and Marketing Management			
4	Algebra		SEC2	
	Sample Surveys and Design of Experiments			
	Network Analysis and Theory of Sequencing			
5			SEC3	DSE 1A
				DSE 2A
				DSE 3A
6			SEC4	DSE 1B
				DSE 2B
				DSE 3B

Discipline Specific Electives (DSE)**DSE 1A (choose one)**

1. Matrices
2. Mechanics
3. Linear Algebra

DSE 1B (choose one)

1. Numerical Methods
2. Complex Analysis
3. Linear Programming

Skill Enhancement Course (SEC)**SEC 1 (choose one)**

1. Logic and Sets
2. Analytical Geometry
3. Integral Calculus

SEC 2 (choose one)

1. Vector Calculus
2. Theory of Equations
3. Number Theory

SEC 3 (choose one)

1. Probability and Statistics
2. Mathematical Finance
3. Mathematical Modeling

SEC 4 (choose one)

1. Boolean Algebra
2. Transportation and Game Theory
3. Graph Theory

Details of Courses under B.Sc. with Mathematics

Course Type		Description	Total Papers	Credits	
				Theory + Practical	Theory*+Tutorial
I Core Courses		4 paper from each 3 of choice	12	12*4 =48 12*2 =24	12*5 =60 12*1=12
II Elective Courses		2 papers from each discipline of choice	6	6*4=24 6*2=12	6*5=30 6*1=6
III Ability Enhancement Courses	Compulsory	(Envs., English/ MIL)	2	2*2=4	2*2=4
	Skill Enhancement Courses	(Skill Based)	2	4*2=8	4*2=8
Totals			26	120	120

Core 1.1: Differential Calculus

Limit and Continuity (ϵ and δ definition), Types of discontinuities, Differentiability of functions, Successive differentiation, Leibnitz's theorem, Partial differentiation, Euler's theorem on homogeneous functions.

Tangents and normals, Curvature, Asymptotes, Singular points, Tracing of curves. Parametric representation of curves and tracing of parametric curves, Polar coordinates and tracing of curves in polar coordinates.

Rolle's theorem, Mean Value theorems, Taylor's theorem with Lagrange's and Cauchy's forms of remainder, Taylor's series, Maclaurin's series of $\sin x$, $\cos x$, e^x , $\log(1+x)$, $(1+x)^m$, Maxima and Minima, Indeterminate forms.

Books Recommended

1. H. Anton, I. Birens and S. Davis, *Calculus*, John Wiley and Sons, Inc., 2002.
2. G.B. Thomas and R.L. Finney, *Calculus*, Pearson Education, 2007.

Core 2.1: Differential Equations

First order exact differential equations. Integrating factors, rules to find an integrating factor.

First order higher degree equations solvable for x , y , p . Methods for solving higher-order differential equations. Basic theory of linear differential equations, Wronskian, and its properties.

Solving a differential equation by reducing its order.

Linear homogenous equations with constant coefficients, Linear non-homogenous equations, The method of variation of parameters, The Cauchy-Euler equation, Simultaneous differential equations, Total differential equations.

Order and degree of partial differential equations, Concept of linear and non-linear partial differential equations, Formation of first order partial differential equations, Linear partial differential equation of first order, Lagrange's method, Charpit's method.

Classification of second order partial differential equations into elliptic, parabolic and hyperbolic through illustrations only.

Books Recommended

1. Shepley L. Ross, *Differential Equations*, 3rd Ed., John Wiley and Sons, 1984.
2. I. Sneddon, *Elements of Partial Differential Equations*, McGraw-Hill, International Edition, 1967.

Core 3.1: Real Analysis

Finite and infinite sets, examples of countable and uncountable sets. Real line, bounded sets, suprema and infima, completeness property of \mathbb{R} , Archimedean property of \mathbb{R} , intervals. Concept of cluster points and statement of Bolzano-Weierstrass theorem.

Real Sequence, Bounded sequence, Cauchy convergence criterion for sequences. Cauchy's theorem on limits, order preservation and squeeze theorem, monotone sequences and their convergence (monotone convergence theorem without proof).

Infinite series. Cauchy convergence criterion for series, positive term series, geometric series, comparison test, convergence of p-series, Root test, Ratio test, alternating series, Leibnitz's test (Tests of Convergence without proof). Definition and examples of absolute and conditional convergence.

Sequences and series of functions, Pointwise and uniform convergence. M_n -test, M -test, Statements of the results about uniform convergence and integrability and differentiability of functions, Power series and radius of convergence.

Books Recommended

1. T. M. Apostol, *Calculus* (Vol. I), John Wiley and Sons (Asia) P. Ltd., 2002.
2. R.G. Bartle and D. R Sherbert, *Introduction to Real Analysis*, John Wiley and Sons (Asia) P. Ltd., 2000.
3. E. Fischer, *Intermediate Real Analysis*, Springer Verlag, 1983.
4. K.A. Ross, *Elementary Analysis- The Theory of Calculus Series-* Undergraduate Texts in Mathematics, Springer Verlag, 2003.

Core 4.1: Algebra

Definition and examples of groups, examples of abelian and non-abelian groups, the group Z_n of integers under addition modulo n and the group $U(n)$ of units under multiplication modulo n .

Cyclic groups from number systems, complex roots of unity, circle group, the general linear group $GL_n(n, \mathbb{R})$, groups of symmetries of (i) an isosceles triangle, (ii) an equilateral triangle, (iii) a rectangle, and (iv) a square, the permutation group $Sym(n)$, Group of quaternions.

Subgroups, cyclic subgroups, the concept of a subgroup generated by a subset and the commutator subgroup of group, examples of subgroups including the center of a group. Cosets, Index of subgroup, Lagrange's theorem, order of an element, Normal subgroups: their definition, examples, and characterizations, Quotient groups.

Definition and examples of rings, examples of commutative and non-commutative rings: rings from number systems, Z_n the ring of integers modulo n , ring of real quaternions, rings of matrices, polynomial rings, and rings of continuous functions. Subrings and ideals, Integral domains and fields, examples of fields: Z_p , Q , R , and C . Field of rational functions.

Books Recommended

1. John B. Fraleigh, *A First Course in Abstract Algebra*, 7th Ed., Pearson, 2002.
2. M. Artin, *Abstract Algebra*, 2nd Ed., Pearson, 2011.
3. Joseph A Gallian, *Contemporary Abstract Algebra*, 4th Ed., Narosa, 1999.
4. George E Andrews, *Number Theory*, Hindustan Publishing Corporation, 1984.

DSE 1A.1: Matrices

R , R_2 , R_3 as vector spaces over R . Standard basis for each of them. Concept of Linear Independence and examples of different bases. Subspaces of R_2 , R_3 .

Translation, Dilation, Rotation, Reflection in a point, line and plane. Matrix form of basic geometric transformations. Interpretation of eigen values and eigen vectors for such transformations and eigen spaces as invariant subspaces.

Types of matrices. Rank of a matrix. Invariance of rank under elementary transformations.

Reduction to normal form, Solutions of linear homogeneous and non-homogeneous equations with number of equations and unknowns upto four.

Matrices in diagonal form. Reduction to diagonal form upto matrices of order 3. Computation of matrix inverses using elementary row operations. Rank of matrix. Solutions of a system of linear equations using matrices. Illustrative examples of above concepts from Geometry, Physics, Chemistry, Combinatorics and Statistics.

Books Recommended

1. A.I. Kostrikin, *Introduction to Algebra*, Springer Verlag, 1984.
2. S. H. Friedberg, A. L. Insel and L. E. Spence, *Linear Algebra*, Prentice Hall of India Pvt. Ltd., New Delhi, 2004.
3. Richard Bronson, *Theory and Problems of Matrix Operations*, Tata McGraw Hill, 1989.

DSE 1A.2: Mechanics

Conditions of equilibrium of a particle and of coplanar forces acting on a rigid Body, Laws of friction, Problems of equilibrium under forces including friction, Centre of gravity, Work and potential energy. Velocity and acceleration of a particle along a curve: radial and transverse

components (plane curve), tangential and normal components (space curve), Newton's Laws of motion, Simple harmonic motion, Simple Pendulum, Projectile Motion.

Books Recommended

1. A.S. Ramsay, *Statics*, CBS Publishers and Distributors (Indian Reprint), 1998.
2. A.P. Roberts, *Statics and Dynamics with Background in Mathematics*, Cambridge University Press, 2003.

DSE 1A.3: Linear Algebra

Vector spaces, subspaces, algebra of subspaces, quotient spaces, linear combination of vectors, linear span, linear independence, basis and dimension, dimension of subspaces.

Linear transformations, null space, range, rank and nullity of a linear transformation, matrix representation of a linear transformation, algebra of linear transformations. Dual Space, Dual Basis, Double Dual, Eigen values and Eigen vectors, Characteristic Polynomial.

Isomorphisms, Isomorphism theorems, invertibility and isomorphisms, change of coordinate matrix.

Books Recommended

1. Stephen H. Friedberg, Arnold J. Insel, Lawrence E. Spence, *Linear Algebra*, 4th Ed., Prentice-Hall of India Pvt. Ltd., New Delhi, 2004.
2. David C. Lay, *Linear Algebra and its Applications*, 3rd Ed., Pearson Education Asia, Indian Reprint, 2007.
3. S. Lang, *Introduction to Linear Algebra*, 2nd Ed., Springer, 2005.
4. Gilbert Strang, *Linear Algebra and its Applications*, Thomson, 2007.

DSE 1B.1: Numerical Methods

Algorithms, Convergence, Bisection method, False position method, Fixed point iteration method, Newton's method, Secant method, LU decomposition, Gauss-Jacobi, Gauss-Siedel and SOR iterative methods.

Lagrange and Newton interpolation: linear and higher order, finite difference operators.

Numerical differentiation: forward difference, backward difference and central Difference.

Integration: trapezoidal rule, Simpson's rule, Euler's method.

Recommended Books

1. B. Bradie, *A Friendly Introduction to Numerical Analysis*, Pearson Education, India, 2007.
2. M.K. Jain, S.R.K. Iyengar and R.K. Jain, *Numerical Methods for Scientific and Engineering*

Computation, 5th Ed., New age International Publisher, India, 2007.

DSE 1B.2: Complex Analysis

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.

Analytic functions, examples of analytic functions, exponential function, Logarithmic function, trigonometric function, derivatives of functions, definite integrals of functions. Contours, Contour integrals and its examples, upper bounds for moduli of contour integrals. Cauchy-Goursat theorem, Cauchy integral formula.

Liouville's theorem and the fundamental theorem of algebra. Convergence of sequences and series, Taylor series and its examples.

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

Books Recommended

1. James Ward Brown and Ruel V. Churchill, *Complex Variables and Applications*, 8th Ed., McGraw – Hill International Edition, 2009.

2. Joseph Bak and Donald J. Newman, *Complex analysis*, 2nd Ed., Undergraduate Texts in Mathematics, Springer-Verlag New York, Inc., New York, 1997.

DSE 1B.3: Linear Programming

Linear Programming Problems, Graphical Approach for Solving some Linear Programs. Convex Sets, Supporting and Separating Hyperplanes. Theory of simplex method, optimality and unboundedness, the simplex algorithm, simplex method in tableau format, introduction to artificial variables, two-phase method, Big-M method and their comparison.

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

Recommended Books

1. Mokhtar S. Bazaraa, John J. Jarvis and Hanif D. Sherali, *Linear programming and Network Flows*, 2nd Ed., John Wiley and Sons, India, 2004.

2. F.S. Hillier and G.J. Lieberman, *Introduction to Operations Research*, 8th Ed., Tata McGraw Hill, Singapore, 2004.

3. Hamdy A. Taha, *Operations Research, An Introduction*, 8th Ed., Prentice-Hall India, 2006.

SEC 1.1: Logic and Sets

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.

Sets, subsets, Set operations, 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.

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.

Book Recommended

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

SEC 1.2: Analytical Geometry

Techniques for sketching parabola, ellipse and hyperbola. Reflection properties of parabola, ellipse and hyperbola. Classification of quadratic equations representing lines, parabola, ellipse and hyperbola. Spheres, Cylindrical surfaces. Illustrations of graphing standard quadric surfaces like cone, ellipsoid.

Books Recommended

1. G.B. Thomas and R.L. Finney, *Calculus*, 9th Ed., Pearson Education, Delhi, 2005.
2. H. Anton, I. Bivens and S. Davis, *Calculus*, John Wiley and Sons (Asia) Pvt. Ltd., 2002.
3. S.L. Loney, *The Elements of Coordinate Geometry*, McMillan and Company, London.
4. R.J.T. Bill, *Elementary Treatise on Coordinate Geometry of Three Dimensions*, McMillan India Ltd., 1994.

SEC 1.3: Integral Calculus

Integration by Partial fractions, integration of rational and irrational functions. Properties of definite integrals. Reduction formulae for integrals of rational, trigonometric, exponential and logarithmic functions and of their combinations.

Areas and lengths of curves in the plane, volumes and surfaces of solids of revolution. Double

and Triple integrals.

Books Recommended

1. G.B. Thomas and R.L. Finney, *Calculus*, 9th Ed., Pearson Education, Delhi, 2005.
2. H. Anton, I. Bivens and S. Davis, *Calculus*, John Wiley and Sons (Asia) P. Ltd., 2002.

SEC 2.1: Vector Calculus

Differentiation and partial differentiation of a vector function. Derivative of sum, dot product and cross product of two vectors.

Gradient, divergence and curl.

Books Recommended

1. G.B. Thomas and R.L. Finney, *Calculus*, 9th Ed., Pearson Education, Delhi, 2005.
2. H. Anton, I. Bivens and S. Davis, *Calculus*, John Wiley and Sons (Asia) P. Ltd. 2002.
3. P.C. Matthew's, *Vector Calculus*, Springer Verlag London Limited, 1998.

SEC 2.2: Theory of Equations

General properties of polynomials, Graphical representation of a polynomials, 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. Symmetric functions, Applications 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.

Books Recommended

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

SEC 2.3: Number Theory

Division algorithm, Lamé's theorem, linear Diophantine equation, fundamental theorem of arithmetic, prime counting function, statement of prime number theorem, Goldbach conjecture, binary and decimal representation of integers, linear congruences, complete set of residues. Number theoretic functions, sum and number of divisors, totally multiplicative functions, definition and properties of the Dirichlet product, the Möbius inversion formula, the greatest integer function, Euler's phi-function.

Books Recommended:

1. David M. Burton, *Elementary Number Theory* 6th Ed., Tata McGraw-Hill Edition, Indian

reprint, 2007.

2. Richard E. Klima, Neil Sigmon, Ernest Stitzinger, *Applications of Abstract Algebra with Maple*, CRC Press, Boca Raton, 2000.

3. Neville Robinns, *Beginning Number Theory*, 2nd Ed., Narosa Publishing House Pvt. Limited, Delhi, 2007.

SEC 3.1: Probability and Statistics

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, continuous distributions: uniform, normal, exponential.

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.

Books Recommended:

1. Robert V. Hogg, Joseph W. McKean and Allen T. Craig, *Introduction to Mathematical Statistics*, Pearson Education, Asia, 2007.

2. Irwin Miller and Marylees Miller, John E. Freund, *Mathematical Statistics with Application*, 7th Ed., Pearson Education, Asia, 2006.

3. Sheldon Ross, *Introduction to Probability Model*, 9th Ed., Academic Press, Indian Reprint, 2007.

SEC 3.2: Mathematical Finance

Basic principles: Comparison, arbitrage and risk aversion, Interest (simple and compound, discrete and continuous), time value of money, inflation, net present value, internal rate of return (calculation by bisection and Newton-Raphson methods), comparison of NPV and IRR. Bonds, bond prices and yields. Floating-rate bonds, immunization.

Asset return, short selling, portfolio return, (brief introduction to expectation, variance, covariance and correlation), random returns, portfolio mean return and variance, diversification, portfolio diagram, feasible set, Markowitz model (review of Lagrange multipliers for 1 and 2 constraints).

Books Recommended:

1. David G. Luenberger, *Investment Science*, Oxford University Press, Delhi, 1998.

2. John C. Hull, *Options, Futures and Other Derivatives*, 6th Ed., Prentice-Hall India, Indian reprint, 2006.

3. Sheldon Ross, *An Elementary Introduction to Mathematical Finance*, 2nd Ed., Cambridge University Press, USA, 2003.

SEC 3.3: Mathematical Modeling

Applications of differential equations: the vibrations of a mass on a spring, mixture problem, free damped motion, forced motion, resonance phenomena, electric circuit problem, mechanics of simultaneous differential equations.

Applications to Traffic Flow. Vibrating string, vibrating membrane, conduction of heat in solids, gravitational potential, conservation laws.

Books Recommended:

1. Shepley L. Ross, *Differential Equations*, 3rd Ed., John Wiley and Sons, 1984.

2. I. Sneddon, *Elements of Partial Differential Equations*, McGraw-Hill, International Edition, 1967.

SEC 4.1: Boolean Algebra

Definition, examples and basic properties of ordered sets, maps between ordered sets, duality principle, maximal and minimal elements, lattices as ordered sets, complete lattices, lattices as algebraic structures, sublattices, products and homomorphisms.

Definition, examples and properties of modular and distributive lattices, Boolean algebras, Boolean polynomials, minimal forms of Boolean polynomials, Quinn-McCluskey method, Karnaugh diagrams, switching circuits and applications of switching circuits.

Books Recommended:

1. B A. Davey and H. A. Priestley, *Introduction to Lattices and Order*, Cambridge University Press, Cambridge, 1990.

2. Rudolf Lidl and Günter Pilz, *Applied Abstract Algebra*, 2nd Ed., Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.

SEC 4.2: Transportation and Game Theory

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.

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

Books Recommended:

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

SEC4.3: Graph Theory

Definition, examples and basic properties of graphs, pseudographs, complete graphs, bi-partite graphs, isomorphism of graphs, paths and circuits, Eulerian circuits, Hamiltonian cycles, the adjacency matrix, weighted graph, travelling salesman's problem, shortest path, Dijkstra's algorithm, Floyd-Warshall algorithm.

Books Recommended:

1. Edgar G. Goodaire and Michael M. Parmenter, *Discrete Mathematics with Graph Theory* 2nd Ed., Pearson Education (Singapore) P. Ltd., Indian Reprint, 2003.
2. Rudolf Lidl and Günter Pilz, *Applied Abstract Algebra*, 2nd Ed., Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.