SYLLABUS
FOR
B.SC. MATHEMATICS (HONOURS) ON CHOICE BASED CREDIT SYSTEM

A SIX SEMESTERS COURSE

(Effective from the academic session 2017 – 2018 and onwards)

COOCH BEHAR PANCHANAN BARMA UNIVERSITY
COOCH BEHAR, WEST BENGAL

AIMS AND OBJECTIVES OF THE NEW SYLLABUS IN MATHEMATICS (HONOURS)

Aims

➢ To initiate students to use meaningful thought to solve different kinds of mathematical problems and to understand the basic structure of mathematics.

➢ To orient students towards various applications of Mathematics.

➢ To improve the point of view of the students on mathematics as per modern age requirement.

➢ To improve retention of mathematical concepts in the student.

➢ To enable the teachers to demonstrate, explain and reinforce abstract mathematical ideas by using models, charts, graphs, pictures, posters and with the help of different software through computer.

➢ To make a student-friendly approach in the learning process of Mathematics.

➢ To propagate free and open source software tools amongst the students and the teachers.

➢ To set up a mathematics laboratory in every college in order to help students to explore the mathematical concepts through activities and experimentation.

➢ To develop a spirit of inquisition in the student.

Objectives

➢ To provide a vibrant and more alive learning process of Mathematics, so that math-phobia can be gradually reduced amongst students.

➢ To improve the scope for individual participation in the process of learning of Mathematics.

➢ To include authentic learning, based on hands-on experience with computers with different software for better understanding of Mathematics.

➢ To promote experimental, problem-oriented and discovery learning of mathematics.

➢ To help the student to build interest and confidence in learning the subject.

➢ To explore the scope for greater involvement of both the mind and the hand which facilitates cognition.

➢ To engage the students in the activity-centered mathematics laboratory, so that problem solving approach develop amongst the students through self understanding.

1. Scheme for CBCS Curriculum

1.1 Credit Distribution across Courses

	Credits		
Course Type	**Total Papers**	**Theory + Practical**	**Theory*+Tutorial**
Core Courses (CC)	14	14*4 =56 14*2 =28	14*5 =70 14*1=14
Discipline Specific Electives (DSE)	4	4*4=16 4*2=8	4*5=20 4*1=4
Generic Electives (GE)	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 (SEC)	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	Modern Indian Language (MIL)/ Environmental Science	**2**
	Core–1	Calculus, Geometry & Differential Equation	**5**
	Core–1 Tutorial	Do	**1**
	Core–2	Algebra	**5**
	Core–2 Tutorial	Do	**1**
	Generic Elective–1	Subject from other than Mathematics	**5**
	Generic Elective–1Tutorial		**1**
II	Ability Enhancement Compulsory Course–II	MIL / Environmental Science	**2**
	Core–3	Real Analysis	**5**
	Core–3 Tutorial	Do	**1**
	Core–4	Differential Equations	**4**
	Core–4 Practical	Do	**2**
	Generic Elective–2	Subject from other than Mathematics	**5**
	Generic Elective–2 Tutorial	-	**1**
III	Core–5	Theory of Real Functions	**5**
	Core–5 Tutorial	Do	**1**
	Core –6	Group Theory	**5**
	Core – 6 Tutorial	Do	**1**
	Core –7	Partial Differential Equation	**4**
	Core –7 Practical	Do	**2**
	Skill Enhancement Course–1	From the list given below	**2**
	Generic Elective–3	Subject from other than Mathematics	**5**
	Generic Elective–3 Tutorial	-	**1**
IV	Core –8	Multivariate Calculus & Vector Analysis	**5**
	Core –8 Tutorial	Do	**1**
	Core –9	Complex Analysis	**4**
	Core –9 Practical	Do	**2**
	Core –10	Ring Theory, Linear Algebra & Metric Spaces	**5**

	Core–10 Tutorial	Do	1
	Skill Enhancement Course-2	From the list given be below	2
	Generic Elective–4	Subject from other than Mathematics	5
	Generic Elective–4 Tutorial	Do	1
V	Core–11	Probability and Statistics	5
	Core–11 Tutorial	Do	1
	Core–12	Laplace Transform, Riemann Integration & Series of functions	5
	Core–12 Tutorial	Do	1
	Discipline Specific Elective–1	From the list given below	5
	Discipline Specific Elective–1 Tutorial	Do	1
	Discipline Specific Elective–2	From the list given below	5
	Discipline Specific Elective–2 Tutorial	Do	1
VI	Core –13	Dynamics of a Particle	5
	Core –13 Tutorial	Do	1
	Core–14	Numerical Methods	4
	Core –14 Practical	Do	2
	Discipline Specific Elective–3	From the list given below	5
	Discipline Specific Elective–3 Tutorial	Do	1
	Discipline Specific Elective–4	From the list given below	5
	Discipline Specific Elective– 4 Tutorial	Do	1

- For choosing subjects of DSE, GE, SEC students are hereby directed to consult with the respective College /Department

1.3 Choices for Discipline Specific Elective (DSE)

Discipline Specific Elective–1 (Choose one)	Discipline Specific Elective–2 (Choose one)	DisciplineSpecificElective–3 (Choose one)	DisciplineSpecificElective–4 (Choose one)
DSE 1(a): Linear Programming and Game theory	**DSE 2(a):** Introduction to Integral equation and Dynamical System	**DSE 3(a):** Number Theory	**DSE 4(a):** Boolean Algebra & Discrete Mathematics
DSE 1(b): Bio-Mathematics	**DSE 2(b):** Industrial Mathematics	**DSE 3(b):** Rigid Dynamics	**DSE 4(b):** Analytical Statics
DSE 1(c): Point Set Topology	**DSE 2(c):** Classical Mechanics	**DSE3(c):**Differential Geometry	**DSE 4(c):** Cryptography

1.4   Choices for Skill Enhancement Courses (SEC)

Skill Enhancement Course-1 (Choose one)	Skill Enhancement Course-2 (Choose one)
SEC 1(a): Logic and Sets	SEC 2(a): Graph Theory
SEC 1(b): Computer Graphics	SEC 2(b): Operating System: Linux
SEC 1(c): Object Oriented Programming in C++	SEC 2(c): Econometrics

1.5   Choices for Generic Elective Courses (for other than Mathematics Honours Subjects)

Generic Elective -1/3 (Choose one)	Generic Elective -2/4 (Choose one)
GE 1(a)/3(a): Differential Calculus	GE 2(a)/4(a): Differential Equations
GE 1(b)/3(b): Real Analysis	GE 2(b)/4(b): Algebra

2. Core Subjects Syllabus

2.1 Core 1 – Calculus, Geometry & Differential Equation

Objectives: This course will help students to understand various kinds of standard functions and graphs, techniques of integrations and limits. It helps to build concepts on three dimensional geometry. Also, it gives basic idea about formation and solution of differential equations.

Calculus, Geometry & Differential Equation	
	6 Credits

Unit 1

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.

Unit 2

Reduction formulae, derivations and illustrations of reduction formulae of the type $\int \sin^n x \, dx$, $\int \cos^n x \, dx$, $\int \tan^n x \, dx$, $\int \sec^n x \, dx$, $\int (\log x)^n dx$, $\int \sin^n x \sin^m x \, dx$, 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.

Unit 3

Reflection properties of conics, rotation of axes and second degree equations, classification of conics using the discriminant, polar equations of conics.

Spheres. Cylindrical surfaces. Central conicoids, paraboloids, plane sections of conicoids, generating lines, classification of quadrics, illustrations of graphing standard quadric surfaces like cone, ellipsoid.

Unit 4

Differential equations and mathematical models. General, particular, explicit, implicit and singular solutions of a differential equation. Exact differential equations and integrating factors, separable equations and equations reducible to this form, linear equation and Bernoulli equations, special integrating factors and transformations.

[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 2 - Algebra

Objectives: Basic concepts of complex algebra, theory of equations, set theory, vector spaces and matrices shall be discussed in this course.

Algebra	
	6 Credits
Unit 1	
Complex Number, Polar representation of complex numbers, nth roots of unity, De Moivre's theorem for rational indices and its applications. Exponential, Sine, Cosine and Logarithm of a Complex number. Definition of $a^z (a \neq 0)$. Gregory's series, Inverse circular function and Hyperbolic function. Theory of equations: Fundamental theorem of Classical Algebra (statement only) ,Nature of roots of an equation, Statement of Rolle's theorem, Relation between roots and coefficients, transformation of equation, Descartes rule of signs, Reciprocal, cubic and bi-quadratic equation. Inequality: The inequality involving AM$\geq$ GM$\geq$ HM, Cauchy-Schwartz inequality.	
Unit 2	
Equivalence relations. Functions, composition of functions, Invertible functions, one to one correspondence and cardinality of a set. Well-ordering property of positive integers, division algorithm, divisibility and Euclidean algorithm. Congruence relation between integers. Principles of Mathematical induction, statement of Fundamental Theorem of Arithmetic.	
Unit 3	
Systems of linear equations, row reduction and echelon forms, vector equations, the matrix equation Ax=b, solution sets of linear systems, applications of linear systems, linear	

independence.

Unit 4

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

Unit 5

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.

Reference Books

- Titu Andreescu and Dorin Andrica, Complex Numbers from A to Z, Birkhauser, 2006.
- Edgar G. Goodaire and Michael M. Parmenter, Discrete Mathematics with Graph Theory, 3rd Ed., Pearson Education (Singapore) P. Ltd., Indian Reprint, 2005.
- David C. Lay, Linear Algebra and its Applications, 3rd Ed., Pearson Education Asia, Indian Reprint, 2007.
- K. Hoffman, R. Kunze, Linear algebra.
- W.S. Burnstine and A.W. Panton, Theory of equations.

2.3   Core 3 – Real Analysis

Objectives: Students will be able to understand about sets in R, sequence and infinite series. That helps them to understand the different core courses of Mathematics in the syllabus.

Real Analysis	
	6 Credits

Unit 1

Review of algebraic and order properties of R, ε-neighborhood of a point in R. Idea of countable sets, uncountable sets and uncountability of R. Bounded above sets, bounded below sets, bounded sets, unbounded sets. Suprema and infima. Completeness property of R and its equivalent properties. The Archimedean property, density of rational (and Irrational) numbers in R, intervals. Limit points of a set, isolated points, open set, closed set, derived set, illustrations of Bolzano-Weierstrass theorem for sets, compact sets in R, Heine-Borel Theorem.

Unit 2
Sequences, bounded sequence, convergent sequence, limit of a sequence, liminf, lim sup. Limit theorems. Monotone sequences, monotone convergence theorem. Subsequences, divergence criteria. Monotone subsequence theorem (statement only), Bolzano Weierstrass theorem for sequences. Cauchy sequence, Cauchy's convergence criterion.
Unit 3
Infinite series, convergence and divergence of infinite series, Cauchy criterion, tests for convergence: comparison test, limit comparison test, ratio test, Cauchy's nth root test, integral test. Alternating series, Leibnitz test. Absolute and conditional convergence.
Reference Books
► R.G. Bartle and D. R. Sherbert, Introduction to Real Analysis, 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.   ► 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 4 – Differential Equations (with Practical)

Objectives: After completing Core 1 course, this course will give further detailed idea about solving the ordinary differential equations and its applications in real life problem. It also includes plotting of solutions using mathematical software to analyze and visualize the solutions.

Differential Equations	
	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

List of Practical (using any software)

1. Plotting of second order solution family of differential equation.

2. Plotting of third order solution family of differential equation.

3. Growth model (exponential case only).

4. Decay model (exponential case only).

5. Lake pollution model (with constant/seasonal flow and pollution concentration).

6. Case of single cold pill and a course of cold pills.

7. Limited growth of population (with and without harvesting).

8. Predatory-prey model (basic volterra model, with density dependence, effect of DDT, two prey one predator).

9. Epidemic model of influenza (basic epidemic model, contagious for life, disease with carriers).

10. Battle model (basic battle model, jungle warfare, long range weapons).

11. Plotting of recursive sequences.

12. Study the convergence of sequences through plotting.

13. Verify Bolzano-Weierstrass theorem through plotting of sequences and hence identify convergent subsequences from the plot.

14. Study the convergence/divergence of infinite series by plotting their sequences of partial sum.

15. Cauchy's root test by plotting nth roots.

16. Ratio test by plotting the ratio of nth and $(n+1)^{th}$ term.

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

2.5   Core 5 – Theory of Real Functions

Objectives: Students will be able to grasp the various aspects of real functions like existence and importance of limits of a functions at a certain point of the domain, continuity and differentiability of real functions. It has been discussed about Mean Value Theorems of various forms of remainder and its applications.

Theory of Real Functions	
	6 Credits
Unit 1	
Limits of functions (ε - δ approach), sequential criterion for limits, divergence criteria. Limit theorems, one sided limits. Infinite limits and limits at infinity. Continuous functions, sequential criterion for continuity and discontinuity. Algebra of continuous functions. Continuous functions on an interval, intermediate value theorem, location of roots theorem, preservation of intervals theorem. Uniform continuity, non-uniform continuity criteria, uniform continuity theorem.	
Unit 2	
Differentiability of a function at a point and in an interval, Caratheodory's theorem, algebra of differentiable functions. Relative extrema, interior extremum theorem. Rolle's theorem. Mean value theorem, intermediate value property of derivatives, Darboux's theorem. Applications of mean value theorem to inequalities and approximation of polynomials.	
Unit 3	
Cauchy's mean value theorem. Taylor's theorem with Lagrange's form of remainder, Taylor's theorem with Cauchy's form of remainder, application of Taylor's theorem to	

convex functions. Taylor's series and Maclaurin's series expansions of exponential and trigonometric functions, $ln\,(1\,+\,x), \frac{1}{ax\,+\,b}$ and $(x+1)^n$. Application of Taylor's theorem to inequalities.

Reference Books
► R. Bartle and D.R. Sherbert, Introduction to Real Analysis, John Wiley and Sons, 2003.
► K.A. Ross, Elementary Analysis: The Theory of Calculus, Springer, 2004.
► A. Mattuck, Introduction to Analysis, Prentice Hall, 1999.
► S.R. Ghorpade and B.V. Limaye, a Course in Calculus and Real Analysis, Springer, 2006.
► 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.

2.6 Core 6 – Group Theory

Objectives: In this course of study, students will learn concepts on group theory from definition to group isomorphisms.

Group Theory	
	6 Credits
Unit 1	
Definition and examples of groups including permutation groups and quaternion groups (illustration through matrices), elementary properties of groups. Subgroups and examples of subgroups, centralizer, normaliser, centre of a group, product of two subgroups.	
Unit 2	
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 3	
External direct product of a finite number of groups, normal subgroups, factor groups, Cauchy's	

theorem for finite abelian groups.

Unit 4

Group homomorphisms, properties of homomorphisms, Cayley's theorem, properties of isomorphisms, First, Second and Third isomorphism theorems.

Reference Books

► John B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.

► M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.

► Joseph A. Gallian, Contemporary Abstract Algebra, 4th Ed., 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 7 – Partial Differential Equation (With Practical)

Objectives: Students will learn about formations and method of solving partial differential equations. Also, with the design of practical syllabus, students will get better insight of solutions of PDEs.

Partial Differential Equation

	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

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. Solution of linear partial differential equations with constant coefficients.

Unit 3: List of Practical (using any software)

1. Plotting of a solution of Cauchy problem for first order PDE.
2. Plotting the characteristics for the first order PDE.
3. Plot the integral surfaces of a given first order PDE with initial data.

4. Plotting of a solution of wave equation $\dfrac{\partial^2 u}{\partial t^2} - c^2 \dfrac{\partial^2 u}{\partial x^2} = 0$ for different initial and boundary conditions.

5. Plotting of a solution of heat equation $\dfrac{\partial u}{\partial t} - c \dfrac{\partial^2 u}{\partial x^2} = 0$ for different initial and boundary conditions.

6. Plotting of a solution of Laplace's equation $\dfrac{\partial^2 u}{\partial x^2} + \dfrac{\partial^2 u}{\partial y^2} = 0$ for different initial and boundary conditions.

Reference Books

► Tyn Myint-U and Lokenath Debnath, *Linear Partial Differential Equations for Scientists and Engineers,* 4th Ed., 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.

2.8 Core 8 – Multivariate Calculus & Vector Analysis

Objectives: After learning about single variable functions, here students will know about various features about function of several variables. They will also learn the theory and applications of vector analysis.

Multivariate Calculus & Vector Analysis	
	6 Credits
Unit 1	
Functions of several variables, limit and continuity of functions of two or more variables, Partial differentiation, total differentiability and differentiability, sufficient condition for differentiability. Chain rule for one and two independent parameters, directional derivatives, the gradient, maximal and normal property of the gradient, tangent planes, Extrema of functions of two variables, method of Lagrange multipliers, constrained optimization problems.	
Unit 2	
Double integration over rectangular region, double integration over non-rectangular region, Double integrals in polar co-ordinates, Triple integrals, triple integral over a parallelepiped and solid regions. Volume by triple integrals, cylindrical and spherical co-ordinates. Change of variables in double integrals and triple integrals.	
Unit 3	
Definition of vector field, divergence and curl. Line integrals, applications of line integrals: mass	

and work. Fundamental theorem for line integrals, conservative vector fields, independence of path.

Unit 4
Green's theorem, surface integrals, integrals over parametrically defined surfaces. Stokes 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. Speigel, Schaum's outline of Vector Analysis.

2.9 Core 9 – Complex Analysis (With Practical)

Objectives: Students will grasp the idea of complex functions, its derivatives and integrations. Also, in the practical classes, they will learn how to represent complex numbers, to find line integrals, contour integration, plotting of complex functions etc by using mathematical software.

Complex Analysis	
	6 Credits

Unit 1
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. Milne's method.

Unit 2
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. Antiderivatives, proof of antiderivative theorem, Cauchy-Goursat theorem, Cauchy integral formula

Unit 3

An extension of Cauchy integral formula, consequences of Cauchy integral formula.

Mobius transformations.

Unit 4 : List of Practical (using any software)

(i) Declaring a complex number e.g. $z_1 = 3 + 4i$, $z_2 = 4 - 7i$ Discussing their algebra $z_1 + z_2$, $z_1 - z_2$, $z_1 * z_2 \, and \, z_1/z_2$ and then plotting them.
(ii) Finding conjugate, modulus and phase angle of an array of complex numbers.
 (iii) Compute the integral over a straight line path between the two specified end points
e.g.,$\int_c f(z)dz$ where C is the straight line path from $a + ib$ to $c + id$.
(iv) Perform contour integration e.g. $\int_c f(z)dz$ where C is the contour given by $g(x, y) = 0$.

(v) Plotting of the complex functions like $f(z) = z\bar{z}$, $f(z) = z^3$, $f(z) = (z^4 - 1)^{\frac{1}{4}}$ etc.
(vi) Finding the residues of the complex function.

Reference Books

- 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.
- 3. L.V. Ahlfors, *Complex Analysis*, McGraw Hill Book Company, 1966.
- 4. J.B. Conway, *Functions of Complex Variable I*, Springer Verlag, New York Inc, 1978.
- 5. Murray R. Spiegel, *Complex Variables*, Schaum's Outline Series, New York, 1964.
- 6. Reinhold Remmert, *Theory of Complex Functions*, Springer Verlag, 1991.
- 7. Walter Rudin, *Real and Complex Analysis*, McGraw Hill, New York, 1997.
- 8. George E. Shilov, *Elementary Real and Complex Analysis*, The MIT Press, Massachusetts, 1973.
- 9. Dennis G. Zill and Patrick D. Shanahan, *A First Course in Complex Analysis wit Applications*, Jones & Bartlett, India, 2010.
- 10. James W. Brown and R.V. Churchill, *Complex Variables and Applications*, 8th Ed., McGrawHill International Edition, 2009.

2.10   Core 10 – Ring theory, Linear Algebra & Metric spaces

Objectives: Introduction of Ring theory should be the next step when the concepts of group theory has been build up. That's why, basic concepts of Ring theory and Metric spaces, further idea of inner product spaces and linear transformations have been introduced in this course.

Ring Theory , Linear Algebra & Metric Spaces

	6 Credits

Unit 1

Ring theory: Definition and examples of rings, properties of rings, sub rings, integral domains and fields, characteristic of a ring. Ideal, ideal generated by a subset of a ring, factor rings, prime and maximal ideals, ring isomorphism(statement only).

Unit 2

Linear algebra: Inner product space. Linear transformations, null space, range, rank and nullity of a linear transformation, matrix representation of a linear transformation, algebra of linear transformations. Isomorphism, Isomorphism theorems, invertibility and isomorphism, change of coordinate matrix.

Unit 3

Metric spaces: Definition and examples of Metric Spaces. Neighbourhoods. Limit points. Interior points. Open and closed sets. Closure and Interior. Boundary points. Subspace of Metric Space.

Cauchy Sequence. Completeness. Cantor Intersection Theorem. Construction of **R** as the completion of incomplete Metric Space **Q** (Deduction of no other completion process is required). Real number as a complete ordered field (No proof of the theorem).

Reference Books

- ► 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 Publishing House, 1999.
- ► 4. Stephen H. Friedberg, Arnold J. Insel, Lawrence E. Spence, *Linear Algebra,* 4th Ed., Prentice- Hall of India Pvt. Ltd., New Delhi, 2004.
- ► 5. S. Lang, *Introduction to Linear Algebra,* 2nd Ed., Springer, 2005.
- ► 6. Gilbert Strang, *Linear Algebra and its Applications*, Thomson, 2007.
- ► 5. S. Kumaresan, *Linear Algebra- A Geometric Approach*, Prentice Hall of India, 1999.
- ► 6. Kenneth Hoffman, Ray Alden Kunze, *Linear Algebra,* 2nd Ed., Prentice-Hall of India Pvt. Ltd., 1971.
- ► 7. S.H. Friedberg, A.L. Insel and L.E. Spence, *Linear Algebra*, Prentice Hall of India Pvt. Ltd., 2004..
  8. Satish Shirali and Harikishan L. Vasudeva, Metric Spaces, Springer Verlag, London, 2006.
  9. S. Kumareasan, Topology of Metric Spaces, 2nd Ed., Narosa Publishing House, 2011.

2.11   Core 11- Probability and Statistics

Objectives: In this course students will know about basic concepts on probability and statistics. Definition of probability, application of Bayes theorem, various probability functions and their applications, numerous measures to determine the nature of sampling data etc. have been discussed in this course.

Probability and Statistics

	6 Credits

Unit 1

Random experiments, Simple and compound events. Event space. Classical and frequency definition of probability and their drawbacks. Axioms of Probability. Statistical regularity. Multiplication rule of Probabilities. Bayes' thorem.

Unit 2

Independent events. Independent random experiments. Independent trials. Bernoulli trials and binomial law. Poisson trials. Random variables. Probability distribution. Distribution function. Discrete and continuous distributions. uniform, binomial, Poisson, geometric, negative binomial, continuous distributions: uniform, normal, exponential. Mathematical expectation, mean, variance, moments, central moments, dispersion, skewness and kurtosis. Median, mode, quartiles, moment generating function, Characteristic function.

Unit 3

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 and calculation of covariance, linear regression for two variables.

Unit 4

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,

Unit 5

Concept of population and Sampling. Sampling distribution of Statistic. Estimates of Population characteristic or parameter. Unbiased and consistent estimates. Sample characteristic as estimates of the corresponding population characteristic. Sampling distributions of the sample mean and variance. Exact sampling distributions for the normal population.

Reference Books

- 1. V.K Rohtagi and A.K. Saleh, *An Introduction to Probability and Statistics*, 2nd Ed., John Wiley & Sons, 2005.

► 2. A.M. Goon, M.K. Gupta and T.S. Dasgupta, *Fundamentals of Statistics* (Vol. I), 7th Ed., The World Press Pvt. Ltd., 2000.

► 3. R.V. Hogg and A.T. Craig, Introduction to Mathematical Statistics, Macmillan Publishing Co. Inc., 1978.

► 4. Neil A. Weiss, *Introductory Statistics*, 7th Ed., Pearson Education, 2007.

► 5. A.M. Goon, M.K. Gupta and T.S. Dasgupta, *An Outline of Statistical Theory* (Vol. II), 2nd Ed., The World Press Pvt. Ltd., 2000.

2.12   Core 12 – Laplace Transform, Riemann Integration & Series of functions

Objectives: Theory and application of Laplace transformations, theory and concepts of Riemann integration and nature, convergence of series of functions and Fourier series will be discussed in this course.

Laplace Transform, Riemann Integration & Series of functions	
	6 Credits

Unit 1

Laplace Transform: Laplace of some standard functions, Existence conditions for the Laplace Transform, Shifting theorems, Laplace transform of derivatives and integrals, Inverse Laplace transform and their properties, Convolution theorem, Initial and final value theorem, Laplace transform of periodic functions, error functions, Heaviside unit step function and Dirac delta function, Applications of Laplace transform to solve ODEs .

Unit 2

Riemann integration and Improper integral: 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. Intermediate Value theorem for Integrals; Fundamental theorem of Integral Calculus.

Improper integrals. Convergence of Beta and Gamma functions.

Unit 3

Series of functions: Pointwise and uniform convergence of sequence of functions. Theorems on continuity, derivability and integrability of the limit function of a sequence of functions.

Series of functions. Theorems on the continuity, derivability and integrability of the sum function of a series of functions; Cauchy criterion for uniform convergence and Weierstrass M-Test.

Unit-4

Fourier series, Trigonometric Fourier series and its convergence. Fourier series of even and odd functions, Fourier half-range series.

Reference Books

► 1. E. Kreyszig, *Advanced Engineering Mathematics*, John Wiley & Sons, 2011.

► 2. R.K. Jain and S.R.K. Iyenger, *Advanced Engineering Mathematics*, Narosa Publishing House, 2009.

► 3. F. B. Hildebrand, *Methods of Applied Mathematics*, Courier Dover Publications, 1992.

► 4. K.A. Ross, *Elementary Analysis, The Theory of Calculus*, Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.

► 5. R.G. Bartle D.R. Sherbert, *Introduction to Real Analysis,* 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.

► 6. Charles G. Denlinger, *Elements of Real Analysis*, Jones & Bartlett (Student Edition), 2011.

2.13   Core 13 – Dynamics of a particle

Objectives: In this course of study, students grab the basic knowledge of the behaviour of objects in motion. Motion in a straight line, Expressions of velocity and acceleration in different coordinate systems, central orbit, motion of a particle with varying mass and particle motion in a resisting medium are the key topics of this course.

Dynamics of a particle

	6 Credits

Unit 1

Motion in straight line under variable acceleration. Simple Harmonic Motion. Hooke's law. Problems on elastic string. Expressions for velocity and acceleration of a particle moving on a plane in Cartesian and Polar coordinates.

Motion of a particle moving on a plane with reference to a set of rotating axes.

Unit 2

Central forces and central orbit.

Tangential and normal accelerations. Circular motion. Simple cases of constrained motion of a particle. Motion of a particle in a plane under different laws of resistance. Motion of a projectile in a resisting medium.

Trajectories in a resisting medium where resistance varies as some integral power of velocity. Terminal velocity. Motion under the inverse square law in a plane. Kepler's law and planetary motion. Escape velocity, time of describing an arc of an orbit, motion of artificial satellites.

Unit 3

Equation of motion of a particle of varying mass. Problems of motion of varying mass such as those of falling raindrops and projected rockets.

Reference Books

► 1. S.L.Loney, Dynamics of a Particle and of Rigid Bodies, Cambridge University Press, Indian Edition-Raddha Publishing House.
► 2. J.G.Chakravorty and P.R.Ghosh, Advanced Analytical Dynamics, U.N.Dhur and Sons.
► 3. S.Ganguly and S.Saha, Analytical Dynamics of a Particle, New Central Book Agency.

► 4. N.Datta and R.N.Jana, Dynamics of a Particle, Shreedhar Prakashani.

2.14   Core 14 – Numerical Methods (with Practical)

Objectives: This course will help students to understand the concept of error, various methods to find a root of an equation, solution of a system of linear equations, interpolation, numerical differentiation and integration etc. The students will also have hand on experience of the topic through computers using any software.

Numerical Methods

Use of Scientific calculator is allowed.	6 Credits

Unit 1

Errors: Relative, Absolute, Round off, Truncation.

Transcendental and Polynomial equations: Bisection method, Newton's method, Secant method. Rate of convergence of these methods.

System of linear algebraic equations: Gaussian Elimination and Gauss Jordan methods. Gauss Jacobi method, Gauss Seidel method and their convergence analysis.

Unit2

Interpolation: Lagrange and Newton's methods. Error bounds. Finite difference operators. Gregory forward and backward difference interpolation.

Unit 3

Numerical Integration: Trapezoidal rule, Simpson's $1/3^{rd}$ rule. Composite Trapezoidal rule, Composite Simpson's $1/3^{rd}$ rule. Ordinary Differential Equations: Euler's method. Runge-Kutta method of orders two and four.

Unit 4 : List of practical (Using any software)

1. Solution of transcendental and algebraic equations by

   - Bisection method

   - Newton Raphson method.

   - Regula Falsi method.

2. Solution of system of linear equations

   - Gaussian elimination method

   - Gauss-Seidel method

3. Numerical Integration

   - Trapezoidal Rule

   - Simpson's one third rule

4. Solution of ordinary differential equations

- Euler method

- Runge- Kutta Method of orders two and four

Reference Books
► 1. Brian 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*, 6th Ed., New age International Publisher, India, 2007.
► 3. C.F. Gerald and P.O. Wheatley, *Applied Numerical Analysis*, Pearson Education, India, 2008

3. Discipline Specific Electives Subjects Syllabus

3.1   DSE 1(a) – Linear Programming and Game Theory

Objectives: In this course, the students will be able to learn about various optimization techniques pertaining to linear programming and apply linear programming to problems arising from real life. Also, the students will learn the basic concepts of game theory through a problem solving approach.

Linear Programming and Game Theory	
	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's zero sum game, solving two person zero sum game, games with mixed strategies, graphical solution procedure, dominance property, linear programming solution of games.	
Reference Books	
► Suresh Chandra, Jayadeva, Aparna Mehra, Numerical optimization with applications,	

Alpha Science.

► 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.

3.2   DSE 1(b) – Bio-Mathematics

Objectives: The students grasp the idea of various bio-mathematical models and techniques which will help them to tackle physical world problems.

Bio-Mathematics	
	6 Credits

Unit 1

Mathematical Biology and the modeling process: an overview. Continuous models: althus model, logistic growth, Allee effect, Gompertz growth, Michaelis-Menten inetics, Holling type growth, Bacterial growth in a Chemostat, Harvesting a single natural population, Prey predator systems and Lotka Volterra equations, Populations in competitions, Epidemic Models (SI, SIR, SIRS, SIC), 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.

Unit 2

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. 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

3.3   DSE 1(c) – Point Set Topology

Objectives: Point set topology has been introduced in this course. Students will learn countability of sets, various topological definitions and proofs and it's connection to metric spaces.

Point Set Topology	
	6 Credits

Unit 1

Countable and Uncountable Sets, Schroeder-Bernstein Theorem, Cantor's Theorem. Cardinal numbers and cardinal arithmetic. Continuum Hypothesis, Zorns Lemma, Axiom of Choice. Well-ordered sets, Hausdorff's Maximal Principle. Ordinal numbers.

Unit 2

Topological spaces, basis and sub-basis for a topology, subspace topology, interior points, limit points, derived set, boundary of a set, closed sets, closure and interior of a set. Continuous functions, open maps, closed maps and homeomorphisms. Product topology, quotient topology, metric topology, Baire category theorem.

Unit 3

Connected and path connected spaces, connected sets in R, components and path components, local connectedness. Compact spaces, compact sets in R. Compactness in metric spaces. Totally bounded spaces, Ascoli-Arzela theorem, the Lebesgue number lemma. Local compactness.

Reference Books

► Munkres, J.R., Topology, A First Course, Prentice Hall of India Pvt.Ltd.,New Delhi, 2000.

► Dugundji, J., Topology, Allyn and Bacon, 1966.

► Simmons, G.F., Introduction to Topology and Modern Analysis, McGraw Hill, 1963.

► Kelley, J.L., General Topology, Van Nostrand Reinhold Co., New York,1995.

► Hocking, J., Young, G., Topology, Addison-Wesley Reading, 1961.

► Steen, L., Seebach, J., Counter Examples in Topology, Holt, Reinhart and Winston, New York, 1970.

- ► Abhijit Dasgupta, Set Theory, Birkhäuser.

3.4 DSE 2(a) – Introduction to Integral equation and Dynamical system

Objectives: Preliminary idea about integral equation and dynamical system have been discussed here. The applications in real world problems have also been discussed in dynamical system.

Introduction to Integral equation and Dynamical system	
	6 Credits

Unit 1

Introduction and basic Examples. Classification, Conversion to Volterra Equation to ODE, Conversion of IVP and BVP to Integral equation, Decomposition, Direct Computation, Successive Approximation, Successive substitution method for Fredholm Integral equations.

Unit 2

Series Solution. Successive approximation. Successive substitution method for Volterra integral equation. Volterra integral equation of first kind. Integral equation with separable kernel.

Unit 3

Formulation of physical system, Existence and uniqueness of solution of a dynamical system, linear system, solution of linear system, fundamental matrix, Fundamental matrices of non autonomous system.

Unit 4

Linear systems with periodic coefficients, stability of systems, stability of linear autonomous systems, stability of non-linear system using linearization, properties of orbits, Phase portrait.

Reference Books

- ► F.G Tricomi, Integral Equations, Dover Publications Inc. New York, 1985
- ► D. Porter and D.S.G. Stirling, Integral Equations: A Practical Treatment from Spectral Theory to Applications, Cambridge University Press, 1990
- ► N.I. Muskhelishvili, Singular Integral Equations, Dover Publications Inc., New York, 2008.
- ► G.C. Layek, An introduction to Dynamical Systems and Chaos, Springer, 2015.
- ► L.Perko, Differential Equations and Dynamical Systems, Springer, 2001.
- ► S.H. Strogatz, Non-linear Dynamics and chaos, CRC Press, 2017

3.5 DSE 2(b) – Industrial Mathematics

Objectives: Applications of mathematics in the field of industrial manufacturing and the theories behind the industrial inventions are discussed here. Introduction of inverse problem, brief theoretical discussions of X-Rays, CT Scan will be studied in this course.

Industrial Mathematics	
	6 Credits

Unit 1

Medical Imaging and Inverse Problems. The content is based on Mathematics of X-ray and CT scan based on the knowledge of calculus, elementary differential equations, complex numbers and matrices.

Unit 2

Introduction to Inverse problems: Why should we teach Inverse Problems? Illustration of Inverse problems through problems taught in Pre-Calculus, Calculus, Matrices and differential equations. Geological anomalies in Earth's interior from measurements at its surface (Inverse problems for Natural disaster) and Tomography.

Unit 3

X-ray: Introduction, X-ray behavior and Beers Law (The fundamental question of image construction) Lines in the place.

Unit 4

Radon Transform: Definition and Examples, Linearity, Phantom (Shepp - Logan Phantom - Mathematical phantoms).

Unit 5

Back Projection: Definition, properties and examples.

Unit 6

CT Scan: Revision of properties of Fourier and inverse Fourier transforms and applications of their properties in image reconstruction. Algorithms of CT scan machine. Algebraic reconstruction techniques abbreviated as ART with application to CT scan.

Reference Books

► Timothy G. Feeman, The Mathematics of Medical Imaging, A Beginners Guide, Springer Under graduate Text in Mathematics and Technology, Springer, 2010.

► C.W. Groetsch, Inverse Problems, Activities for Undergraduates, The Mathematical Association of America, 1999.

► Andreas Kirsch, An Introduction to the Mathematical Theory of Inverse Problems, 2nd Ed., Springer, 2011

3.6 DSE 2(c) – Classical Mechanics

Objectives: Students will learn about mechanics of a system of particles, Newtonian mechanics, Galilean coordinates, D'Alemberts principle, conservation principles etc in this course of study.

Classical Mechanics	
	6 Credits

Unit 1

Mechanics of a system of Particles: Conservation Principles, conservation of linear momentum, angular momentum and energy, Constraints of motion. Degrees of freedom.

Unit 2

Newtonian Mechanics: Limitations, Galilean Invariants. Generalized coordinates. Holonomic and non-homonomic systems. Scleronomic and Rheonomic systems. Generalized potential. Virtual work. D'Alembert's principle. Energy integrals for conservative fields.

Unit 3

Moment of a force about a point, about an axis. Angular momentum about a point, about an axis. Angular momentum principle about centre of mass. Conservation of angular momentum (about a point and an axis). Impulsive forces.

Unit 4

Configurations and degrees of freedom of a multi-particle system, energy principle, energy conservation. Rocket motion in free space and under gravity, collision of elastic bodies. The two-body problem.

Reference Books

- ► S.L.Gupta, V.Kumar, H.V.Sharma, Classical Mechanics, Pragati Prakashan,Meerut.
- ► M.R.Spiegel, Theoretical Mechanics, McGraw Hill
- ► R.N.Tiwari & B.S.Thakur, Classical Mechanics, Prentice Hall of India.
- ► H.Goldstein, Classical Mechanics, Narosa Publishing House.

3.7 DSE 3(a) – Number Theory

Objectives: Students will learn about number theory and the topic like congruences, Chinese remainder theorem, Fermat's little theorem, integer modulo n, Fermat's last theorem etc are key features of this course.

Number Theory	
	6 Credits

Unit 1

Linear diophantine equation, The fundamental theorem of arithmetic, statement of prime number theorem, Goldbach conjecture, linear congruences, reduced and complete set of residues. Chinese remainder theorem, Fermat's little theorem, Wilson's theorem.

Unit 2

Number theoretic functions, sum and number of divisors, multiplicative and totally multiplicative functions, Mobius function, the Mobius inversion formula, the greatest integer function, Euler's phi-function, Euler's theorem, 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. Pythagorean triple, primitive Pythagorean triple, Fermat's Last theorem.

Reference Books

►   David M. Burton, Elementary Number Theory, 6th Ed., Tata McGraw-Hill, Indian reprint, 2007.

►   Neville Robinns, Beginning Number Theory, 2nd Ed., Narosa Publishing House Pvt. Ltd., Delhi, 2007

3.8   DSE 3(b) – Rigid Dynamics

Objectives: Motion of a three dimensional body under various forces and situations have been discussed here. Students will learn to set up equations of motion and to solve different kinds of problems relating to dynamics of rigid bodies.

Rigid dynamics	
	6 Credits

Unit 1:

Momental ellipsoid. Equimomental system. Principal axis. D'Alembert's principle. D'Alembert's equations of motion. Principles of moments. Principles of conservations of linear and angular momentum. Independence of the motion of centre of inertia and the motion relative to the centre of inertia. Principle of energy. Principle of conservation of energy.

Unit 2:

Equation of motion of a rigid body about a fixed axis. Expression for kinetic energy and moment of momentum of a rigid body moving about a fixed axis. Compound pendulum. Interchange ability of the point of suspension and centre of oscillation. Minimum time of oscillation. Reaction of axis of rotation.

Unit 3:
Equations of motion of a rigid body moving in two dimensions. Expression for kinetic energy and angular momentum about the origin of a rigid body moving in two dimensions. Two dimensional motion of a solid of revolution down a rough inclined plane. Necessary and sufficient condition for pure rolling. Two-dimensional motion of a solid of revolution moving on a rough horizontal plane.
Unit 4
Equations of motion under impulsive forces. Equation of motion about a fixed axis under impulsive forces Centre of percussion. To show that (i) if there is a definite straight line such that the sum of the moments of the external impulses acting on a system of particles about it vanishes, then the total angular momentum of the system about that line remains unaltered, (ii) the change of K.E.. system of particles moving in any manner under the application of impulsive forces is equal to the work done by the impulsive forces applied to a rigid body moving in two dimensions.
Reference Books

- ► S.Mollah, Dynamics of Rigid Bodies

- ► S.L.Loney, Dynamics of a Particle and of Rigid Bodies, Cambridge University Press, Indian

    Edition , Radha Publishing House

3.9   DSE 3(c) – Differential Geometry

Objectives: Primary concepts of space curves, planar curves, torsion, Serret-Frenet Formula, theory of surfaces, developables and geodesics are the key concern of this course.

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

- ► T.J. Willmore, An Introduction to Differential Geometry, Dover Publications, 2012.

- B. O'Neill, Elementary Differential Geometry, 2nd Ed., Academic Press, 2006.
- C.E. Weatherburn, Differential Geometry of Three Dimensions, Cambridge University Press2003.
- 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

3.10   DSE 4(a) – Boolean Algebra and Discrete Mathematics

Objectives: Preliminary idea about Boolean algebra and its implementation to modern day computers have been discussed here. Also, foundations of discrete Mathematics have been introduced in this course.

Boolean Algebra and Discrete Mathematics	
	6 Credits

Unit 1

Boolean Algebra: Huntington postulates for Boolean algebra, Algebra of sets and switching algebra as examples of Boolean Algebra, duality principle, Boolean functions, Normal forms, minimal and maximal forms of Boolean polynomials .

Unit 2

Karnaugh maps, Design of switching circuits, Logic gates.

Unit 3

Discrete Mathematics: Principle of inclusion and exclusion, Pigeon-hole principle, Finite combinatorics, Generating functions, Partitions, Recurrence relations, Linear difference equations with constant coefficients.

Unit 4

Partial and linear orderings, Chains and anti-chains, Lattices, Distributive lattices, Complementation, sub-lattices, products and homomorphisms.

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. G. Chakraborty and P. R. Ghosh, Advanced Higher Algebra, U. N. Dhur and Sons.

| ► | M. Morris Mano, Digital Logic and Computer Design, Prentice Hall of India,1998 |

3.11 DSE 4(b) – Analytical Statics

Objectives: Basic concepts of analytical statics like centre of gravity, principle of virtual work, stable and unstable equilibrium and three dimensional forces has been introduced. Different real world problems in statics have also been discussed.

Analytical statics	
	6 Credits

Unit 1

Definition of Center of Gravity (C.G.). General formula for the determination of C.G. Determination of C.G. of any arc, area of solid of known shape by method of integration.
Astatic equilibrium , astatic center, positions of equilibrium of a particle lying on a smooth plane curve under the action of given forces. Action at a joint in a frame work.

Unit 2

Virtual Work: Principle of virtual work for a single particle. Deduction of the conditions for equilibrium of a particle under coplanar forces from the principle of virtual work. The principle of virtual work for a rigid body. Forces which do not appear in the equation of virtual work. Forces which appear in the equation of virtual work. The principle of virtual work for any system of coplanar forces acting on a rigid body. Converse of the principle of virtual work.

Unit 3

Stable and unstable equilibrium. Co-ordinates of a body and of a system of bodies. Degree of freedom. Field of forces. Conservative field. Potential energy of a system. The energy test of stability. Condition for stability of equilibrium of a perfectly rough heavy body lying on fixed body.

Unit 4

Forces in the three dimensions. Moment of a force about a line. Axis of a couple. Resultant of any two couples acting on a body. Resultant of any number of couples acting on a rigid body. Reduction of a system of forces acting on a rigid body. Resultant forces in an invariant of a system but the resultant couple is not an invariant. Conditions for equilibrium of a system of forces acting on a body. Deductions of the conditions for equilibrium of a system of forces acting on a rigid body from the principle of virtual work. Poinsot's central axis. A given system of forces can have only one central axis. Condition that a given system of forces may have a single resultant. Invariant of a given system of forces. Equation of the central axis of a given system of forces.

Reference Books

►	M.C.Ghosh, Analytical Statics, Shreedhar Prakashani.
►	S.A.Mollah, Analytical Statics, Books & Allied.
►	B.C.Das & B.N.Mukherjee, Statics, U.N.Dhur and Sons.
►	S.L.Loney, Statics, Cambridge University Press, Indian Edition-Raddha Publishing House.

►   Sukumar Mondal, Advanced Analytical Statics, U.N.Dhur and Sons.

3.12   DSE 4(c) – Cryptography

Objectives: Basic concepts, techniques and different algorithms of cryptography have been introduced. Also, the student shall learn the applications of cryptography in different fields .

Cryptography	
	6 Credits

Unit 1

Basic concepts & techniques, plaintext & cipher text, substitution techniques, transposition techniques, encryption & decryption, symmetric & asymmetric key cryptography, key range & key size.

Unit 2

Symmetric key algorithm, algorithm types & modes, overview of symmetric key cryptography, DES(data encryption standard) algorithm, IDEA(international data encryption algorithm) algorithm, RC5algorithm.

Unit 3

Asymmetric key algorithm, digital signature and RSA introduction, overview of asymmetric key cryptography, RSA algorithm, symmetric & asymmetric key cryptography together, digital signature, RSA signature schemes, knapsack problem.

Unit 4

Introduction to elliptic curves, group structure, rational points on elliptic curves, elliptic curve cryptography, applications in cryptography and factorization, known attacks.

Reference Books

►   N. Koblitz, A Course in Number Theory and Cryptography, Springer 2006.

►   C. Washington, Elliptic curves: number theory and cryptography, Chapman & Hall/CRC, 2003.

►   J. Silverman and J. Tate, Rational Points on Elliptic Curves, Springer-Verlag, 2005.

►   G.A. Jones and J.M. Jones, Elementary Number Theory, Springer-Verlag, 1998.

►   R.A. Mollin, An Introduction to Cryptography, Chapman & Hall, 2001.

4. Skill Enhancement Subjects Syllabus

4.1 SEC 1(a)–Logic and Sets

Objectives: Introduction of logic and sets has been discussed. Students will learn about truth table, different propositions, predicates and quantifiers, various operations between two sets and logical equivalences etc in this course.

Logic and Sets	
	2 Credits
Unit 1	
Introduction, propositions, truth table, negation, conjunction and disjunction. Implications, biconditional propositions, converse, contra positive and inverse propositions and precedence of logical operators. Propositional equivalence: Logical equivalences. Predicates and quantifiers: Introduction, quantifiers, binding variables and negations.	
Unit 2	
Sets, subsets, set operations and the laws of set theory and Venn diagrams. Examples of finite and infinite sets. Finite sets and counting principle. Empty set, properties of empty set. Standard set operations. classes of sets. Power set of a set.	
Unit 3	
Difference and Symmetric difference of two sets. Set identities, generalized union and intersections. Relation: Product set. Composition of relations, types of relations, partitions, equivalence Relations with example of congruence modulo relation. Partial ordering relations, n-ary relations.	
Reference Books	
► R.P. Grimaldi, Discrete Mathematics and Combinatorial Mathematics, Pearson Education, 1998. ► P.R. Halmos, Naive Set Theory, Springer, 1974. ► E. Kamke, Theory of Sets, Dover Publishers, 1950.	

4.2 SEC 1(b) – Computer Graphics

Objectives: Development of computer graphics, various graphic storage, definitions of points, line and curves, coordinate system and linear transformations etc will be studied here.

Computer Graphics	
	2 Credits

Unit 1
Development of computer Graphics: Raster Scan and Random Scan graphics storages, displays processors and character generators, colour display techniques, interactive input/output devices.
Unit 2
Points, lines and curves: Scan conversion, line-drawing algorithms, circle and ellipse generation, conic-section generation, polygon filling anti-aliasing.
Unit 3
Two-dimensional viewing: Coordinate systems, linear transformations, line and polygon clipping algorithms.
Reference Books
► D. Hearn and M.P. Baker, Computer Graphics, 2nd Ed., Prentice–Hall of India, 2004.
► J.D. Foley, A van Dam, S.K. Feiner and J.F. Hughes, Computer Graphics: Principals andPractices, 2nd Ed., Addison-Wesley, MA, 1990.
► D.F. Rogers, Procedural Elements in Computer Graphics, 2nd Ed., McGraw Hill BookCompany, 2001.
► D.F. Rogers and A.J. Admas, Mathematical Elements in Computer Graphics, 2nd Ed.,McGraw Hill Book Company, 1990.

4.3   SEC 1(c) – Object Oriented Programming in C++

Objectives: The basic characteristics of object oriented programming languages, different components and structures in C++ programming language will be discussed in this course.

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

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

4.4　　　　SEC 2(a) – Graph Theory

Objectives: Basic concepts of graphs, Eulerian circuits, Eulerian graphs, Hamiltonian cycles, representation of a graph by matrix etc. has been introduced in this course. Also, students shall learn the different applications of 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 UniversityPress, Cambridge, 1990.
- ► Edgar G. Goodaire and Michael M. Parmenter, Discrete Mathematics with Graph Theory, 2ndEdition, Pearson Education (Singapore) P. Ltd., Indian Reprint 2003.
- ► Rudolf Lidl and Gunter Pilz, Applied Abstract Algebra, 2nd Ed., Undergraduate Texts inMathematics, Springer (SIE), Indian reprint, 2004.
- ► Narsingh Deo, Graph Theory with Applications to Engineering and Computer Science, Prentice-Hall of India Pvt. Ltd., New Delhi.

4.5   SEC 2(b) – Operating System: Linux

Objectives: Linux is all that will be discussed in this course. It's history, features, usefulness and limitations will be the main agenda in this course.

Operating System: 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.

4.6   SEC 2(c) – Econometrics

Objectives: Econometrics has been introduced in this course of study. Different statistical distributions, regression models and testing of hypothesis will be learnt by the students.

Econometrics	
	2 Credits

Unit 1
Statistical Concepts of Normal distribution; chi-square, t and F-distributions; estimation of parameters; properties of estimators; testing of hypothesis: defining statistical hypotheses; distributions of test statistics; testing hypotheses related to population parameters; Type I and Type II errors; power of a test; tests for comparing parameters from two samples.

Unit 2
Simple Linear Regression Model: Two Variable Case Estimation of model by method of ordinary least squares; properties of estimators; goodness of fit; tests of hypotheses; scaling and units of measurement; confidence intervals; Gauss-Markov theorem; forecasting.

Unit 3
Multiple Linear Regression Model Estimation of parameters; properties of OLS estimators; goodness of fit - R2 and adjusted R2 ; partial regression coefficients; testing hypotheses – individual and joint; functional forms of regression models; qualitative (dummy) independent variables.

Reference Books
1. Jay L. Devore, Probability and Statistics for Engineers, Cengage Learning, 2010.   2. John E. Freund, Mathematical Statistics, Prentice Hall, 1992.   3. Richard J. Larsen and Morris L. Marx, An Introduction to Mathematical Statistics and its Applications, Prentice Hall, 2011.   4. D. N. Gujarati and D.C. Porter, Essentials of Econometrics, McGraw Hill, 4th Ed., International Edition, 2009.   5. Christopher Dougherty, Introduction to Econometrics, Oxford University Press, 3rd Ed., Indian edition, 2007.

5. Generic Elective (GE) Subjects Syllabus

5.1   GE 1(a)/3(a): Differential Calculus

Objectives: This course will help students to understand limit, continuity, differentiability, partial differentiation, mean value theorems, maxima and minima, indeterminate forms etc. Various applications of calculus shall also be discussed.

Differential Calculus	
	6 Credits
Unit 1	
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.	
Unit 2	

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

Unit 3

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, $log(l + x)$, $(l + x)^m$, Maxima and Minima, Indeterminate forms.

Reference Books

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.

5.2   GE 1(b)/3(b): Real Analysis

Objectives: Students will be able to understand about sets in R, sequences, series of functions and infinite series etc in this course.

Real Analysis	
	6 Credits
Unit 1	
Finite and infinite sets, examples of countable and uncountable sets. Real line, bounded sets, suprema and infima, completeness property of R, Archimedean property of R, intervals. Concept of cluster points and statement of Bolzano-Weierstrass theorem.	
Unit 2	
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).	
Unit 3	
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.	
Unit 4	
Sequences and series of functions, Pointwise and uniform convergence. Mn-test, M-test, Statements of the results about uniform convergence and integrability and differentiability of functions, Power series and radius of convergence.	
Reference Books	
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.	

5.3   GE 2(a)/4(a): Differential Equations

Objectives: The basics of ordinary and partial differential equations have been introduced in this course. Various methods to find the solutions of ordinary and partial differential equations and the classification of second order partial differential equation shall be discussed.

Differential Equations	
	6 Credits
Unit 1	
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.	
Unit 2	
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.	
Unit 3	
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.	
Unit 4	
Classification of second order partial differential equations into elliptic, parabolic and hyperbolic through illustrations only.	
Reference Books	
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.	

5.4   GE 2(b)/4(b) : Algebra

Objectives: Basic concepts of different types of groups, rings and field shall be discussed through a large number of examples in this course of study.

Algebra	
	6 Credits
Unit 1	
Definition and examples of groups, examples of abelian and non-abelian groups, the group Zn 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 GLn (n,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.	

Unit 2

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.

Unit 3

Definition and examples of rings, examples of commutative and non-commutative rings: rings from number systems, Zn 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: Zp, 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*, Narosa, 1999.
4. George E Andrews, *Number Theory*, Hindustan Publishing Corporation, 1984.