Syllabus

Mathematics (Honours)

Version 2

submitted to

Gauhati University

under the

Choice Based Credit System

By

Department of Mathematics

Gauhati University

"This is approved in the Academic Council held on 08/11/2019"

1. Introduction to CHOICE BASED CREDIT SYSTEM (CBCS):

The CBCS provides an opportunity for the students to choose courses from the prescribed courses comprising core, elective/minor or skill based courses. The courses can be evaluated following the grading system, which is considered to be better than the conventional marks system. Therefore, it is necessary to introduce uniform grading system in the entire higher education in India. This will benefit the students to move across institutions within India to begin with and across countries. The uniform grading system will also enable potential employers in assessing the performance of the candidates. In order to bring uniformity in evaluation system and computation of the Cumulative Grade Point Average (CGPA) based on student's performance in examinations, the UGC has formulated the guidelines to be followed.

2. Outline of Choice Based Credit System:

2.1 Core Course: A course, which should compulsorily be studied by a candidate as a core requirement is termed as a Core course.

2.2 Elective Course: Generally a course which can be chosen from a pool of courses and which may be very specific or specialized or advanced or supportive to the discipline/ subject of study or which provides an extended scope or which enables an exposure to some other discipline/subject/domain or nurtures the candidate's proficiency/skill is called an Elective Course.

2.2.1 Discipline Specific Elective (DSE) Course: Elective courses may be offered by the main discipline/subject of study is referred to as Discipline Specific Elective. The University/Institute may also offer discipline related Elective courses of interdisciplinary nature (to be offered by main discipline/subject of study).

2.2.2 Dissertation/Project: An elective course designed to acquire special/advanced knowledge, such as supplement study/support study to a project work, and a candidate studies such a course on his own with an advisory support by a teacher/faculty member is called dissertation/project.

2.2.3 Generic Elective (GE) Course: An elective course chosen generally from an unrelated discipline/subject, with an intention to seek exposure is called a Generic Elective.P.S.: A core course offered in a discipline/subject may be treated as an elective by other discipline/subject and vice versa and such electives may also be referred to as Generic Elective.

3. Ability Enhancement Courses (AEC)/Competency Improvement Courses/Skill Development Courses/Foundation Course: The Ability Enhancement (AE) Courses may be of two kinds: AE Compulsory Course (AECC) and AE Elective Course (AEEC). "AECC" courses are the courses based upon the content that leads to Knowledge enhancement. They are

((i) Environmental Science(ii) English/MIL Communication) are mandatory for all disciplines. AEEC courses are value-based and/or skill-based and are aimed at providing hands-on-training, competencies, skills, etc.

3.1 AE Compulsory Course (AECC): Environmental Science, English Communication/MIL Communication.

3.2 AE Elective Course (AEEC): These courses may be chosen from a pool of courses designed to provide value-based and/or skill-based instruction.

Project work/Dissertation is considered as a special course involving application of knowledge in solving / analyzing /exploring a real life situation / difficult problem. A Project/Dissertation work would be of 6 credits. A Project/Dissertation work may be given in lieu of a discipline specific elective paper.

4. BACHELOR OF MATHEMATICS (Hons.) Programme Details:

4.1. Programme Objectives:

Students who choose BMATH(H) Programme, develop the ability to think critically, logically and analytically and hence use mathematical reasoning in everyday life.

Pursuing a degree in mathematics will introduce the students to a number of interesting and useful ideas in preparations for a number of mathematics careers in education, research, government sector, business sector and industry.

The program covers the full range of mathematics. The course lays a structured foundation of Calculus, Real and Complex analysis, Algebra, Differential equations and Mathematical modelling, Number theory, Graph theory, Mechanics and C-programming.

An exceptionally broad range of topics covering Pure and Applied Mathematics:Linear Algebra, Metric spaces, Statistics, Linear Programming and Applications, Mathematical Finance, and Bio-Mathematics cater to varied interests and ambitions.Also, to carry out the hand on sessions in Computer lab using various CAS software to have a deep conceptual understanding of the above tools to widen the horizon of students' self-experience.

4.2. Programme Learning Outcomes: The completion of the BMATH(H) Programme shall enable a student to:

i) Communicate mathematics effectively by oral, written, computational and graphic means.
ii) Create mathematical ideas from basic axioms.
iii) Gauge the hypothesis, theories, techniques and proofs provisionally.
iv) Utilize mathematics to solve theoretical and applied problems by critical understanding, analysis and synthesis.
v) Identify applications of mathematics in other disciplines and in the real world, leading to enhancement of career prospects in a plethora of fields.
vi) Appreciate the requirement of lifelong learning through continued education and research.

4.3. Programme Structure: The BMATH(H) programme is a three-year course divided into six-semesters. A student is required to complete 148 credits for the completion of course and the award of degree.

		Semester	***Semester***
Part – I	First Year	Semester I : 22	Semester II: 22
Part – II	Second Year	Semester III: 28	Semester IV: 28
Part – III	Third Year	Semester V: 24	Semester VI: 24

4.4. Programme Implementation Requirement:

The BMATH(H) programme is a three-year course divided into six-semesters. For proper implementation of the UGCBCS programme the following infrastructure are necessary:

(a) Sufficient lab facilities with computers and software
(b) Atleast 7 faculties for Honours and5 faculties without Honours.

4.5.Instruction for questions paper setter: Question Paper setter should set from the prescribed text books,mentioned in the syllabus.

5. Credit allocation (B.Sc. Honours):

Course	*Credits	
	Theory+Practical	Theory+Tutorial
I Core Course (6 credits)		
(14 papers)	14X4=56	14x5=70
Core Course Practical / Tutorial* (14 Papers)	14x2=28	14x1=14
I. Elective Course (6 credits) (8 Papers)		
A.1. Discipline Specific Elective(4 Papers)	4x4=16	4x5=20
A.2. Discipline Specific Elective Practical/ Tutorial* (4 Papers)	4×2 = 8	4×1 = 4
B.1. Generic Elective/ Interdisciplinary(4 Papers)	4x4=16	4x5=20
B.2. Generic Elective Practical/ Tutorial* (4 Papers)	4x2=8	4x1=4
Optional dissertation or project work in place of one Discipline Specific Elective paper (6 credits) in 6th semester		
1.Ability Enhancement Compulsory Courses (AECC) (2 Papers of 4 credit each)	2x4=4	2x4=8
Environmental Science		
English Communication		
2. Skill Enhancement Courses (SEC)(Minimum 2)(2 Papers of 4 credit each)	2x4=8	2x4=8
Total credit	148	148

*Wherever there is practical, there will be no tutorial and vice-versa

CBCS Course Structure for B.Sc. (Hons.) Mathematics Programme
SEMESTER WISE PLACEMENT OF THE COURSES

Sem	Core Course(14)	Ability Enhancement Compulsory Course (AECC)(2)	Skill Enhancement Course (SEC)(2)	Discipline SpecificElective (DSE)(4)	GenericElective(GE)(4) (Otherthan Mathematics Honours)
I	MAT-HC-1016: Calculus(including practical) MAT-HC-1026: Algebra	ENG-AE-1014			MAT-HG-1016 / MAT-RC-1016 MAT-HG 1026
II	MAT-HC-2016: Real Analysis MAT-HC-2026: Differential Equations(including practical)	ENV-AE-2014			MAT-HG-2016 / MAT-RC-2016 MAT-HG-2026
III	MAT-HC-3016: Theory of Real Functions MAT-HC-3026: Group Theory-I MAT-HC-3036: Analytical Geometry		MAT-SE-3014 MAT-SE-3024		MAT-HG-3016 / MAT-RC-3016 MAT-HG-3026
IV	MAT-HC-4016:Multivariate Calculus MAT-HC-4026: Numerical Methods (including practical) MAT-HC-4036: Ring Theory		MAT-SE-4014 MAT-SE-4024		MAT-HG-4016 / MAT-RC-4016 MAT-HG-4026
V	MAT-HC-5016: Riemann Integration and Metric spaces MAT-HC-5026: Linear Algebra			DSE-1 MAT-HE-5016 MAT-HE-5026 MAT-HE-5036 DSE-2 MAT-HE-5046 MAT-HE-5056 MAT-HE-5066	
VI	MAT-HC-6016: Complex Analysis MAT-HC-6026: Partial Differential Equations (including practical)			DSE-3 MAT-HE-6016 MAT-HE-6026 MAT-HE-6036 MAT-HE-6046 DSE-4 MAT-HE-6056 MAT-HE-6066 MAT-HE-6076 Project In lieu of DSE-3 and DSE-4	

Legends:HC: Core Papers HE: Discipline Specific Elective Papers

SE: Skill Enhancement PapersHG: Generic Elective Papers

Core Papers:

1. MAT-HC-1016: Calculus (including practical)
2. MAT-HC-1026: Algebra
3. MAT-HC-2016: Real Analysis
4. MAT-HC-2026: Differential Equations(including practical)
5. MAT-HC-3016: Theory of Real Functions
6. MAT-HC-3026: Group Theory-I
7. MAT-HC-3036: Analytical Geometry
8. MAT-HC-4016:Multivariate Calculus
9. MAT-HC-4026: Numerical Methods (including practical)
10. MAT-HC-4036: Ring Theory
11. MAT-HC-5016: Riemann Integration and Metric spaces
12. MAT-HC-5026: Linear Algebra
13. MAT-HC-6016: Complex Analysis
14. MAT-HC-6026: Partial Differential Equations (including practical)

Skill Enhancement Course (SEC) papers

SEC 1(choose one)

(i) MAT-SE-3014: Computer Algebra Systems and Related Software
(ii) MAT-SE-3024: Combinatorics and Graph Theory

SEC 2 (choose one)

(i) MAT-SE-4014: R-Programming
(ii) MAT-SE-4024: LATEX and HTML

Discipline Specific Electives (DSE) papers

DSE 1 (choose one)

(i) MAT-HE-5016: Number Theory
(ii) MAT-HE-5026: Mechanics
(iii) MAT-HE-5036: Probability and Statistics

DSE 2 (choose one)

(i) MAT-HE-5046: Linear Programming
(ii) MAT-HE-5056: Spherical Trigonometry and Astronomy
(iii) MAT-HE-5066: Programming in C

DSE-3 (choose one)

(i) MAT-HE-6016: Boolean Algebra and Automata Theory
(ii) MAT-HE-6026: Bio-Mathematics
(iii) MAT-HE-6036: Mathematical Modeling
(iv) MAT-HE-6046: Hydromechanics

DSE 4 (choose one)

(i) MAT-HE-6056: Rigid Dynamics
(ii) MAT-HE-6066: Group Theory II
(iii) MAT-HE-6076: Mathematical Finance

Project (in lieu of DSE3 and DSE4)

Generic Elective (GE) papers

GE 1 (choose one)
(i). MAT-HG-1016/MAT-RC-1016: Calculus
(ii). MAT-HG-1026: Analytic Geometry

GE 2 (Choose one)
(i). MAT-HG-2016/MAT-RC-2016: Algebra
(ii). MAT-HG-2026: Discrete Mathematics

GE 3 (choose one)
(i). MAT-HG-3016/MAT-RC-3016: Differential Equations
(ii). MAT-HG-3026: Linear Programming

GE 4 (choose one)
(i). MAT-HG-4016/MAT-RC-4016: Real Analysis
(ii). MAT-HG-4026: Numerical Analysis

Detailed Syllabus

SEMESTER-I

MAT-HC-1016: Calculus (including practical)

Total marks: 100 (Theory: 60, Practical 20, Internal Assessment: 20)

Lectures 2 Practical, Credits 6 (4+2) *Each unit carry equal credit*

Course Objectives: The primary objective of this course is to introduce the basic tools of calculus and geometric properties of different conic sections which are helpful in understanding their applications in planetary motion, design of telescope and to the real world problems. Also, computer lab will help to have a deep conceptual understanding of the above tools in true sense.

Course Learning Outcomes: This course will enable the students to:
i) Learn first and second derivative tests for relative extremum and apply the knowledge in problems in business, economics and life sciences.
ii) Sketch curves in a plane using its mathematical properties in different coordinate systems.
iii) Compute area of surfaces of revolution and the volume of solids by integrating over cross-sectional areas.
iv) Understand the calculus of vector functions and its use to develop the basic principles of planetary motion.

UNIT 1: 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, asymptotes, curve tracing in Cartesian coordinates, tracing in polar coordinates of standard curves, L'Hopital's rule, applications in business, economics and life sciences.

[1]: Chapter 4 (Sections 4.3-4.7).
[2]: Chapter 6 (Section 6.1-6.8), Chapter 10 (Section 10.1-10.6).

UNIT 2: Reduction formulae, derivations and illustrations of reduction formulae of the type $\int \sin^n x\,dx$, $\int \cos^n x\,dx$, $\int \tan^n x\,dx$, $\int \sec^n x\,dx$, $\int (\log x)^n\,dx$, $\int \sin^n x \cos^m x\,dx$, volumes by slicing, disks and washers methods, volumes by cylindrical shells, parametric equations, parameterizing a curve, arc length, arc length of parametric curves, area of surface of revolution.

[1]: Chapter 9 (Sections 9.4).
[2]: Chapter 7 (Sections 7.1-7.5), Chapter 5 (Section 5.1-5.5 (excluding arc length by numerical methods))

UNIT 3: Triple product, introduction to vector functions, operations with vector-valued functions, limits and continuity of vector functions, differentiation and integration of vector functions, tangent and normal components of acceleration, modelling ballistics and planetary motion, Kepler's second law.

[1] Chapter 9 (Section 9.3), Chapter 10

Practical / Lab work to be performed on a computer:
List of the practical to be done using Matlab / Mathematica / Maple / Scilab / Maxima etc.

(i). Plotting the graphs of the following functions: ax, $[x]$ (greatest integer function),
$\sqrt{ax+b}, |ax+b|, c \pm |ax+b|, x^{\pm n}, x^{1/n}, n \in Z$
$|x|/x$, $\sin(1/x)$, $x\sin(1/x)$, and , $e^{\pm 1/x}$ for $x \neq 0$.
e^{ax+b}, $\log(ax+b)$, $1/(ax+b)$, $\sin(ax+b)$, $\cos(ax+b)$, $|\sin(ax+b)|$, $|\cos(ax+b)|$.
Observe and discuss the effect of changes in the real constants a, b and c on the graphs.

(ii). Plotting the graphs of polynomial of degree 4 and 5, the graphs of their first andsecond derivatives, and analysis of these graphs in context of the concepts covered in Unit 1.

(iii). Sketching parametric curves, e.g., Trochoid, Cycloid, Epicycloid and Hypocycloid.

(iv). Tracing of conic in cartesian coordinates.

(v). Obtaining surface of revolution of curves.

(vi). Graph of hyperbolic functions.

(vii). Computation of limit, Differentiation, Integration and sketching of vector-valued functions.

(viii). Complex numbers and their representations, Operations like addition, Multiplication, Division, Modulus. Graphical representation of polar form.

(ix). Find numbers between two real numbers and plotting of finite and infinite subset of R

Text Books:

1. M. J. Strauss, G. L. Bradley and K. J. Smith, Calculus (3rd Edition), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2007.
2. H. Anton, I. Bivens and S. Davis, Calculus (10th Edition), John Wiley and sons (Asia), Pt Ltd., Singapore, 2011.

MAT-HC-1026:Algebra

Total marks: 100(Theory: 80 Internal Assessment: 20)

Per week:5 Lectures 1 Tutorial, Credits 6,*Each unit carry equal credit*

Course Objectives: The primary objective of this course is to introduce the basic tools of set theory, functions, induction principle, theory of equations, complex numbers, number theory, matrices and determinant to understand their connection with the real-world problems.

Course Learning Outcomes: This course will enable the students to:

i) Employ De Moivre's theorem in a number of applications to solve numerical problems.

ii) Learn about equivalent classes and cardinality of a set.

iii) Use modular arithmetic and basic properties of congruences.

iv) Recognize consistent and inconsistent systems of linear equations by the row echelon form of the augmented matrix.

v) Learn about the solution sets of linear systems using matrix method and Cramer's rule

UNIT-1: Polar representation of complex numbers, nth roots of unity, De Moivre's theorem for rational indices and its applications.

[1]: Chapter 2

UNIT-2: Statements and logic, statements with quantifier, compound statements, implications, proofs in Mathematic; Sets, operations on sets, family of sets, power sets, Cartesian product; Functions, one-one, onto functions and bijections, Composition of functions, Inverse of a function, Image and Inverse image of subsets; Relation, Equivalence relations, Equivalence classes and partitions of a set, congruence modulo n in integers; Induction Principles, the well-ordering principle, greatest common divisor of integers.

[2] Chapters 1 – 5.

UNIT 3: Systems of Linear Equations, row reduction and echelon forms, vector equations, the matrix equation Ax =b, solution sets of linear systems, linear independence, introduction to linear transformations, the matrix of a linear transformation; Matrix operations, inverse of a matrix, characterizations of invertible matrices; Determinants, Cramer's rule

[3]: Chapter 1 (Sections 1.1 – 1.9); Chapter 2 (Sections, 2.1 – 1.3); Chapter 3 (Sections 3.1 – 3.3)

Text Books:

1. TituAndreescu and DorinAndrica, Complex Numbers from A to …. Z, Birkhauser, 2006.
2. A. Kumar, S. Kumaresan and B.K. Sarma, A Foundation Course in Mathematics, Narosa, 2018.
3. David C. Lay, Linear Algebra and its Applications (3rd Edition), Pearson Education Asia, Indian

Reprint, 2007.

Reference Books:

1. S. Barnard and J.M. Child, Higher Algebra, Arihant, 2016.
2. Edgar G. Goodaire and Michael M. Parmenter, Discrete Mathematics with Graph Theory (3rd Edition), Pearson Education (Singapore) Pvt. Ltd., Indian Reprint, 2005.
3. Gilbert Strang, Linear Algebra and its Applications, Thomson, 2007.

GENERIC ELECTIVE PAPERS

MAT-HG-1016/ MAT-RC-1016:Calculus

Total Marks: 100(Theory: 80, Internal Assessment: 20)
Per week: 5 Lectures, 1 Tutorial Credits**:** 6,*Each unit carry equal credit*

Course Objectives: Calculus is referred as 'Mathematics of change' and is concerned with describing the precise way in which changes in one variable relate to the changes in another. Through this course, students can understand the quantitative change in the behaviour of the variables and apply them on the problems related to the environment.

Course Learning Outcomes: The students who take this course will be able to:
i) Understand continuity and differentiability in terms of limits.
ii) Describe asymptotic behavior in terms of limits involving infinity.
iii) Use derivatives to explore the behavior of a given function, locating and classifying its extrema, and graphing the function.
iv) Understand the importance of mean value theorems.

Unit 1: Graphs of simple concrete functions such as polynomial, Trigonometric, Inverse trigonometric, Exponential and logarithmic functions
[1] Chapter 1 (Sections 1.1 to 1.3), and Chapter 7 (Sections 7.2, 7.3, and 7.6)

Unit 2: Limits and continuity of a function including approach, Properties of continuous functions including Intermediate value theorem.
[2] Chapter 1

Unit 3: Differentiability, Successive differentiation, Leibnitz theorem, Recursion formulae for higher derivatives.
[2] Chapter 3 (Sections 3.2, 3.3, and 3.6), and Exercise 26, page 184.

Unit 4: Rolle's theorem, Lagrange's mean value theorem with geometrical interpretations and simple applications, Taylor's theorem, Taylor's series and Maclaurin's series, Maclaurin's series expansion of functions such as heir use in polynomial approximation and error estimation.
[1] Chapter 4 (Sections 4.2, and 4.3), [2] Chapter 9 (Sections 9.8, and 9.9)

Unit 5: Functions of two or more variables, Graphs and level curves of functions of two variables, Partial differentiation up to second order.
[2] Chapter 13 (Sections 13.1, and 13.3)

Text books:

1. Thomas, Jr. George B., Weir, Maurice D., & Hass, Joel (2014). *Thomas' Calculus* (13thed). Pearson Education, Delhi. Indian Reprint 2017.
2. Anton, Howard, Bivens, Irl, & Davis, Stephen (2013). *Calculus* (10th ed.). John Wiley & Sons Singapore Pte. Ltd. Reprint (2016) by Wiley India Pvt. Ltd. Delhi

MAT-HG-1026: Analytic Geometry

Total Marks: 100(Theory: 80, Internal Assessment: 20)
Per week: 5 Lectures, 1 Tutorial Credits**:** 6,*Each unit carry equal credit*

Course Objectives: The primary objective of this course is to introduce the basic tools of two dimensional coordinate systems, general conics, and three dimensional coordinates systems. Also, introduces the vectors in coordinate systems with geometrical properties

Course Learning Outcomes: This course will enable the students to:
i) Transform coordinate systems, conic sections
ii) Learn polar equation of a conic, tangent, normal and related properties
iii) Have a rigorous understanding of the concept of three dimensional coordinate systems
iv) Understand geometrical properties of dot product, cross product of vectors

UNIT 1: Transformation of coordinates, pair of straight lines. Parabola, parametric coordinates, tangent and normal, ellipse and its conjugate diameters with properties, hyperbola and its asymptotes, general conics: tangent, condition of tangency, pole and polar, centre of a conic, equation of pair of tangents, reduction to standard forms, central conics, equation of the axes, and length of the axes, polar equation of a conic, tangent and normal and properties.
[1] Chapter 3, 4, 10

UNIT 2: Three-Dimensional Space: Vectors
Rectangular coordinates in 3-space, Spheres and Cylindrical surfaces, Vector viewed geometrically,Vectors in coordinates system, Vectors determine by length and angle, Dot product, Cross product and their geometrical properties, Parametric equations of lines in 2-space and 3-space.
[1] Chapter 11 (11.1, 11.2, 11.3 to 11.5)

Text Books:

1. R. M. Khan, Analytical Geometry of two and three dimension and vector analysis. New Central Book agency 2012.
2. Anton, Howard, Bivens, Irl, & Davis, Stephen (2013). *Calculus* (10th ed.). John Wiley & Sons Singapore Pte. Ltd. Reprint (2016) by Wiley India Pvt. Ltd. Delhi.

Reference Book:
1. E. H. Askwith, The Analytical Geometry of the Conic Sections, Nabu Press (27 February 2012)
2. R. J. T. Bell, Coordinate Solid Geometry, Macmillan, 1983.

SEMESTER-II

MAT-HC-2016: Real Analysis

Total marks: 100(Theory: 80 Internal Assessment: 20)
Per week: 5 Lectures 1 Tutorial, Credits 6, *Each unit carry equal credit*

Course Objectives: The course will develop a deep and rigorous understanding of real line and of defining terms to prove the results about convergence and divergence of sequences and series of real numbers. These concepts have wide range of applications in real life scenario.

Course Learning Outcomes: This course will enable the students to:
i) Understand many properties of the real line *R*, including completeness and Archimedean properties.
ii) Learn to define sequences in terms of functions from *N* to a subset of *R*.
iii) Recognize bounded, convergent, divergent, Cauchy and monotonic sequences and to calculate their limit superior, limit inferior, and the limit of a bounded sequence.

iv) Apply the ratio, root, alternating series and limit comparison tests for convergence and absolute convergence of an infinite series of real numbers.

UNIT 1: Algebraic and order properties of R, absolute value and real line, bounded sets, supremum and infimum, completeness property of R, the Archimedean property, the density theorem, intervals, nested interval theorem.
[1] Chapter 2

UNIT-2: Real sequences, limit of a sequence, convergent sequence, bounded sequence, limit theorems, monotone sequences, monotone convergence theorem, subsequences, monotone subsequence theorem, Bolzano Weierstrass theorem for sequences, Cauchy sequences, Cauchy's convergence criterion, properly divergence sequences.
[1] Chapter 3

UNIT 3: Infinite series, convergence and divergence of infinite series, Cauchy criterion, Tests for convergence: comparison test, limit comparison test, ratio test, root test, integral test, Absolute convergence, rearrangement theorem, alternating series, Leibniz test, conditional (nonabsolute) convergence.
[1] Chapter 9 Sections 9.1-3.

Text Book:

1. R.G. Bartle and D. R. Sherbert, Introduction to Real Analysis, 3rd Ed., John Wiley and Sons, 2002.

Reference Books:

1. Gerald G. Bilodeau , Paul R. Thie, G.E. Keough, *An Introduction to Analysis,* Jones & Bartlett, Second Edition, 2010.
2. A. Kumar and S. Kumaresan, *Basic Course in Real Analysis*, CRC Press, 2014.
3. K. A. Ross, Elementary Analysis: The Theory of Calculus, Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.

MAT-HC-2026: Differential Equations(including practical)

Total Marks: 100: (Theory 60, Practical 20, Internal assessment 20)
Per week: 4 Lectures 2 Practical, Credits 6(4+2)*Each unit carry equal credit*

Course Objectives: The main objective of this course is to introduce the students to the exciting world of differential equations, mathematical modeling and their applications.

Course Learning Outcomes: The course will enable the students to:
i) Learn basics of differential equations and mathematical modeling.
ii) Formulate differential equations for various mathematical models.
iii) Solve first order non-linear differential equations and linear differential equations of higher order using various techniques.
iv) Apply these techniques to solve and analyze various mathematical models.

UNIT 1: 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.
[2] Chapter 1 (Sections 1.1, and 1.6), [3] Chapter 2, [2] Chapter 1 (Section 1.4, pages 35 to 38), and Chapter 2 (Section 2.3). [3] Chapter 3 (Section 3.3, A and B with Examples 3.8, 3.9)

UNIT 2: Introduction to compartmental model, exponential decay model, exponential growth of population, limited growth of population, limited growth with harvesting.
[1] Chapter 2 (Sections 2.1, 2.5, and 2.6), [1] Chapter 2 (Sections 2.7, and 2.8), [1] Chapter 3 (Sections 3.1 to 3.3)

UNIT 3: 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.
[2] Chapter 3 (Sections 3.1 to 3.3, Sections 3.4 (pages 172 to 177), and 3.5), [1] Chapter 5 (Sections 5.1, 5.2, 5.4, and 5.9), and Chapter 6 (Sections 6.1 to 6.4).

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).

Text Books:

1. Barnes, Belinda &Fulford, Glenn R. (2015). *Mathematical Modelling with Case Studies, Using* Maple *and* MATLAB (3rd ed.). CRC Press, Taylor & Francis Group.
2. Edwards, C. Henry, Penney, David E., &Calvis, David T. (2015). *Differential Equation and Boundary Value Problems*: *Computing and Modeling* (5th ed.). Pearson Education.
3. Ross, Shepley L. (2004). *Differential Equations* (3rd ed.). John Wiley & Sons. India

Reference Books:

1. Martha L Abell, James P Braselton, *Differential Equations with MATHEMATICA*, 3rd Ed., Elsevier Academic Press, 2004.
2. Ross, Clay C. (2004). *Differential Equations*: *An Introduction with Mathematica* (2nd ed.). Springer.

GENERIC ELECTIVE PAPERS

MAT-HG-2016/MAT-RC-2016: Algebra

Total Marks: 100(Theory: 80, Internal Assessment: 20)
Per week: 5 Lectures, 1 Tutorial Credits:6, *Each unit carry equal credit*

Course Objectives: The primary objective of this course is to introduce the basic tools of theory of equations, complex numbers, number theory, matrices, determinant, along with algebraic structures like group, ring and vector space to understand their connection with the real-world problems.

Course Learning Outcomes: This course will enable the students to:
i) Learn how to solve the cubic and biquadratic equations, also learn about symmetric functions of the roots for cubic and biquadratic
ii) Employ De Moivre's theorem in a number of applications to solve numerical problems.
iii) Recognize consistent and inconsistent systems of linear equations by the row echelon form of the augmented matrix. Finding inverse of a matrix with the help of Cayley-Hamilton theorem
iv) Recognize the mathematical objects that are groups, and classify them as abelian, cyclic and permutation groups, ring etc.
v) Learn about the concept of linear independence of vectors over a field, and the dimension of a vector space

Unit 1: Theory of Equations and Expansions of Trigonometric Functions:
Fundamental Theorem of Algebra, Relation between roots and coefficients of *n*th degree equation, Remainder and Factor Theorem, Solutions of cubic and biquadratic equations, when some conditions on roots of the equation are given, Symmetric functions of the roots for cubic and biquadratic; De Moivre's

theorem (both integral and rational index), Solutions of equations using trigonometry and De Moivre's theorem, Expansion for in terms of powers of in terms of cosine and sine of multiples of x.
[2] Chapter 3, 4 [3] Chapter 7 (Sections 7.6 and 7.7)

Unit 2: Matrices:
Types of matrices, Rank of a matrix, Invariance of rank under elementarytransformations, Reduction to normal form, Solutions of linear homogeneous and nonhomogeneous equations with number of equations and unknowns up to four; Cayley-Hamilton theorem, Characteristic roots and vectors.
[4] Chapter 3 (Sections 3.2, 3.5, and 3.7,Section 3.9)Chapter 2 (Sections 2.1 to 2.5)Chapter 7 (Section 7.1, and Example 7.2.2)

Unit 3: Groups, Rings and Vector Spaces:
Integers modulo n, Permutations, Groups, Subgroups, Lagrange's theorem, Euler's theorem, Symmetry Groups of a segment of a line, and regular n-gons for $n = 3, 4, 5$, and 6; Rings and subrings in the context of C[0,1] and Definition and examples of a vector space, Subspace and its properties, Linear independence, Basis and dimension of a vector space.
[1] Chapter 1 (Section 1.4), and Chapter 2 (Section 2.3)Chapter 3 (Sections 3.1, and 3.2)(Sections 3.2, 3.3, and 3.6) and Chapter 5 (Section 5.1)
[4] Chapter 4 (Sections 4.1, 4.3, and 4.4)

Text Books:

1. Beachy, John A., & Blair, William D. (2006). *Abstract Algebra* (3rd ed.). Waveland Press, Inc.
2. Burnside, William Snow (1979). *The Theory of Equations*, Vol. 1 (11th ed.) S. Chand & Co. Delhi. Fourth Indian Reprint.
3. Gilbert, William J., & Vanstone, Scott A. (1993). *Classical Algebra* (3rd ed.). Waterloo Mathematics Foundation, Canada.
4. Meyer, Carl D. (2000). *Matrix Analysis and Applied Linear Algebra*. Society for Industrial and Applied Mathematics (Siam).

Reference Books:

1. Dickson, Leonard Eugene (2009). *First Course in The Theory of Equations*. The Project Gutenberg EBook (http://www.gutenberg.org/ebooks/29785)
2. Gilbert, William J. (2004). *Modern Algebra with Applications* (2nd ed.). John Wiley & Sons.

MAT-HG-2026: Discrete Mathematics

Total Marks:100 (Theory: 80 Internal Assessment: 20)
Per week: 5 Lectures, 1 Tutorial, Credits:6, *Each unit carry equal credit*

Course Objectives: The course aims at introducing the concepts of ordered sets, lattices, sublattices and homomorphisms between lattices. It also includes introduction to modular and distributive lattices along with complemented lattices and Boolean algebra. Then some important applications of Boolean algebra are discussed in switching circuits.

Course Learning outcomes: After the course, the student will be able to:
i) Understand the notion of ordered sets and maps between ordered sets.
ii) Learn about lattices, modular and distributive lattices, sublattices and homomorphisms between lattices.
iii) Become familiar with Boolean algebra, Boolean homomorphism, Karnaugh diagrams, switching circuits and their applications.

Unit 1: Ordered Sets

Definitions, Examples and basic properties of ordered sets, Order isomorphism, Hasse diagrams, Dual of an ordered set, Duality principle, Maximal and minimal elements, Building new ordered sets, Maps between ordered sets.
[1] Chapter 1 (Sections 1.1 to 1.5 and 1.14 to 1.26, and 1.34 to 1.36)
[3] Chapter 1 [Section 1 (1.1 to 1.3)]

Unit 2: Lattices
Lattices as ordered sets, Lattices as algebraic structures, Sublattices, Products and homomorphisms; Definitions, Examples and properties of modular and distributive lattices, The M3 – N5 Theorem with applications, Complemented lattice, Relatively complemented lattice, Sectionally complemented lattice. homomorphisms.
[1] Chapter 2 (Sections 2.1 to 2.19)Chapter 4 (Sections 4.1 to 4.11)
[3] Chapter 1 [Section 1 (1.5 to 1.20)]Chapter 2 [Section 2 (2.1 to 2.14)]

Unit 3: Boolean Algebras and Switching Circuits
Boolean Algebras, De Morgan's laws, Boolean homomorphism, Representation theorem; Boolean polynomials, Boolean polynomial functions, Disjunctive normal form and conjunctive normal form, Minimal forms of Boolean polynomial, Quinn-McCluskey method, Karnaugh diagrams, Switching circuits and applications of switching circuits.
[3] Chapter 1 (Sections 3, 4 and 6) Chapter 2 (Sections 7 and 8).

Text Books:
1. Davey, B. A., & Priestley, H. A. (2002). *Introduction to Lattices and Order* (2nd ed.). Cambridge University press, Cambridge.
2. Goodaire, Edgar G., & Parmenter, Michael M. (2011). *Discrete Mathematics with Graph Theory* (3rd ed.). Pearson Education (Singapore) Pvt. Ltd. Indian Reprint.
3. Lidl, Rudolf & Pilz, Gunter. (2004). *Applied Abstract Algebra* (2nd ed.), Undergraduate Texts in Mathematics. Springer (SIE). Indian Reprint.

SEMESTER-III
MAT-HC-3016: Theory of Real Functions
Total Marks: 100(Theory 80 Internal assessment 20)
Per week: 5 Lectures 1 Tutorial, Credits,*Each unit carry equal credit*

Course Objectives: It is a basic course on the study of real valued functions that would develop an analytical ability to have a more matured perspective of the key concepts of calculus, namely; limits, continuity, differentiability and their applications

Course Learning Outcomes: This course will enable the students to:
i) Have a rigorous understanding of the concept of limit of a function.
ii) Learn about continuity and uniform continuity of functions defined on intervals.
iii) Understand geometrical properties of continuous functions on closed and bounded intervals.
iv) Learn extensively about the concept of differentiability using limits, leading to a better understanding for applications.
v) Know about applications of mean value theorems and Taylor's theorem

UNIT 1: Cluster point or limit point of a set, limits of a function (ε-δ approach), sequential criterion for limits, divergence criteria,limit theorems, one sided limits, infinite limits and limits at infinity.
[1] Chapter 4

UNIT 2: Continuous functions, sequential criterion for continuity and discontinuity,algebra of continuous functions,continuous functions on intervals, maximum-minimum theorem, intermediate value theorem, location of roots theorem, preservation of intervals theorem,uniform continuity, uniform continuity theorem.

[1] Chapter 5

UNIT 3: Differentiability of a function at a point and in an interval, Caratheodory's theorem, chain rule, derivative of inverse function, Rolle's theorem, mean value theorem, Darboux's theorem, Cauchy mean value theorem, L'Hospital's rules, Taylor's theorem and applications to inequalities, Taylor's series expansions of exponential and trigonometric functions, ln(1 + x), 1/(ax+b) and $(1+x)^n$.

[1] Chapter 6, and Taylor series as in Section 9.4.

Text Book:

1. R. Bartle and D.R. Sherbert, Introduction to Real Analysis, John Wiley and Sons, 2015.

Reference Books:

1. Ajit Kumar and S. Kumaresan, A Basic Course in Real Analysis, CRC Press, Indian Edn. 2014.
2. K.A. Ross, Elementary Analysis: The Theory of Calculus, Springer, 2004.
3. A.Mattuck, Introduction to Analysis, Prentice Hall, 1999.
4. S.R. Ghorpade and B.V. Limaye, A Course in Calculus and Real Analysis, Springer, 2006.

MAT-HC-3026: Group Theory - I

Total Marks: 100 (Theory 80 Internal assessment 20)

Per week 5 Lectures 1 Tutorial Credits,*Each unit carry equal credit*

Course Objectives: The objective of the course is to introduce the fundamental theory of groups and their homomorphisms. Symmetric groups and group of symmetries are also studied in detail. Fermat's Little theorem is studied as a consequence of the Lagrange's theorem on finite groups.

Course Learning Outcomes: The course will enable the students to:

i) Recognize the mathematical objects that are groups, and classify them as abelian, cyclic and permutation groups, etc.

ii) Link the fundamental concepts of groups and symmetrical figures.

iii) Analyze the subgroups of cyclic groups and classify subgroups of cyclic groups.

iv) Explain the significance of the notion of cosets, normal subgroups and factor groups.

v) Learn about Lagrange's theorem and Fermat's Little theorem.

vi) Know about group homomorphisms and group isomorphisms.

UNIT 1: Symmetries of a square, Dihedral groups, definition and examples of groups including permutation groups and quaternion groups (illustration through matrices), elementary properties of groups. Subgroups and examples of subgroups, centralizer, normalizer, center of a group, product of two subgroups. Properties of cyclic groups, classification of subgroups of cyclic groups.

[1]: Chapters 1, Chapter 2, Chapter 3 (including Exercise 20 on page 66 and Exercise 2 on page 86), Chapter 4.

UNIT 2: 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. External direct product of a finite number of groups, normal subgroups, factor groups, Cauchy's theorem for finite abelian groups.

[1]: Chapter 5 (till end of Theorem 5.7), Chapter 7 (till end of Theorem 7.2, including Exercises 6 and 7 on page 168), Chapter 8 (till the end of Example 2), Chapter 9 (till end of Example 10, Theorem 9.3 and 9.5).

UNIT 3: Group homomorphisms, properties of homomorphisms, Cayley's theorem, properties of isomorphisms, First, Second and Third isomorphism theorems.

[1]: Chapter 6 (till end of Theorem 6.2), Chapter 10.

Text Book:

1. Gallian, Joseph. A. (2013). *Contemporary Abstract Algebra* (8th ed.). Cengage Learning India Private Limited, Delhi. Fourth impression, 2015.

Reference Books:

1. John B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.
2. G. Santhanam, Algebra, Narosa Publishing House, 2017.
3. Joseph J. Rotman, An Introduction to the Theory of Groups, 4th Ed., Springer Verlag, 1995.
4. David S. Dummit and Richard M. Foote, Abstract Algebra (2nd Edition), John Wiley and Sons (Asia) Pvt. Ltd, Singapore, 2003.

MAT-HC-3036: Analytical Geometry

Total Marks: 100: (Theory 80, Internal assessment 20)

Per week: 5 Lectures 1 Tutorial Credits 6,*Each unit carry equal credit*

Course Objectives: The primary objective of this course is to introduce the basic tools of two dimensional coordinates systems, general conics, and three dimensional coordinate systems.

Course Learning Outcomes: This course will enable the students to:

i) Learn conic sections and transform co-ordinate systems
ii) Learn polar equation of a conic, tangent, normal and properties
iii) Have a rigorous understanding of the concept of three dimensional coordinates systems

UNIT 1: Transformation of coordinates, pair of straight lines. Parabola, parametric coordinates, tangent and normal, ellipse and its conjugate diameters with properties, hyperbola and its asymptotes, general conics: tangent, condition of tangency, pole and polar, centre of a conic, equation of pair of tangents, reduction to standard forms, central conics, equation of the axes, and length of the axes, polar equation of a conic, tangent and normal and properties.

[1] Chapter 3,4, 10

UNIT 2: Plane, straight lines and shortest distance. Sphere, cone and cylinder, central conicoids, ellipsoid, hyperboloid of one and two sheets, diametral planes, tangent lines, director sphere, polar plane, section with a given centre

[2] Chapters 4,5,6,7 (upto page 125)

Text Books:

1. R. M. Khan, Analytical Geometry of two and three dimension and vector analysis. New Central Book agency 2012.
2. R. J. T. Bell, Coordinate Solid Geometry, Macmillan, 1983.

Reference Book:

1. E. H. Askwith, The Analytical Geometry of the Conic Sections,Nabu Press (27 February 2012)

SKILL ENHANCEMENT COURSE

SEC-1

MAT-SE-3014: Computer Algebra Systems and Related Software

Total marks: 100 (Theory 60, Internal assessment 20, Practical 20)

Per week; 2 Lectures 2 Practical, Credits 4(2+2)*Each unit carry equal credit*.

Course Objectives: This course aims at familiarizing students with the usage of mathematical softwares (/Mathematica/MATLAB/Maxima/Maple) and the statistical software **R**. The basic emphasis is on plotting and working with matrices using CAS. Data entry and summary commands will be studied in **R**. Graphical representation of data shall also be explored.

Course Learning Outcomes: This course will enable the students to:

i) Use of softwares; Mathematica/MATLAB/Maxima/Maple etc. as a calculator, for plotting functions and animations

ii) Use of CAS for various applications of matrices such as solving system of equations and finding eigenvalues and eigenvectors.

iii) Understand the use of the statistical software **R** as calculator and learn to read and get data into **R.**

iv) Learn the use of **R** in summary calculation, pictorial representation of data and exploring relationship between data.
v) Analyze, test, and interpret technical arguments on the basis of geometry

Unit 1: Introduction to CAS and Applications:
Computer Algebra System (CAS), Use of a CAS as a calculator, Computing and plotting functions in 2D, Plotting functions of two variables using Plot3D and Contour Plot, Plotting parametric curves surfaces, Customizing plots, Animating plots, Producing tables of values, working with piecewise defined functions, Combining graphics.
[1] Chapter 12 (Sections 12.1 to 12.5)
[2] Chapter 1, and Chapter 3 (Sections 3.1 to 3.6, and 3.8) Chapter 6 (Sections 6.2, and 6.3)

Unit 2: Working with Matrices:
Simple programming in a CAS, Working with matrices, Performing Gauss elimination, operations (transpose, determinant, inverse), Minors and cofactors, Working with large matrices, Solving system of linear equations, Rank and nullity of a matrix, Eigenvalue, eigenvector and diagonalization.
[2] Chapter 7 (Sections 7.1 to 7.8)

Practical:
Six practicals should be done by each student. The teacher can assign practical from the exercises from [1,2].

Text Books:

1. Bindner, Donald & Erickson, Martin. (2011). *A Student's Guide to the Study, Practice, and Tools of Modern Mathematics*. CRC Press, Taylor & Francis Group, LLC.
2. Torrence, Bruce F., & Torrence, Eve A. (2009). *The Student's Introduction to Mathematica*:*A Handbook for Precalculus, Calculus, and Linear Algebra* (2nd ed.). Cambridge University Press

MAT-SE-3024: Combinatorics and Graph Theory

Total marks: 100(Theory 80, Internal Assessment 20)
Per week: 4 Lectures, Credits4, *Each unit carry equal credit*.

Course Objectives: This course aims to provide the basic tools of conuting principles, pigeonhole principle. Also introduce the basic concepts of graphs, Eulerian and Hamiltonian graphs, and applications to dominoes, Diagram tracing puzzles, Knight's tour problem and Gray codes.

Course Learning Outcomes: This course will enable the students to:
i) Learn about the counting principles, permutations and combinations, Pigeonhole principle
ii) Understand the basics of graph theory and learn about social networks, Eulerian and Hamiltonian graphs, diagram tracing puzzles and Knight's tour problem.

Unit 1: Basic counting principles, Permutations and combinations, the inclusion-exclusion principle, Pigeonhole principle.
[2] Chapter 1 (Sections 1.1, 1.2, 1.3), Chapter 2 (Sections 2.1, 2.2) Chapter 4 (Section 4.1) Chapter 8 (Section 8.1).
Unit 2: Graphs, Diagraphs, Networks and subgraphs, Vertex degree, Paths and cycles, Regular and bipartite graphs, Four cube problem, Social networks, Exploring and travelling, Eulerian and Hamiltonian graphs, Applications to dominoes, Diagram tracing puzzles, Knight's tour problem, Gray codes.
[1] Chapter 1 (Section 1.1), and Chapter 2

Text Books:

1. Aldous, Joan M., & Wilson, Robin J. (2007). *Graphs and Applications*: *An Introductory Approach*. Springer. Indian Reprint.

2. Sharad S. Sane, Combinatorial Techniques, Hindustan Book Agency, 2013.

Reference Books:

1. Michael Towusend, Discrete Mathematics; Applied Combinatorics and Graph Theory, Benjamin-Cummings Pub Co (March 1, 1987)
2. K.R. Parthasarathi, Basic Graph Theory,Tata McGraw-Hill, 1994.
3. C.L. Liu and D. Mohapatra_Elements of discrete mathematics, McGraw Hill, Computer Science Series. 2017

GENERIC ELECTIVE PAPERS

MAT-HG-3016/MAT-RC-3016: Differential Equations

Total Marks: 100(Theory: 80, Internal Assessment: 20)
Per week: 5 Lectures, 1 Tutorial, Credits: 6,*Each unit carry equal credit*

Course Objectives: The main objective of this course is to introduce the students to the exciting world of ordinary differential equations, mathematical modeling and their applications.

Course Learning Outcomes: The course will enable the students to:
i) Learn basics of differential equations and mathematical modelling.
ii) Solve first order non-linear differential equations and linear differential equations of higher order using various techniques.

Unit 1: First Order Ordinary Differential Equations

First order exact differential equations, Integrating factors, Rules to find an integrating factor
[1] Chapter 1 (Section 1.1,1.2 1.4), [2] Chapter 1 (Sections 1.1, and 1.2)Chapter 2 (Sections 2.1, and 2.2)

Linear equations and Bernoulli equations, Orthogonal trajectories and oblique trajectories; Basictheory of higher order linear differential equations, Wronskian, and its properties; Solving differential equation by reducing its order.
[2] Chapter 2 (Sections 2.3, and 2.4), Chapter 3 (Section 3.1), and Chapter 4 (Section 4.1)

Unit 2: Second Order Linear Differential Equations

Linear homogenous equations with constant coefficients, Linear non-homogenous equations, The method of variation of parameters, The Cauchy-Euler equation; Simultaneous differential equations.
[1] Chapter 2 (Section 2.2), [2] Chapter 4 (Sections 4.2, 4.3, 4.4, 4.5,4.6) Chapter 7 (Sections 7.1, 7.3)

Text Books:

1. Kreyszig, Erwin (2011). *Advanced Engineering Mathematics* (10th ed.). John Wiley &Sons, Inc. Wiley India Edition 2015.
2. Ross, Shepley L. (1984). *Differential Equations* (3rd ed.). John Wiley & Sons, Inc

MAT-HG-3026: Linear Programming

Total Marks: 100 (Theory: 80 Internal Assessment: 20)
Per week: 5 Lectures, 1 Tutorial Credits: 6,*Each unit carry equal credit*

Course Objectives: This course develops the ideas underlying the Simplex method. The course covers Linear rogramming problems with applications to transportation, assignment and game problem. Such problems arise in manufacturing resource planning and financial sectors.

Course Learning Outcomes: This course will enable the students to:
i) Learn about the graphical solution of linear programming problem with two variables.

ii) Learn about the relation between basic feasible solutions and extreme points.
iii) Understand the theory of the simplex method used to solve linear programming problems.
iv) Learn about two-phase and big-M methods to deal with problems involving artificial variables.
v) Learn about the relationships between the primal and dual problems.
vi) Solve transportation and assignment problems.
vii) Apply linear programming method to solve two-person zero-sum game problems.

Unit 1: The Linear Programming Problem**:** Standard, Canonical and matrix forms, Graphical solution. Hyperplanes, Extreme points, Convex and polyhedral sets. Basic solutions; Basic Feasible Solutions; Reduction of any feasible solution to a basic feasible solution; Correspondence between basic feasible solutions and extreme points.

[1] Chapter 1 (Section 1.1, 1.4 and 1.6)
[2] Chapter 2 (Sections 2.16, 2.19 and 2.20), Chapter 3 (Sections 3,2, 3.4 and 3.10)

Unit 2: Simplex Method**:** Optimal solution, Termination criteria for optimal solution of the Linear Programming Problem, Unique and alternate optimal solutions, Unboundedness; Simplex Algorithm and its Tableau Format; Artificial variables, Two-phase method, Big-M method.
[1] Chapter 3 (Sections 3.3, 3.6, 3.7 and 3.8)

Unit 3: Motivation and Formulation of Dual problem; Primal-Dual relationships; Fundamental Theorem of Duality; Complimentary Slackness.
[1] Chapter 4 (Sections 4.1 to 4.3)
[1] Chapter 6 (Section 6.1, and 6.2, up to Example 6.4)

Unit 4: Applications
*Transportation Problem***:** Definition and formulation; Methods of finding initial basic feasible solutions; North West corner rule. Least cost method; Vogel's Approximation method; Algorithm for solving Transportation Problem.
*Assignment Problem***:** Mathematical formulation and Hungarian method of solving.
*Game Theory***:** Basic concept, Formulation and solution of two-person zero-sum games, Games with mixed strategies, Linear Programming method of solving a game.
[3] Chapter 5 (Sections 5.1, 5.3, and 5.4)
[2] Chapter 11 (Sections 11.12, and 11.13)

Text Books:

1. Bazaraa, Mokhtar S., Jarvis, John J. and Sherali, Hanif D. (2010). *Linear Programmingand Network Flows* (4th ed.). John Wiley and Sons.
2. Hadley, G. (1997). *Linear Programming*. Narosa Publishing House. New Delhi.
3. Taha, Hamdy A. (2010). *Operations Research*: *An Introduction* (9th ed.). Pearson.

Reference Books:

1. Hillier, Frederick S. & Lieberman, Gerald J. (2015). *Introduction to Operations Research* (10th ed.). McGraw-Hill Education (India) Pvt. Ltd.
2. Thie, Paul R., &Keough, G. E. (2014). *An Introduction to Linear Programming andGame Theory*. (3rd ed.). Wiley India Pvt. Ltd.

SEMESTER-IV

MAT-HC-4016: Multivariate Calculus

Total Marks: 100 (Theory80, Internal assessment 20)
Per week: 5 lectures 1 Tutorial, Credits 6,*Each unit carry equal credit*
(Use of Scientific calculator is allowed)

Course Objectives: To understand the extension of the studies of single variable differential and integral calculus to functions of two or more independent variables. Also, the emphasis will be on the use of Computer Algebra Systems by which these concepts may be analyzed and visualized to have a better understanding. This course will facilitate to become aware of applications of multivariable calculus tools in physics, economics, optimization, and understanding the architecture of curves and surfaces in plane and space etc.

Course Learning Outcomes: This course will enable the students to:
i) Learn the conceptual variations when advancing in calculus from one variable to multivariable discussion.
ii) Understand the maximization and minimization of multivariable functions subject to the given constraints
iii) Learn about inter-relationship amongst the line integral, double and triple integral formulations.
iv) Familiarize with Green's, Stokes' and Gauss divergence theorems

UNIT 1: Functions of several variables, Level curves and surfaces, Limits and continuity, Partial differentiation, Higher order partial derivative, Tangent planes, Total differential and differentiability, Chain rule, Directional derivatives, The gradient, Maximal and normal property of the gradient, Tangent planes and normal lines.
[1] Chapter 11 (Sections 11.1 and 11.2, 11.3 and 11.4,11.5, 11.6)

UNIT 2: Extrema of functions of two variables, Method of Lagrange multipliers, Constrained optimization problems; Definition of vector field, Divergence and curl.
[1] Chapter 11 [Section 11.7 (up to page 605)], Section 11.8 (pages 610-614)], Chapter13 (Section 13.1)

UNIT 3: Double integration over rectangular and nonrectangular regions, Double integrals in polar coordinates, Triple integral over a parallelepiped and solid regions, Volume by triple integrals,triple integration in cylindrical and spherical coordinates, Change of variables in doubleandtriple integrals.
[1] Chapter 12 (Sections 12.1-12.4)

UNIT 4: Line integrals, Applications of line integrals**:** Mass and Work, Fundamental theorem for line integrals, Conservative vector fields, Green's theorem, Area as a line integral; Surface integrals, Stokes' theorem, The Gauss divergence theorem.
[1] Chapter 12 (Sections 12.5 and 12.6) Chapter 13 (Section 13.2, 13.3), [Sections 13.4 (pages 712 to 716), 13.5 (pages 723 to 726)]

Textbook:

[1] Strauss, Monty J., Bradley, Gerald L., & Smith, Karl J. (2007). *Calculus* (3rd ed.). Dorling Kindersley (India) Pvt. Ltd. (Pearson Education). Delhi. Indian Reprint 2011

Reference Books:

1. Marsden, J. E., Tromba, A., & Weinstein, A. (2004). *Basic Multivariable Calculus*. Springer (SIE). First Indian Reprint.
2. G.B. Thomas and R.L. Finney, Calculus, 9th Ed., Pearson Education, Delhi, 2005.
3. M. J. Strauss, G. L. Bradley and K. J. Smith, Calculus (3 Edition), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2007.
4. James Stewart, Multivariable Calculus, Concepts and Contexts, 2nd Ed., Brooks /Cole, Thomson Learning, USA, 2001.

MAT-HC-4026: Numerical Methods (including practical)

Total marks: 100: (Theory: 60, Practical 20, Internal Assessment: 20)
Per week: 4 Lectures, 2 Practical, Credits 6(4+2), *Each unit carry equal credit*

Course Objectives: To comprehend various computational techniques to find approximate value for possible root(s) of non-algebraic equations and to find the approximate solutions of system of linear equations and

ordinary differential equations. Also, use of Computer Algebra System (CAS) by which the numerical problems can be solved both numerically and analytically, and to enhance the problem solving skills.

Course Learning Outcomes: The course will enable the students to:
i) Learn some numerical methods to find the zeroes of nonlinear functions of a single variable and solution of a system of linear equations, up to a certain given level of precision.
ii) Know about methods to solve system of linear equations, such as False position method, Fixed point iteration method, Newton's method, Secant method and LU decomposition.
iii) Interpolation techniques to compute the values for a tabulated function at points not in the table.
iv) Applications of numerical differentiation and integration to convert differential equations into difference equations for numerical solutions.

UNIT 1: Algorithms, Convergence, Bisection method, False position method, Fixed point iteration method, Newton's method, Secant method, LU decomposition.
[1] Chapter 1 (Sections 1.1-1.2), Chapter 2 (Sections 2.1-2.5), Chapter 3 (Section 3.5, 3.8).

UNIT 2: Lagrange and Newton interpolation: linear and higher order, finite difference operators.
[1] Chapter 5 (Sections 5.1, 5.3) [2] Chapter 4 (Section 4.3).

UNIT 3: Numerical differentiation: forward difference, backward difference and central difference. Integration: trapezoidal rule, Simpson's rule, Euler's method.
[1]: Chapter 6 (Sections 6.2, 6.4), Chapter 7 (Section 7.2)
Note: Emphasis is to be laid on the algorithms of the above numerical methods.

***Practical / Lab work to be performed on a computer*:**
Use of computer aided software (CAS), for example *Matlab* / *Mathematica* / *Maple* / *Maxima* etc., for developing the following Numerical programs:

(i) Calculate the sum 1/1 + 1/2 + 1/3 + 1/4 + ----------+ 1/ N.
(ii) To find the absolute value of an integer.
(iii) Enter 100 integers into an array and sort them in an ascending order.
(iv) Any two of the following
(a) Bisection Method
(b) Newton Raphson Method
(c) Secant Method
(d) RegulaiFalsi Method
(v) LU decomposition Method
(vi) Gauss-Jacobi Method
(vii) SOR Method or Gauss-Siedel Method
(viii) Lagrange Interpolation or Newton Interpolation
(ix) Simpson's rule.

Note: For any of the CAS *Matlab* / *Mathematica* / *Maple* / *Maxima* etc., 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.

Text Books:

1. B. Bradie, *A Friendly Introduction to Numerical Analysis*, Pearson Education, India, 2007.
2. M. K. Jain, S. R. K. IyengarandR. K. Jain, *Numerical Methods for Scientific and Engineering Computation*, New age International Publisher, India, 5th edition, 2007.

Reference Book:

1. C. F. Gerald and P. O. Wheatley, *Applied Numerical Analysis*, Pearson Education, India,7th edition, 2008

MAT-HC-4036: Ring Theory

Total Marks: 100: (Theory80 Internal Assessment: 20)

Per week: 5 Lectures, 1 Tutorial,Credits 6,*Each unit carry equal credit*

Course Objectives: The objective of this course is to introduce the fundamental theory of rings and their corresponding homomorphisms. Also introduces the basic concepts of ring of polynomials and irreducibility tests for polynomials over ring of integers.

Courses Learning Outcomes: On completion of this course, the student will be able to:
i) Appreciate the significance of unique factorization in rings and integral domains.
ii) Learn about the fundamental concept of rings, integral domains and fields.
iii) Know about ring homomorphism and isomorphism theorems of rings.
iv) Learn about the polynomial rings over commutative rings, integral domains, Euclidean domains, and UFD

UNIT 1: Definition and examples of rings, properties of rings, subrings, integral domains and fields, characteristic of a ring. Ideals, ideal generated by a subset of a ring, factor rings, operations on ideals, prime and maximal ideals. Ring homomorphisms, properties of ring homomorphisms, Isomorphism theorems I, II and III, field of quotients.
[1]: Chapter 12, Chapter 13, Chapter 14, Chapter 15.

UNIT 2: Polynomial rings over commutative rings, division algorithm and consequences, principal ideal domains, factorization of polynomials, reducibility tests, irreducibility tests, Eisenstein criterion, unique factorization in Z[x]**.** Divisibility in integral domains, irreducibles, primes, unique factorization domains, Euclidean domains.
[1]: Chapter 16, Chapter 17, Chapter 18.

Text Books:

1. Joseph A. Gallian, Contemporary Abstract Algebra, 4th Ed., Narosa Publishing House, New Delhi, 1999.

Reference Books:

1. John B. Fraleigh (2002), A First Course in Abstract Algebra, 7th Ed., Pearson.
2. M. Artin (2011), Abstract Algebra, 2nd Ed., Pearson.
3. D.A.R. Wallace (1998), Groups, Rings and Fields, Springer Verlag London Ltd.
4. G. Santhanam (2017), Algebra, Narosa Publishing House.

SKILL ENHANCEMENT COURSE

SEC-2

MAT-SE-4014: R Programming

Total marks: 100 (Theory 60, Internal assessment 20, Practical 20)

Per week: 2 Lectures 2 Practical, Credits 4(2+2)

Course Objectives: The purpose of this course is to help using **R**, a powerful free software program for doing statistical computing and graphics. It can be used for exploring and plotting data, as well as performing statistical tests.

Course Learning Outcomes: This course will enable the students to:
i) Become familiar with **R** syntax and to use **R** as a calculator.
ii) Understand the concepts of objects, vectors and data types.
iii) Know about summary commands and summary table in **R**.
iv) Visualize distribution of data in **R** and learn about normality test.
v) Plot various graphs and charts using **R**.

Unit 1: **Getting Started with R - The Statistical Programming Language**
Introducing **R**, using **R** as a calculator; Explore data and relationships in **R**; Reading and getting data into **R:** combine and scan commands, viewing named objects and removing objects from **R**, Types and structures of data items with their properties, Working with history commands, Saving work in **R**; Manipulating vectors, Data frames, Matrices and lists; Viewing objects within objects, Constructing data objects and their conversions.
[1] Chapter 14 (Sections 14.1 to 14.4), [2] Chapter 2, Chapter 3

Unit 2: **Descriptive Statistics and Tabulation**
Summary commands**:** Summary statistics for vectors, Data frames, Matrices and lists; Summary tables.
[2] Chapter 4

Unit 3: **Distribution of Data**
Stem and leaf plot, Histograms, Density function and its plotting, The Shapiro-Wilk test for normality, The Kolmogorov-Smirnov test.
[2] Chapter 5

Unit 4: **Graphical Analysis with R**
Plotting in **R:** Box-whisker plots, Scatter plots, Pairs plots, Line charts, Pie charts, Cleveland dot charts, Bar charts; Copy and save graphics to other applications.
[1] Chapter 14 (Section 14.7)[2] Chapter 7

Practical to be done in the Computer Lab using Statistical Software R:
[1] Chapter 14 (Exercises 1 to 3)
[2] Relevant exercises of Chapters 2 to 5, and 7
Note: The practical may be done on the database to be downloaded from https://data.gov.in/

Textbooks:

1. Bindner, Donald & Erickson, Martin. (2011). *A Student's Guide to the Study, Practice, and Tools of Modern Mathematics*. CRC Press, Taylor & Francis Group, LLC.
2. Gardener, M. (2012). *Beginning* **R:** *The Statistical Programming Language*, Wiley Publications.

MAT-SE-4024: LaTeX and HTML (practical)
Total marks: 100 (Theory 60, Internal assessment 20, Practical 20)
Per week: 2 Lectures 2 Practical, Credits 4(2+2)

Course Objectives: The purpose of this course is to acquaint students with the latest typesetting skills, which shall enable them to prepare high quality typesetting, beamer presentation and webpages

Course Learning Outcomes: After studying this course the student will be able to:
i) Create and typeset a LaTeX document.
ii) Typeset a mathematical document using LaTex.
iii) Learn about pictures and graphics in LaTex.
iv) Create beamer presentations.
v) Create web page using HTML.

Unit 1: Elements of LaTeX; Hands-on-training of LaTex; graphics in LaTeX; PSTricks; Beamer presentation
[1] Chapters 9,10, 11.

Unit 2: HTML, creating simple web pages, images and links, design of web pages.
[1] Chapter 9-11, 15

Practical: Six practical should be done by each student. The teacher can assign practical from the exercises from [1].

Text Book:

1. Martin J. Erickson and Donald Bindner, A Student's Guide to the Study, Practice, and Tools of Modern Mathematics, CRC Press, Boca Raton, FL, 2011.

Reference Book:

1. L. Lamport, LATEX: A Document Preparation System, User's Guide and Reference Manual. Addison-Wesley, New York, second edition, 1994.

GENERIC ELECTIVE PAPERS

MAT-HG-4016/ MAT-RC-4016: Real Analysis

Total Marks: 100(Theory: 80 Internal Assessment: 20)
Per week: 5 Lectures, 1 Tutorial, Credits:6,*Each unit carry equal credit*

Course Objectives: The course will develop a deep and rigorous understanding of real line R and of defining terms to prove the results about convergence and divergence of sequences and series of real numbers. **Course**

Course Learning Outcomes: This course will enable the students to:
i) Understand many properties of the real line R, including completeness and Archimedean properties.
ii) Learn to define sequences in terms of functions from R to a subset of R.
iii) Recognize bounded, convergent, divergent, Cauchy and monotonic sequences and to calculate their limit superior, limit inferior, and the limit of a bounded sequence.
iv) Apply the ratio, root, alternating series and limit comparison tests for convergence and absolute convergence of an infinite series of real numbers.

Unit 1: Order completeness of Real numbers, Open and closed sets, Limit of functions, Sequentialcriterion for limits, Algebra of limits, Properties of continuous functions, Uniform continuity.
[1] Chapter 2 (Sections 2.1, and 2.2, Sections 2.3, and 2.4)Chapter 11 (Section 11.1, Definition and Examples only)

Unit 2: Sequences, Convergent and Cauchy sequences, Subsequences, Limit superior and limit inferiorof a bounded sequence, Monotonically increasing and decreasing sequences, Infinite series andtheir convergences, Positive term series, Comparison tests, Cauchy's nth root test,D'Alembert's ratio test, Raabe's test, Alternating series, Leibnitz test, Absolute and conditionalconvergence.
[1] Chapter 3, (Sections 3.1, 3.2,3.3,3.4,3.5,3.7), Chapter 9 [Section 9.1(excluding grouping of series)]Sections 9.2 (Statements of tests only), and 9.3 (9.3.1, 9.3.2), Chapter 4 (Sections 4.1 to 4.3).Chapter 5 (Sections 5.1, 5.3, 5.4 excluding continuous extension and approximation)

Text Book:

1. Bartle, Robert G., &Sherbert, Donald R. (2015). *Introduction to Real Analysis* (4th ed.) Wiley India Edition.

Reference Book:

1. Ross, Kenneth A. (2013). *Elementary Analysis*: *The Theory of Calculus* (2nd ed.). Undergraduate Texts in Mathematics, Springer. Indian Reprint
2. Bilodeau, Gerald G., Thie, Paul R., &Keough, G. E. (2010). *An Introduction to Analysis* (2nd ed.). Jones & Bartlett India Pvt. Ltd. Student Edition. Reprinted 2015.

MAT-HG-4026: Numerical Analysis

Total Marks:100 (Theory: 80 Internal Assessment: 20)

Per week: 5 Lectures, 1 Tutorial,Credits:6, *Each unit carry equal credit*

Course Objectives: To comprehend various computational techniques to find approximate value for possible root(s) of non-algebraic equations, to find the approximate solutions of system of linear equations and Quadratic equations.

Course Learning Outcomes: The course will enable the students to:

i) Learn some numerical methods to find the zeroes of nonlinear functions of a single variable and solution of a system of linear equations, up to a certain given level of precision.

ii) Know about iterative and non-iterative methods to solve system of linear equations

iii) Know interpolation techniques to compute the values for a tabulated function at points not in the table.

iv) Integrate a definite integral that cannot be done analytically

v) Find numerical differentiation of functional values

vi) Solve differential equations that cannot be solved by analytical methods

Unit 1: Gaussian elimination method (with row pivoting), Gauss-Jordan method; Iterative methods**:**Jacobi method, Gauss-Seidel method; Interpolation**:** Lagrange form, Newton form, Finite difference operators, Gregory-Newton forward and backward difference interpolations, Piecewise polynomial interpolation (Linear and Quadratic).

[2] Chapter 3 (Sections 3.1, and 3.2), Chapter 6 (Sections 6.1, and 6.2) Chapter 8 (Section 8.1, Section 8.3 (8.3.1, and 8.3.2)

[3] Chapter 3 (Sections 3.2, and 3.4) Chapter 4 (Section 4.2)Chapter 4 (Sections 4.3, and 4.4)

[1] Chapter 18 (Sections 18.1 to 18.3)

Unit 2: Numerical differentiation**:** First and second order derivatives; Numerical integration**:** Trapezoid rule, Simpson's rule; Extrapolation methods**:** Richardson extrapolation, Romberg integration;Ordinary differential equation**:** Euler's method, Modified Euler's methods (Heun and Mid-point).

[2] Chapter 11 [Sections 11.1 (11.1.1, 11.1.2, 11.1.4), and 11.2 (11.2.1, 11.2.2, 11.2.4)]

[1] Chapter 22 (Sections 22.1, 22.2, 22.3)

Text Books:

1. Chapra, Steven C. (2018). *Applied Numerical Methods with* MATLAB *for Engineers and* Scientists (4th ed.). McGraw-Hill Education.

2. Fausett, Laurene V. (2009). *Applied Numerical Analysis Using* MATLAB. Pearson. India

3. Jain, M. K., Iyengar, S. R. K., & Jain R. K. (2012). *Numerical Methods for Scientific andEngineering Computation* (6th ed.). New Age International Publishers. Delhi.

SEMESTER-V

MAT-HC-5016: Riemann Integration and Metric spaces

Total Marks: 100: (Theory 80, Internal assessment 20)

Per week: 5 Lectures 1 Tutorial, Credits 6,*Each unit carry equal credit*

Course Objectives: To understand the integration of bounded functions on a closed and bounded interval and its extension to the cases where either the interval of integration is infinite, or the integrand has infinite limits at a finite number of points on the interval of integration. Up to this stage, students do study the concepts of analysis which evidently rely on the notion of distance. In this course, the objective is to develop the usual idea of distance into an abstract form on any set of objects, maintaining its inherent characteristics, and the resulting consequences.

Course Learning Outcomes: The course will enable the students to:
i) Learn about some of the classes and properties of Riemann integrable functions, and the applications of the Fundamental theorems of integration.
ii) Know about improper integrals including, beta and gamma functions.
iii) Learn various natural and abstract formulations of distance on the sets of usual or unusual entities. Become aware one such formulations leading to metric spaces.
iv) Analyse how a theory advances from a particular frame to a general frame.
v) Appreciate the mathematical understanding of various geometrical concepts, viz. Balls or connected sets etc. in an abstract setting.
vi) Know about Banach fixed point theorem, whose far-reaching consequences have resulted into an independent branch of study in analysis, known as fixed point theory.
vii) Learn about the two important topological properties, namely connectedness and compactness of metric spaces.

UNIT 1: Riemann integration: upper and lower sums; Darbouxintegrability, properties of integral, Fundamental theorem of calculus, mean value theorems for integrals, Riemann sum and Riemann integrability, Riemann integrability of monotone and continuous functions on intervals, sum of infinite series as Riemann integrals, logarithm and exponential functions through Riemann integrals, improper integrals, Gamma functions.
[1] Chapter 6

UNIT 2: Metric spaces: definition and examples, sequences in metric spaces, Cauchy sequences, complete metric spaces. Open and closed balls, neighbourhood, open set, interior of a set. Limit point of a set, closed set, diameter of a set, Cantor's theorem. Subspaces, dense sets, separable spaces.
[2] Chapter 1 Sections 1.1-4, Chapter 2 Sections 2.1, 2.2
UNIT 3: Continuous mappings, sequential criterion and other characterizations of continuity. Uniform continuity. Homeomorphism, Contraction mappings, Banach contraction mapping principle. Connectedness, connected subsets of **R,** connectedness and continuous mappings.
[2] Chapter 3, Sections 3.1, 3.4, 3.5, 3.7 (up to 3.7.7), Chapter 4 Sections 4.1.

Text Books:

1. Ajit Kumar and S. Kumaresan, A Basic Course in Real Analysis, CRC Press, Indian Edn. 2014.
2. SatishShirali&Harikishan L. Vasudeva, Metric Spaces, Springer Verlag London (2006) (First Indian Reprint 2009)

Reference Books:

1. R.G. Bartle D.R. Sherbert, Introduction to Real Analysis, 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.
2. Charles G. Denlinger, Elements of Real Analysis, Jones & Bartlett (Student Edition), 2011.
3. S. Kumaresan, Topology of Metric Spaces, 2nd Ed., Narosa Publishing House, 2011.
4. G.F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, 2004.

MAT-HC-5026: Linear Algebra

Total Marks: 100: (Theory 80 Internal Assessment: 20)

Per week: 5 Lectures 1 Tutorial. Credits 6,*Each unit carry equal credit*

Course Objectives: The objective of this course is to introduce the fundamental theory of vector spaces, also emphasizes the application of techniques using the adjoint of a linear operator and their properties to least squares approximation and minimal solutions to systems of linear equations.

Course Learning Outcomes: The course will enable the students to:
i) Learn about the concept of linear independence of vectors over a field, and the dimension of a vector space.
ii) Basic concepts of linear transformations, dimension theorem, matrix representation of a linear transformation, and the change of coordinate matrix.
iii) Compute the characteristic polynomial, eigenvalues, eigenvectors, and eigenspaces, as well as the geometric and the algebraic multiplicities of an eigenvalue and apply the basic diagonalization result.
iv) Compute inner products and determine orthogonality on vector spaces, including Gram−Schmidt orthogonalization to obtain orthonormal basis.
v) Find the adjoint, normal, unitary and orthogonal operators.

Unit 1: Vector spaces and subspaces, null space and column space of a matrix, linear transformations, kernel and range, linearly independent sets, bases, coordinate systems, dimension of a vector space, rank, change of basis.
[1]: Chapter 4 (Sections 4.1 – 4.7)

Unit 2: Eigenvectors and eigenvalues of a matrix, the characteristic equation, diagonalization, eigenvectors of a linear transformation, complex eigenvalues,
[1]: Chapter 4 (Sections 5.1 – 5.5)
Invariant subspaces and Cayley-Hamilton theorem.
[2]: Chapter 5 (Section 5.4)

Unit 3: Inner product, length, and orthogonality, orthogonal sets, orthogonal projections, the Gram–Schmidt process, inner product spaces; Diagonalization of symmetric matrices,the Spectral Theorem.
[1]: Chapter 6 (Sections 6.1 – 6.4, 6.7); Chapter 7 (Section 7.1)

Text Books:

1. David C. Lay, Linear Algebra and its Applications (3rd Edition), Pearson Education Asia, Indian Reprint, 2007.
2. Stephen H. Friedberg, Arnold J. Insel, Lawrence E. Spence, *Linear Algebra* (4th Edition), Prentice-Hall of India Pvt. Ltd., New Delhi, 2004.

Reference Books:

1. S. Kumaresan, Linear Algebra- A Geometric Approach, Prentice Hall of India,1999.
2. Gilbert Strang, Linear Algebra and its Applications, Thomson, 2007.
3. Kenneth Hoffman, Ray Alden Kunze, Linear Algebra, 2nd Ed., Prentice-Hall of India Pvt. Ltd., 1971.
4. G. Schay, Introduction to Linear Algebra, Narosa, 1997.

DISCIPLINE SPECIFIC ELECTIVE PAPERS

DSE-1

MAT-HE-5016: Number Theory

Total Marks: 100 (Theory 80 Internal assessment 20)
Per week: 5 lectures 1 Tutorial Credits 6,*Each unit carry equal credit*

Course Objectives: In number theory there are challenging open problems which are comprehensible at undergraduate level, this course is intended to build a micro aptitude of understanding aesthetic aspect of mathematical instructions and gear young minds to ponder upon such problems.

Course Learning Outcomes: This course will enable the students to:
i) Learn about some fascinating discoveries related to the properties of prime numbers, and some of the open problems in number theory, viz., Goldbach conjecture etc.
ii) Know about number theoretic functions and modular arithmetic.
iii) Solve linear, quadratic and system of linear congruence equations.

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.
[1] Chapter 2 (Section 2.5), [2] Chapter 2 (Section 2.2, 2.3), [1] Chapter 4 (Sections 4.2, 4.4), Chapter 5:Section 5.2

Understand the theory behind friction and center of gravity

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 phifunction, Euler's theorem, reduced set of residues, some properties of Euler's phi-function.
[1] Chapter 6 (Sections 6.1 to 6.2, 7.2, 7.3, and 7.4)

Text Books:

1. David M. Burton, *Elementary Number Theory,* 6th Ed., Tata McGrawHill, Indian reprint,2007.
2. G. A. JonesandJ. Mary Jones,*Elementary Number Theo*ry. Undergraduate Mathematics Series (SUMS). First Indian Print. 2005

Reference Books:

1. Neville Robinns, *Beginning Number Theory,* 2nd Ed., Narosa Publishing House Pvt. Ltd., Delhi, 2007.
2. K. C. Chowdhury, A First Course in Number Theory, Asian Books Publications 2012

MAT-HE-5026: Mechanics

Total Marks: 100: (Theory 80, Internal assessment 20)
Per week: 5 Lectures 1 Tutorial, Credits 6(5+1) *Each unit carry equal credit*

Course Objectives: The course aims at understanding the various concepts of physical quantities and the related effects on different bodies using mathematical techniques. It emphasizes knowledge building for applying mathematics in physical world.

Course Learning Outcomes: The course will enable the students to:
i) Know about the concepts in statics such as moments, couples, equilibrium in both two and three dimensions.
ii) Understand the theory behind friction and center of gravity.
iii) Know about conservation of mechanical energy and work-energy equations.
iv) Learn about translational and rotational motion of rigid bodies.

UNIT 1: Composition and resolution of forces, Parallelogram of forces, Triangle of forces, Converse of triangle of forces, Lami's Theorem, Parallel forces, Moment of a force about a point and an axis. Couple, Resultant of a system of forces. Equilibrium of coplanar forces. Friction, C.G of an arc, plane area, surface of revolution, solid of revolution, Catenary.
[1] Chapter 1-9 related sections only

UNIT 2: Velocities and acceleration along radial and transverse directions and along tangential and normal directions, motion in a straight line under variable acceleration, simple harmonic motion and elastic string. Newton's law of motion. Work, Energy and momentum,Conservative forces-Potential energy, Impulsive forces, Motion in resisting medium.
[1] Vol-II Chapter I Sections 1.1, 1.2,1.3, Chapter –2 Sections 2.1,2.2, Chapter 3 Sections 3.1.3.2, Chapter 4 Sections 4.1, Chapter 5 Sections 5.1,5.3, Chapter 6 Sections 6.1,6.3.
[2] Chapter 3 (Sections: 3.1, 3.2, 3.3,3.4).

Text Book:

1. S. L. Loney, The elements of Statics and Dynamics (Vol I & II) PublisherArihant, 4th Edition 2014.
2. F. Chorlton, Textbook of Dynamics, CBS, Publications 2nd Edition, 1985

Reference books:

1. A.S. Ramsay, Statics, Cambridge University Press, publication year:2009
2. A.S. Ramsay, Dynamics, Cambridge University Press,publication year:2009
3. M. R. Spiegel, Theoretical Mechanics, SchaumSeries 2010.

MAT-HE-5036: Probability and Statistics

Total Marks: 100 (Theory: 80, Internal Assessment: 20)
Per week: 5 Lectures, 1 Tutorial,**Credits**6,*Each unit carry equal credit*

Course Objectives: To make the students familiar with the basic statistical concepts and tools which are needed to study situations involving uncertainty or randomness. The course intends to render the students to several examples and exercises that blend their everyday experiences with their scientific interests.

Course Learning Outcomes: This course will enable the students to:
i) Learn about probability density and moment generating functions.
ii) Know about various univariate distributions such as Bernoulli, Binomial, Poisson, gamma and exponential distributions.
iii) Learn about distributions to study the joint behavior of two random variables.
iv) Measure the scale of association between two variables, and to establish a formulation helping to predict one variable in terms of the other, i.e., correlation and linear regression.
v) Understand central limit theorem, which helps to understand the remarkable fact that**:** the empirical frequencies of so many natural populations, exhibit a bell-shaped curve, i.e., a normal distribution

UNIT-1: Sample space, Probability set function, Real random variables - Discrete and continuous,Cumulative distribution function, Probability mass/density functions, Transformations,Mathematical expectation, Moments, Moment generating function, Characteristic function.
[1] Chapter 1 (Sections 1.1, 1.3, 1.5,1.6 to 1.9)

UNIT-2: Discrete distributions**:** Uniform, Bernoulli, Binomial, Negative binomial, Geometric andPoisson; Continuous distributions**:** Uniform, Gamma, Exponential, Chi-square, Beta and normal; Normal approximation to the binomial distribution.
[2] Chapter 5 (Sections 5.2 to 5.4, Sections 5.5, and 5.7)
[2] Chapter 6 (Sections 6.2 to 6.4, Sections 6.5, and 6.6)

UNIT-3: Joint cumulative distribution function and its properties, Joint probability density function,Marginal

distributions, Expectation of function of two random variables, Joint momentgenerating function, Conditional distributions and expectations.
[1] Chapter 2 (Sections 2.1, and 2.3)

UNIT-4: The Correlation coefficient, Covariance, Calculation of covariance from joint moment generating function, Independent random variables, Linear regression for two variables, The method of least squares, Bivariate normal distribution, Chebyshev's theorem, Strong law of large numbers, Central limit theorem and weak law of large numbers.
[1] Chapter 2 (Section 2.4, and Section 2.5), [2] Chapter 14 (Sections 14.1 to 14.3)
[2] Chapter 6 (Section 6.7), and Chapter 4 (Section 4.4), [3] Chapter 2 (Section 2.8, and Exercise 76, page 89)

Text Books:

1. Hogg, Robert V., McKean, Joseph W., & Craig, Allen T. (2013). *Introduction toMathematical Statistics* (7th ed.). Pearson Education, Inc.
2. Miller, Irwin & Miller, Marylees. (2014). John E. Freund's *Mathematical Statistics withApplications*(8th ed.). Pearson. Dorling Kindersley (India).
3. Ross, Sheldon M. (2014). *Introduction to Probability Models* (11th ed.). Elsevier Inc.

Reference Books:

1. Mood, A. M., Graybill, F. A. &Boes, D. C. (1974). *Introduction to the Theory ofStatistics*(3rd ed.). McGraw-Hill Education Pvt. Ltd. Indian Edition (2017)

DSE-2

MAT-HE-5046: Linear Programming

Total Marks: 100 (Theory: 80 Internal Assessment: 20)
Per week: 5 Lectures, 1 TutorialCredits: 6,*Each unit carry equal credit*

Course Objectives: This course develops the ideas underlying the Simplex Method for Linear Programming Problem, as an important branch of Operations Research. The course covers Linear rogramming with applications to transportation, assignment and game problem. Such problems arise in manufacturing resource planning and financial sectors.

Course Learning Outcomes: This course will enable the students to:
i) Learn about the graphical solution of linear programming problem with two variables.
ii) Learn about the relation between basic feasible solutions and extreme points.
iii) Understand the theory of the simplex method used to solve linear programming problems.
iv) Learn about two-phase and big-M methods to deal with problems involving artificial variables.
v) Learn about the relationships between the primal and dual problems.
vi) Solve transportation and assignment problems.
vii) Apply linear programming method to solve two-person zero-sum game problems.

Unit 1: The Linear Programming Problem**:** Standard, Canonical and matrix forms, Graphical solution. Hyperplanes, Extreme points, Convex and polyhedral sets. Basic solutions; Basic Feasible Solutions; Reduction of any feasible solution to a basic feasible solution; Correspondence between basic feasible solutions and extreme points.
[1] Chapter 1 (Section 1.1, 1.4, and 1.6)
[2] Chapter 2 (Sections 2.16, 2.19, and 2.20), and Chapter 3 (Sections 3,2, 3.4, and 3.10)

Unit 2: Simplex Method**:** Optimal solution, Termination criteria for optimal solution of the Linear Programming Problem, Unique and alternate optimal solutions, Unboundedness; Simplex Algorithm and its Tableau Format; Artificial variables, Two-phase method, Big-M method.
[1] Chapter 3 (Sections 3.3, and 3.6, 3.7, and 3.8)

Unit 3: Motivation and Formulation of Dual problem; Primal-Dual relationships; Fundamental Theorem of Duality; Complimentary Slackness.
[1] Chapter 4 (Sections 4.1 to 4.3)
[1] Chapter 6 (Section 6.1, and 6.2, up to Example 6.4)

Unit 4: Applications
*Transportation Problem***:** Definition and formulation; Methods of finding initial basic feasible solutions; North West corner rule. Least cost method; Vogel's Approximation method; Algorithm for solving Transportation Problem.
*Assignment Problem***:** Mathematical formulation and Hungarian method of solving.
*Game Theory***:** Basic concept, Formulation and solution of two-person zero-sum games, Games with mixed strategies, Linear Programming method of solving a game.
[3] Chapter 5 (Sections 5.1, 5.3, and 5.4)
[2] Chapter 11 (Sections 11.12, and 11.13)

Text Books:
1. Bazaraa, Mokhtar S., Jarvis, John J. and Sherali, HanifD. (2010). *Linear Programmingand Network Flows* (4th ed.). John Wiley and Sons.
2. Hadley, G. (1997). *Linear Programming*. Narosa Publishing House. New Delhi.
3. Taha, Hamdy A. (2010). *Operations Research*: *An Introduction* (9th ed.). Pearson.

Reference Books:
1. Hillier, Frederick S. & Lieberman, Gerald J. (2015). *Introduction to Operations Research* (10th ed.). McGraw-Hill Education (India) Pvt. Ltd.
2. Thie, Paul R., &Keough, G. E. (2014). *An Introduction to Linear Programming andGame Theory*. (3rd ed.). Wiley India Pvt. Ltd.

MAT-HE-5056: Spherical Trigonometry and Astronomy
TotalMarks: 100 (Theory 80, Internal Assessment 20)
Per week: 5 Lecture Tutorial 1, Credits 6,*Each unit carry equal credit*

Course Objectives: This main objective of this course is to provide the spherical triangles, Napier's rule of circular parts and Planetary motion

Course Learning Outcomes: This course will enable the students to:
i) Learn about the properties of spherical and polar triangles
ii) know about fundamental formulae of spherical triangles
iii) learn about the celestial sphere, circumpolar star, rate of change of zenith distance and azimuth
iv) learn about Keplar's law of planetary motion, Cassini's hypothesis, differential equation for fraction

Unit1:Section of a sphere by a plane, spherical triangles, properties of spherical and polar triangles, fundamental formulae of spherical triangles, sine formula, cosine formula, sine-cosine formula, cot formula, Napier's rule of circular parts.
[1] Chapter 1: Sections: 1-8, 16

Unit2: The standard (or geometric) celestial sphere, system of coordinates, conversion of one coordinate system to the another system, diurnal motion of heavenly bodies, sidereal time, solar time(mean), rising and setting of stars, circumpolar star, dip of the horizon, rate of change of zenith distance and azimuth, examples.
[1] Chapter 2 Sections 18,19,22,27

Unit3: Planetary motion: annual motion of the sun, planetary motion, synodic period, orbital period, Keplar's law of planetary motion, deduction of Keplar's law from Newton's law of gravitation, the equation of the orbit, velocity of a planet in its orbit,components of linear velocity perpendicular to the radius vector and to the major axis, direct and retrograde motion in a plane, laws of refraction: refraction for small zenith distance, general

formula for refraction, Cassini's hypothesis, differential equation for fraction, effect of refraction on sunrise, sunset, right ascension and declination, shape of the disc of the sun.
[1] Chapter 5 Sections 57-59,64-69, 74, 81-83

Text Book:

1. W.M. Smart and R. M. Green Spherical Astronomy.Cambridge University Press; 6 edition, 1977.

Reference Books:

1. Sir Robert Ball, Spherical Astronomy, Publisher: Forgotten Books 2018
2. Br Nnow Franz, Brunnow Franz, Spherical Astronomy Publisher: BiblioLife, Aug 2009.

MAT-HE-5066: Programming in C (including practical)

Total Marks: 100 (Theory 60, Practical 20, Internal Assessment 20)
Per week: 4 Lectures 2 Tutorial, Credits 6(4+2) *Each unit carry equal credit*

Course Objectives: This course introduces C programming in the idiom and context of mathematics and imparts a starting orientation using available mathematical libraries, and their applications.

Course Learning Outcomes: After completion of this paper, student will be able to:
i) Understand and apply the programming concepts of C which is important to mathematical investigation and problem solving.
ii) Learn about structured data-types in C and learn about applications in factorization of an integer and understanding Cartesian geometry and Pythagorean triples.
iii) Use of containers and templates in various applications in algebra.
iv) Use mathematical libraries for computational objectives.
v) Represent the outputs of programs visually in terms of well formatted text and plots.

Unit 1: Variables, constants, reserved words, variable declaration, initialization, basic data types, operators and expression (arithmetic, relational, logical, assignment, conditional, increment and decrement), hierarchy of operations for arithmetic operators, size of and comma operator, mixed mode operation and automatic (implicit) conversion, cast (explicit) conversion, library functions, structure of a C program, input/output functions and statements.

Unit 2:Control Statements: if-else statement (including nested if-else statement), switch statement.
Loop control Structures (for and nested for, while and do-while). Break, continue, go to statements, exit function.

Unit 3: Arrays and subscripted variables: One and Two dimensional array declaration, accessing values in an array, initializing values in an array, sorting of numbers in an array, addition and multiplication of matrices with the help of array.
Functions: function declaration, actual and formal arguments, function prototype, calling a function by value, recursive function.

Programmes for practical:
To find roots of a quadratic equation, value of a piecewise defined function (single variable), factorial of a given positive integer, Fibonacci numbers, square root of a number, cube root of a number, sum of different algebraic and trigonometric series, a given number to be prime or not, sum of the digits of any given positive integer, solution of an equation using N-R algorithm, reversing digits of an integer. Sorting of numbers in an array, to find addition, subtraction and multiplication of matrices. To find sin(x), cos(x) with the help of functions.
[1] Chapters 3, 4, 5, 6, 7 and 9

Text Book:

1. T. Jeyapoovan, A First Course in Programming with C T. Jeyapoovan, Vikash Publishing House Pvt.Ltd.

Reference books:

1. E. Balaguruswamy, Programming with C, Schaum Series.
2. Y. Kanetkar, *Let us C*, B.P. Publication.

SEMESTER-VI

MAT-HC-6016: Complex Analysis (including practical)

Total marks: 100: (Theory: 60, Practical 20, Internal Assessment: 20)
Per week: 4 Lectures, Practical 2, Credits 6(4+2)*Each unit carry equal credit*

Course Objectives: This course aims to introduce the basic ideas of analysis for complex functions with visualization through relevant practicals. Emphasis has been given on Cauchy's theorems, series expansions and calculation of residues.

Course Learning Outcomes: Completion of the course will enable the students to:
i) Learn the significance of differentiability of complex functions leading to the understanding of Cauchy−Riemann equations.
ii) Learn some elementary functions and can evaluate the contour integrals.
iii) Understand the role of Cauchy−Goursat theorem and the Cauchy integral formula.
iv) Expand some simple functions as their Taylor and Laurent series, classify the nature of singularities, find residues and apply Cauchy Residue theorem to evaluate integrals.

UNIT 1: Properties of complex numbers, regions in the complex plane, functions of complex variable, mappings. Derivatives, differentiation formulas, Cauchy-Riemann equations, sufficient conditions for differentiability. Limits, Limits involving the point at infinity, continuity.
[1]: Chapter 1 (Section 11), Chapter 2 (Section 12, 13) Chapter 2 (Sections 15, 16, 17, 18, 19, 20, 21, 22)

UNIT 2: Analytic functions, examples of analytic functions, exponential function, Logarithmic function, trigonometric function, derivatives of functions, definite integrals of functions.
[1]: Chapter 2 (Sections 24, 25), Chapter 3 (Sections 29, 30, 34),Chapter 4 (Section 37, 38)

UNIT 3: Contours, Contour integrals and its examples, upper bounds for moduli of contour integrals.
[1]: Chapter 4 (Section 39, 40, 41, 43)

UNIT 4: Antiderivatives, proof of antiderivative theorem, Cauchy-Goursat theorem, Cauchy integral formula. Liouville's theorem and the fundamental theorem of algebra.
[1]: Chapter 4 (Sections 44, 45, 46, 50), Chapter 4 (Sections 51, 52, 53)
Convergence of sequences and series, Taylor series and its examples. Laurent series and its examples, absolute and uniform convergence of power series.
[1]: Chapter 5 (Sections 55, 56, 57, 58, 59, 60, 62, 63, 66)

LAB WORK TO BE PERFORMED ON A COMPUTER
(MODELING OF THE FOLLOWING PROBLEMS USING MATLAB/ MATHEMATICA/ MAPLE ETC.)

1. Declaring a complex number and graphical representation. e.g. $Z_1 = 3 + 4i$, $Z_2 = 4 - 7i$
2. Program to discuss the algebra of complex numbers, e.g.,
   $Z_1 = 3 + 4i$, $Z_2 = 4 - 7i$, then find $Z_1 + Z_2$, $Z_1 - Z_2$, $Z_1 * Z_2$ and Z_1 / Z_2
3. To find conjugate, modulus and phase angle of an array of complex numbers. e.g.
   Z = [2+ 3i, 4-2i, 6+11i, 2-5i]
4. To compute the integral over a straight line path between the two specified end points.

e. g.,$\oint \mathrm{Sin}z\, dz$, along the contour C which is a straight line path from -1+ i to 2 - i.

5. To perform contour integration., e.g.,
   (i) $\oint(z^2 - 2z + 1)dz$along the Contour C given by $x = y^2 + 1; -2 \le y \le 2$.
   (ii) $\oint(z^3 + 2z^2 + 1)dz$ along the contour C given by $x^2 + y^2 = 1$, which can be
   (iii) parameterized by x = cos (t), y = sin (t) for $0 \le y \le 2\pi$.
6. To plot the complex functions and analyze the graph. e.g.,
   (i) $f(z) = z, iz, z^2, z^3, e^z$ and $(z^4-1)^{1/4}$, etc.
7. To perform the Taylor series expansion of a given function f(z) around a given point z. The number of terms that should be used in the Taylor series expansion is given for each function. Hence plot the magnitude of the function and magnitude of its Taylors series expansion, e.g.,
   (i) f(z) = exp(z) around z = 0, n =40 and
   (i) $f(z) = \exp(z^2)$ around z = 0, n = 160.
8. To determines how many terms should be used in the Taylor series expansion of a given function f(z) around z = 0 for a specific value of z to get a percentage error of less than 5%. e.g., for f(z) = exp(z) around z =0, execute and determine the number of necessary terms to get a percentage error of less than 5 % for the following values of z:
   (i) z = 30 + 30i (ii) z = 10 +103 i
9. To perform Laurents series expansion of a given function f(z) around a given point z. e.g., (i) $f(z)= (\sin z -1)/z^4$ around z = 0 (ii) $f(z) = \cot(z)/z^4$ around z = 0.

Text Book:

1. James Ward Brown and Ruel V. Churchill, Complex Variables and Applications (Eighth Edition), McGraw – Hill International Edition, 2009.

Reference Book:

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

MAT-HC-6026: Partial Differential Equations (including practical)

Total marks: 100: (Theory: 60, Practical 20, Internal Assessment: 20)

Per week: 4 Lectures, 2 Practical, Credits 6(4+2), *Each unit carry equal credit*

Course Objectives: The main objectives of this course are to teach students to form and solve partial differential equations and use them in solving some physical problems.

Course Learning Outcomes: The course will enable the students to:

i) Formulate, classify and transform first order PDEs into canonical form.

ii) Learn about method of characteristics and separation of variables to solve first order PDE's.

iii) Classify and solve second order linear PDEs.

iv) Learn about Cauchy problem for second order PDE and homogeneous as well as nonhomogeneous wave equations.

v) Apply the method of separation of variables for solving second order PDEs.

Unit 1: Introduction, Classification, Construction of first order partial differential equations (PDE). Cauchy's problem for first order equations, linear equations of the first order, Integral surfaces passing through a given curve, Nonlinear partial differential equations of the first order, Cauchy's method of characteristics, Charpit's method. Solutions satisfying given conditions, Jocobi's method.

[1] Chapter 2 (Sections 2.1 to 2.3), [2] Chapter 2 (Section 3, 4,5, 7,8,10,12, 13)

Unit 2: Canonical form of first order PDE, Method of separation of variables for first order PDE.

[1] Chapter 2 (Sections 2.6 and 2.7)

Unit 3: Reduction to canonical forms, Equations with constant coefficients, General solution.

[1] Chapter 4 (Sections 4.1 to 4.5), [2] Chapter 3 (Sections 4, 5)

Practical /Lab work to be performed in a Computer Lab:
Modelling of the following similar problems using Mathematica /MATLAB/ Maple/ Maxima/ Scilab etc.

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

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

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

(c) $u(x,0) = \phi(x);\ u_t(x,0) = \psi(x);\ \ u_x(0,t) = 0, x > 0; t > 0$

(d) $u(x,0) = \phi(x);\ u_t(x,0) = \psi(x);\ \ u(0,t) = 0, u(l,t) = 0; x > 0; t > 0$

5. Solving systems of ordinary differential equations.
6. Solution of one-Dimensional heat equation $u_t = k\, u_{xx}$, for a homogeneous rod of length l.
   That is - solve the IBVP:

$$u_t = k\, u_{xx}, \qquad 0 < x < l, \qquad t > 0$$
$$u(0,t) = 0, \qquad u(l,t) = 0, \qquad t \geq 0$$
$$u(0,t) = f(x), \ \ 0 \leq x \leq l$$

Text Book:

1. TynMyint-U and LokenathDebnath**,** *Linear Partial Differential Equation for Scientists and Engineers*, Springer, Indian reprint, 2006.
2. Sneddon, I. N. (2006). *Elements of Partial Differential Equations*, Dover Publications. Indian Reprint.

Reference Book:

1. Stavroulakis, Ioannis P &Tersian, Stepan A. (2004). *Partial Differential Equations*: *An Introduction with Mathematica and* MAPLE (2nd ed.). World Scientific.

DISCIPLIN ESPECIFIC PAPERS

DSE-3

MAT-HE-6016: Boolean Algebra and Automata Theory

Total Marks: 100 (Theory 80 Internal Assessment 20)
Per week 5 Lectures, Tutorial 1, Credits 6,*Each unit carry equal credit*

Course Objectives: This course aims to introduce the basic ideas and properties of ordered sets, Lattices, Boolean algebra and automata theory.

Course Learning Outcomes: The course will enable the students to:
i) Learn about the order isomorphism, Hasse diagrams, building new ordered set.
ii) Learn about the algebraic structure lattices, properties of modular and distributive lattices.
iii) Get ideas about the Boolean algebra, Switching circuits and applications of switching circuits.
iv) Appreciate the theory of automata and its applications

Unit 1: Ordered Sets

Definitions, Examples and basic properties of ordered sets, Order isomorphism, Hasse diagrams, Dual of an ordered set, Duality principle, Maximal and minimal elements, Building new ordered sets, Maps between ordered sets.

[1] Chapter 1 (Sections 1.1 to 1.5 and 1.14 to 1.26, and 1.34 to 1.36), [3] Chapter 1 [Section 1 (1.1 to 1.3)]

Unit 2: Lattices

Lattices as ordered sets, Lattices as algebraic structures, Sublattices, Products and homomorphisms; Definitions, Examples and properties of modular and distributive lattices, The M3 – N5 Theorem with applications, Complemented lattice, Relatively complemented lattice, Sectionally complemented lattice homomorphisms.

[1] Chapter 2 (Sections 2.1 to 2.19) Chapter 4 (Sections 4.1 to 4.9) (Sections 4.10, and 4.11)

[3] Chapter 1 [Section 1 (1.5 to 1.20)] Chapter 1 [Section 2 (2.1 to 2.6) Chapter 1 [Section 2 (2.7 to 2.14)]

Unit 3: Boolean Algebras and Switching Circuits

Boolean Algebras, De Morgan's laws, Boolean homomorphism, Representation theorem; Boolean polynomials, Boolean polynomial functions, Disjunctive normal form and conjunctive normal form, Minimal forms of Boolean polynomial, Quinn-McCluskey method, Karnaugh diagrams, Switching circuits and applications of switching circuits.

[3] Chapter 1 (Sections 3, and 4) Chapter 1 (Section 6) Chapter 2 (Sections 7, and 8).

Unit 4: 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.

[4] Chapter 1, 2,3,4

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.

[4] Chapter 5

Text Books:

1. Davey, B. A., & Priestley, H. A. (2002). *Introduction to Lattices and Order* (2nd ed.). Cambridge University press, Cambridge
2. Goodaire, Edgar G. andParmenter, Michael M. (2011). *Discrete Mathematics with Graph Theory* (3rd ed.). Pearson Education (Singapore) Pvt. Ltd. Indian Reprint.
3. Lidl, Rudolf and Pilz, Gunter. (2004). *Applied Abstract Algebra* (2nd ed.), Undergraduate Texts in Mathematics. Springer (SIE). Indian Reprint.
4. J.E. Hopcroft, R. Motwani and J. D. Ullman, *Introduction to Automata Theory, Languages, and Computation,* 2nd Ed., Addison-Wesley, 2001.

Reference Books:

1. H.R. Lewis, C.H. Papadimitriou, C. Papadimitriou, *Elements of the Theory of Computation*, 2nd Ed., Prentice-Hall, NJ, 1997.
2. J.A. Anderson, *Automata Theory with Modern Applications*, Cambridge University Press, 2006.

MAT-HE-6026: Bio-Mathematics

Total Marks: 100 (Theory: 80, Internal Assessment: 20)
Per week: 5 Lectures, 1 Tutorial Credits: 6,*Each unit carry equal credit*

Course Objectives: The focus of the course is on scientific study of normal functions related to living systems. The emphasis is on exposure to nonlinear differential equations with examples such as heartbeat, chemical reactions and nerve impulse transmission. The basic concepts of the probability to understand molecular evolution and genetics have also been applied.

Course Learning outcomes: Apropos conclusion of the course will empower the student to:
i) Learn the development, analysis and interpretation of bio mathematical models such as population growth, cell division, and predator-prey models.
ii) Learn about the mathematics behind heartbeat model and nerve impulse transmission model.
iii) Appreciate the theory of bifurcation and chaos.
iv) Learn to apply the basic concepts of probability to molecular evolution and genetics.

Unit 1: Basic concepts and definitions, Mathematical model, properly posed mathematical problems, System of differential equation, Existence theorems, Homogeneous linear systems, Non-homogeneous linear systems, Linear systems with constant coefficients, Eigenvalues and eigenvectors, Linear equation with periodic coefficients. Population growth model, administration of drug and epidemics, Cell division Predator Prey Model, Chemical reactions and enzymatic catalysis.
[4] Chapter 1 and Chapter 5 [2] Chapter 1 (Sections 1.1 to 1.3), Chapter 4 (Sections 4.4 to 4.5)

Unit 2: Stability and Modeling of Biological phenomenon
The Phase Plane, Local Stability, Autonomous Systems, Stability of Linear Autonomous Systems with Constant Coefficients, Linear Plane Autonomous Systems, Method of Lyapunov for Non–Linear Systems, Limit Cycles, Forced Oscillations. Mathematics of Heart Physiology**:** The local model, The Threshold effect, The phase plane analysis and the Heart beat model, Physiological considerations of the Heart beat model, A model of the Cardiac pace-maker. Mathematics of Nerve impulse transmission**:** Excitability & repetitive firing, Travelling waves.
[4] Chapter 8 (Sections 8.1 to 8.6)
[2] Chapter 4 (Sections 4.1 to 4.3), Chapter 5 (Sections 5.1 and 5.7), Chapter 6 (Sections 6.4 and 6.5), Chapter 7 (Sections 7.1 and 7.3)

Unit 3: Bifurcation and Chaos
Bifurcation and chaos**:** Bifurcation, Bifurcation of a limit cycle, Discrete bifurcation, Chaos, Stability, The Poincare plane.
[2] Chapter 13 (Sections 13.1 to 13.4)

Unit 4: Modelling Molecular Evolution and Genetics
ModellingMolecularEvolution**:** Matrixmodels of base substitutionsfor DNAsequences, The Jukes-Cantor Model, the Kimura Models, Phylogeneticdistances.
Constructing Phylogenetictrees**:**Unweightedpair-groupmethodwitharithmeticmeans (UPGMA), Neighbour-Joining Method, Maximum Likelihood approaches.
Genetics**:**Mendelian Genetics, Probability distributions in Genetics, Linked genes and Genetic Mapping, Statistical Methods and Prediction techniques.
[1] Chapter 4 (Sections 4.4 and 4.5), Chapter 5 (Section 5.1 to 5.3), Chapter 6 (Sections 6.1 and 6.2)

Text Books:

1. Allman, Elizabeth S., & Rhodes, John A . (2004). *Mathematical Models in Biology*. Cambridge University Press.
2. Jones, D. S., & Sleeman B. D. (2003). *Differential Equations and Mathematical Biology,* Chapman & Hall, CRC Press, London, UK.
3. Murray, J. D.(2002). *An Introduction to Mathematical Biology*. Springer.
4. Myint, Tyn– I. (1977). *Ordinary Differential Equation*. Elsevier Science Ltd.

5. Simmons, G. F.,& Krant, S. G. (2015). *Differential Equations*. McGraw Hill Education.
6. Strogatz, Steven H. (1994). *Nonlinear Dynamics and Chaos*. Perseus Book Publishing. LLC.

MAT-HE-6036: Mathematical Modelling (including practical)

Total Marks: 100 (Theory: 60, Practical 20, Internal Assessment: 20)

Per week: 4 Lectures, 2 practical Credits: 6 (4+2)*Each unit carry equal credit*

Course Objectives: The main objective of this course is to teach students how to model physical problems using differential equations and solve them. Also, the use of Computer Algebra Systems (CAS) by which the listed problems can be solved both numerically and analytically.

Course Learning Outcomes: The course will enable the students to:
i) Know about power series solution of a differential equation and learn about Legendre's and Bessel's equations.
ii) Use of Laplace transform and inverse transform for solving initial value problems.
iii) Learn about various models such as Monte Carlo simulation models, queuing models, and linear programming models.

Unit 1: Power series solution of a differential equation about an ordinary point, Solution about a regular singular point, The method of Frobenius; Legendre's and Bessel's equation.
[1] Chapter 8 (Sections 8.1 to 8.3, Section 8.5 up to Equation (19), page 551)

Unit 2: Laplace transform and inverse transform, application to initial value problem up to second order.
[1] Chapter 7 (Sections 7.1 to 7.3)

Unit 3: Monte Carlo Simulation Modelling**:** Simulating deterministic behaviour (area under a curve, volume under a surface); Generating Random Numbers**:** Middle square method, Linear congruence; Queuing Models**:** Harbor system, Morning rush hour.
[2] Chapter 5 (Sections 5.1 to 5.2, and 5.5), Chapter 7

Practical / Lab work to be performed in Computer Lab:
Modelling of the following problems using Mathematica/MATLAB/Maple /Maxima/Scilab etc.

(i) 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].
(ii) Automatic computation of coefficients in the series solution near ordinary points.
(iii) Plotting of the Bessel's function of first kind of order 0 to 3.
(iv) Automating the Frobenius Series Method.
(v) Random number generation and then use it for one of the following:
(a) Simulate area under a curve. (b) Simulate volume under a surface.
(vi) Programming of either one of the queuing model:
(a) Single server queue (e.g. Harbor system). (b) Multiple server queue (e.g. Rush hour).
(vii) Programming of the Simplex method for 2 / 3 variables

Text Books:

1. Edwards, C. Henry, Penney, David E., & Calvis, David T. (2015). *Differential Equation and Boundary Value Problems*: *Computing and Modeling* (5th ed.). Pearson.
2. Giordano, Frank R., Fox, William P., & Horton, Steven B. (2014). *A First Course in Mathematical Modeling* (5th ed.). Brooks/Cole, Cengage Learning.

MAT-HE-6046: Hydromechanics

Total Marks: 100: (Theory 80 Internal assessment: 20)

Per week: 5 Lectures, 1 Tutorial, Credits 6, *Each unit carry equal credit*

Course Objectives: The main objectives of this course are to teach students about fluid pressure on plane surfaces, curved surfaces and Gas law. Also, introduces velocity of a fluid at a point, Eulerian and Lagrangian method, velocity potential and acceleration of a fluid at a point.

Course Learning Outcomes: The course will enable the students to:

i) Know about Pressure equation, rotating fluids.

ii) Learn about Fluid pressure on plane surfaces, resultant pressure on curved surfaces, Gas law, mixture of gases

iii) Learn about the Eulerian and Lagrangian method.

iv) Learn about equation of continuity, examples, acceleration of a fluid at a point

Unit 1: Hydrostatics

Pressure equation, condition of equilibrium, lines of force, homogeneous and heterogeneous fluids, elastic fluids, surface of equal pressure, fluid at rest under action of gravity, rotating fluids. Fluid pressure on plane surfaces, centre of pressure, resultant pressure on curved surfaces. Gas law, mixture of gases, internal energy, adiabatic expansion.

[1] Voll-I Chapter 1-4(related sections only)

Unit 2 Hydrodynamics

Real and ideal fluid, velocity of a fluid at a point, Eulerian and Lagrangian method, stream lines and path lines, steady and unsteady flows, velocity potential, rotational and irrotational motions, material local, convective derivatives, local and particle rate of change, equation of continuity, examples, acceleration of a fluid at a point.

[1] Vol-II Chapter 1

Text Book:

1. Besant, W. H., Ramsey, A. S., *A Treatise on Hydromechanics*. (part I & part II), G.Bell And Sons Limited. CBS Publication 1988(Indian print).

Reference Books:

1. H. Lamb, Hydrodynamics, University Press
2. F.Chorlton, Fluid dynamics, CBS Publisher First Edition 1985

DSE-4

MAT-HE-6056: Rigid Dynamics

Total Marks 100(Theory80 Internal assessment20)

Per week: 5 Lectures1 Tutorial, Credits 6, *Each unit carry equal credit*

Course Objectives: The main objectives of this course is to introduce moments and products of inertia, theorem of six constants, D'Alembert's principle, Motion of a body in two dimension and Lagrange's equations.

Course Learning Outcomes: The course will enable the students to:

i) Know how to find the moments and products of inertia.

ii) Learn about the motion of the centre of inertia

iii) Learn about the D'Alembert's principle and Lagrange's equations

iv) Learn about motion of a body in two dimension

Unit1: Moments and products of inertia, parallel axes theorem, theorem of six constants, the momental ellipsoid, equimomental systems, principle axes.
Unit2: D'Alembert's principle, the general equation of motion of a rigid body, motion of the centre of inertia and motion relative to the centre of inertia.
Unit3: Motion about a fixed axis, the compound pendulum, centre of percussion. Motion of a body in two dimension under finite and impulsive forces.
Unit4: Conservation of momentum and energy, generalized coordinates, Lagrange's equations, initial motions.
[1] Chapter -11-18 (related sections only)

Text Book:

1. S.L. Loney, An elementary treatise on the Dynamics of a particle and of Rigid bodies, Cambridge University Press Kindle Edition August 2018.

Reference Book:

1. A.S. Ramsey, Dynamics PartI, Cambridge University Press; 1 edition, 1952.

MAT-HE-6066: Group Theory II

Total Marks: 100 (Theory: 80, Internal Assessment: 20)
Per week: 5 Lectures, 1 Tutorial, Credits: 6,*Each unit carry equal credit*

Course Objectives: The course will develop an indepth understanding of one of the most important branch of the abstract algebra with applications to practical real-world problems. Classification of all finite abelian groups (up to isomorphism) can be done.

Course Learning Outcomes: The course shall enable students to:
i) Learn about automorphisms for constructing new groups from the given group.
ii) Learn about the fact that external direct product applies to data security and electric circuits.
iii) Understand fundamental theorem of finite abelian groups.
iv) Be familiar with group actions and conjugacy in S_n.
v) Understand Sylow theorems and their applications in checking non-simplicity.

Unit 1: Isomorphismsm, automorphisms, inner automorphisms, Automorphisms groups; External direct products of groups and their properties; the group of units modulo *n* as an external direct product
[1] Chapter 6 Chapter 8

Unit 2: Normal subgroups, factor groups and their applications, Internal direct products, of subgroups, Fundamental theorem of finite Abelian groups, isomorphism classes of finite abelian groups.
[1] Chapter 9 Chapter 11 (with proof of Fundamental theorem)

Unit 3: Conjugacy classes, The class equation, Conjugacy classes in the symmetric group S_n, *p*-groups, The Sylow theorems and their applications.
[1] Chapter 24, [2] Chapter 4 [Section 4.3(Pages 125-126,Ex 2-12)]

Unit 4: Finite simple groups, nonsimplicity tests; Generalized Cayley's theorem, Index theorem, Embedding theorem and applications. Simplicity of A_5.
[1] Chapter 25

Text Books:

1. Gallian, Joseph. A. (2013). *Contemporary Abstract Algebra* (8th ed.). Cengage Learning India Private Limited. Delhi. Fourth impression, 2015.
2. Dummit, David S., & Foote, Richard M. (2016). *Abstract Algebra* (3rd ed.). Student Edition. Wiley India.

Reference Book:

1. Joseph J. Rotman, (1995). *An Introduction to The Theory of Groups* (4th ed.). Springer Verlag, New York.
2. John B. Fraleigh (2002), A First Course in Abstract Algebra, 7th Ed., Pearson.
3. G. Santhanam (2017), Algebra, Narosa Publishing House.

MAT-HE-6076: Mathematical Finance

Total Marks: 100 (Theory: 80, Internal Assessment: 20)
Per week: 5 Lectures, 1 Tutorial Credits: 6,*Each unit carry equal credit*

Course Objectives: This course is an introduction to the application of mathematics in financial world, that enables the student to understand some computational and quantitative techniques required for working in the financial markets and actuarial mathematics.

Course Learning outcomes: On completion of this course, the student will be able to:
i) Know the basics of financial markets and derivatives including options and futures.
ii) Learn about pricing and hedging of options, as well as interest rate swaps.
iii) Learn about no-arbitrage pricing concept and types of options.
iv) Learn stochastic analysis (Ito formula, Ito integration) and the Black−Scholes model.
v) Understand the concepts of trading strategies and valuation of currency swaps.

Unit 1: Interest Rates: Types of rates, Measuring interest rates, Zero rates, Bond pricing, Forward rate,Duration, Convexity, Exchange traded markets and OTC markets, Derivatives--Forward contracts, Futures contract, Options, Types of traders, Hedging, Speculation, Arbitrage.
[1] Chapter 4 (Section 4.1 to 4.4, 4.6, 4.8, and 4.9) Chapter 1 (Sections 1.1 to 1.9)

Unit 2: Mechanics and Properties of Options: No Arbitrage principle, Short selling, Forward price for an investment asset, Types of Options,Option positions, Underlying assets, Factors affecting option prices, Bounds on option prices,Put-call parity, Early exercise, Effect of dividends.
[1] Chapter 5 (Sections 5.2 to 5.4), Chapter 8 (Sections 8.1 to 8.3), Chapter 9 (Section 9.1,Sections 9.2 to 9.7)

Unit 3: Stochastic Analysis of Stock Prices and Black-Scholes Model
Binomial option pricing model, Risk neutral valuation (for European and American options on assets following binomial tree model), Lognormal property of stock prices, Distribution of rate of return, expected return, Volatility, estimating volatility from historical data, Extension of risk neutral valuation to assets following GBM, Black-Scholes formula for European options.
[1] Chapter 11 (Sections 11.1 to 11.5) Chapter 13 (Sections 13.1 to 13.4, 13.7, and 13.8)

Unit 4: Hedging Parameters, Trading Strategies and Swaps
Hedging parameters (the Greeks: Delta, Gamma, Theta, Rho and Vega), Trading strategies involving options, Swaps, Mechanics of interest rate swaps, Comparative advantage argument, Valuation of interest rate swaps, Currency swaps, Valuation of currency swaps.
[1] Chapter 17 (Sections 17.1 to 17.9) Chapter 10 (except box spreads, calendar spreads and diagonal spreads) Chapter 7 (Sections 7.1 to 7.4, and 7.7 to 7.9)

Text Book:

1. Hull, J. C., &Basu, S. (2010). *Options, Futures and Other Derivatives* (7th ed.). Pearson Education. New Delhi.

Reference Books:

1. Luenberger, David G. (1998). *Investment Science*, Oxford University Press. Delhi.
2. Ross, Sheldon M. (2011). *An elementary Introduction to Mathematical Finance* (3rd ed.). Cambridge University Press. USA.