Semester-wise Syllabus (FYUGP) Department of Mathematics, Bhattadev University (NEP 2020)

Department of Mathematics
Bhattadev University
Semester wise Details of B.Sc. (FYUGP)
Course & Credit Scheme

Introduction:

The university grants commission (UGC) has initiated several measures to bring equity, efficiency and excellence in the higher education system of country. The important measures taken to enhance academic standards and quality in higher education include innovation and improvements in curriculum, teaching-learning process, examination and evaluation systems, besides governance and other matters. But due to the various diversities present in the system of higher education, there are multiple approaches followed by universities towards examination, evaluation and grading system. However, the academic reforms recommended by the UGC in the recent past have led to overall improvement in the higher education system. On the basis of the recommendation, apart from the flexibility and freedom in designing

The examination, there is a need to devise a sensible system for awarding the grades based on the performance of students. the NEP-2020 based **Four-Year Undergraduate Programme (FYUGP)**, being adopted by Bhattadev University, is an 8-semester (4-year) programme of 160 credits with multiple exit and entry options at the successful completion of courses assigned at the end of each year.

• Students who opt to exit after completion of the first year and have secured 40 credits will be awarded a certificate if, in addition, they complete one vocational course of 4 credits during the summer vacation of the first year.

• Students who opt to exit after completion of the second year and have secured 80 credits will be awarded the diploma if, in addition, they complete one vocational course of 4 credits during the summer vacation of the second year.

• Students who opt to exit after completion of the third year and have secured 120 credits will be eligible for the bachelor degree in the major discipline without honours.

• Students after completion of the fourth year and have secured 160 credits will be eligible for the bachelor degree with honours in the major discipline.

• Students are allowed to re-enter the degree programme within three years and complete the degree programme within the stipulated maximum period of seven years.

Outline of Courses:

The broad categories of courses and minimum credits required for the 4-year Honours degrees as per the UGC document are as follows:

1. **Major (Core) course/paper:** 80 credits
2. **Minor course/paper:** 32 credits
3. **Interdisciplinary course/paper (IDC):** 9 credits
4. **Ability Enhancement Course/paper (AEC):** 8 credits
5. **Skill Enhancement Course/paper (SEC):** 9 credits
6. **Value Added Course/paper (VAC):** 8 credits
7. **Summer Internship:** 2 credits
8. **Research Project/ Dissertation:** 12 credits (for Honours with Research degree)

The following points may be noted:

• In lieu of the Research Project, a student may study 3 courses each of 4 credits (i.e. total 12 credits), leading to an Honours degree (without Research).

• For the 4-year Honours degrees the Major subject/ discipline requires 80 credits and the. Minor subject/ discipline require 32 credits.

• For a Double Major, the minimum credit requirements are 48 (3-year degree) and 60 (4- year Honours degree) respectively in a subject/ discipline other than the original Major.

• In the UGC framework, papers in Major and Minor disciplines are categorized into levels of 100, 200, 300 and 400. Therefore, a course (paper) offered by a Department, say with 4 credits and of level 200, may be taken both as a Major (Core) course by one student and as a Minor course by another student having a different Major discipline, possibly in different semesters.

Definitions of Keywords:

In FYUGP the terminologies those are relevant to the B.Sc. curricula have been briefly described below.

Academic Year: Two consecutive (one odd + one even) semesters constitute one academic year.

Semester: Each semester will consist of 15 weeks of regular academic work. The odd semester may be scheduled from July to December and even semester from January to June under normal circumstance.

Programme: An educational programme leading to award of a Certificate, Diploma or Degree (B.Sc., B.A., etc.)

Discipline: This means a particular subject.

Course: Each programme is equipped with number courses of various disciplines/subjects. The course of a particular discipline/subject refers to the content of the papers the students have to study in that discipline/subject required in obtaining a degree. The courses should define learning objectives and learning outcomes. A course may be designed to comprise lectures /tutorials/laboratory work/ field work/outreach activities/project work /seminars /assignments / presentations etc. or a combination of any of these.

Honours: A particular discipline/subject that a student opts as major subject. (e.g. honours in Physics)

Core Course (CC): A discipline/subject specific compulsory basic course.

Skill Enhancement Course (SEC): A course designed by a department for enhancement of skill of the students in a particular discipline/subject.

Minor Course (M): A course in a discipline/subject corresponding to a subject other than the major subject.

Value Added Course (VAC): Value-based education to include management of biological resources and biodiversity for the development of humanistic, ethical, sustainable development and living, constitutional, and universal human values of truth, righteous conduct, peace, love, nonviolence, scientific temper, citizenship values, and life skills.

Ability Enhancement Course (AEC): These are compulsory courses. For science programme there will be two of them. AEC-1 is Communicative English & AEC-2 is Environmental Science.

Vocational Course (VOC): A vocational course is focused on practical work, preparing students for a particular trade or skilled profession. These courses are best for students who have a good idea of their career path and want to gain the knowledge to get there.

Levels of Courses:

100 - 199: Foundation or introductory courses.

200 - 299: Intermediate level courses.

300 - 399: Higher level courses.
400 - 499: Advanced courses.

Credit: A unit by which the course work is measured. It determines the number of hours of instructions required per week.

Theory/Tutorial classes: 1 credit = 1 hour / week
Practical classes: 1 credit = 2 hours / week

Credit Point: It is the product of grade point and number of credits for a course.
Letter Grade: It is an index of the performance of students in a said course.
Grade Point: It is a numerical weight allotted to each letter grade on a certain point scale. The following table explains the above two points.

Letter Grade	Grade Point	Performance	Letter Grade	Grade Point	Performance
O	10	Outstanding	C+	5	Average
A+	9	Excellent	C	4	Pass
A	8	Very Good	F	0	Fail
B+	7	Good	I	0	Absent/Incomplete
B	6	Above Average			

Semester Grade Point Average (SGPA): It is a measure of performance of work done in a semester. It is ratio of total credit points secured by a student in various courses registered in a semester and the total course credits taken during that semester. It shall be expressed up to two decimal places. If C_i = credit point in the ith course/paper and G_i = grade point obtained by a student in the ith course/paper then the grade point average in the ith Semester, i.e. SGPA is given by $S_i = \Sigma\, C_i\, G_i / \Sigma C_i$.

Cumulative Grade Point Average (CGPA): It is a measure of overall cumulative performance of a student over all semesters. The CGPA is the ratio of total credit points secured by a student in various courses in all semesters and the sum of the total credits of all courses in all the semesters. It is expressed up to two decimal places. If S_i = Semester Grade point average in the ith Semeter, S = total number of semesters in the program, then the cumulative grade point average, ie CGPA scored by the student is given by $C = \Sigma S_i / S$.

Grade Sheet/Report: Based on the grades earned, a grade certificate shall be issued to all the registered students after every semester. The grade certificate will display the course details (code, title, number of credits, grade secured) along with SGPA of that semester and CGPA earned till that semester.

Programme Objectives:

1. To develop conscience towards social responsibility, human values and sustainable development through curriculum delivery and extra-curricular activities
2. To develop scientific temperament with strong fundamental knowledge of the subject
3. To develop analytical thinking and problem-solving skills needed for various entrance and competitive examinations and Post Graduate Studies

4. To train students in laboratory skills and handling equipment along with soft skills needed for placement.

Programme Outcome:

1. The students will graduate with holistic development.
2 The students will be qualified to continue higher studies in their subject.
3. The students will be eligible to appear for various competitive examinations and pursue higher education.
4. The students will be able to apply for the jobs with a minimum requirement of B. Sc. Program.

Programme Specific Objectives:

The B.Sc. In Mathematics Program will enable the students;
1. To develop basic understanding of Fundamentals of Physics as a discipline.
2. To bring the scientific temperament by experiencing the nature and natural phenomena on day to day basis and also increase student competency.
3. To encourage students about applicability of knowledge and Interdisciplinary approach in today's life and thereby increasing the employability.

Programme Specific Outcomes:

1. **Knowledge:** Learners are encouraged to apply the knowledge of mathematics and science fundamentals to various solutions of complex problems. As such, knowledge of the subject is the sole objective of any student learner. A student is exposed to a wide range of topics in various subjects and is given intensive training in each of the courses that have laboratory related work.

2. **Problem Analyses:** Well equipped with an understanding of the analytical methods involved, they are in a position to interpret and analyze results so obtained from experiments and draw suitable conclusions against their supported data acquired.

3. **Designing Solutions:** Having acquired knowledge of subjects, students are trained to think out of the box, design and conduct an experiment or a series of experiments that demonstrate their understanding of the methods and processes involved. For example, as a part of the project of the final year, students in the subject of Physics are encouraged to calculate the overall power consumption of the institution and think of ways and means of minimizing this consumption through alternate sources of energy.

4. **Communication Development:** The medium of instruction being English, proficiency in the subject through English is one of the primary objectives of the science program. In order to improve the writing and oral skills of learners, the program caters to ensuring that learners become effective, clear communicators in written and oral work and are capable of explaining complex issues in accessible terms.

5. **Employability:** With our learners long-term professional pursuits being quite varied, many are drawn to careers that require scientific skills or technical expertise or strong quantitative reasoning abilities. Keeping this in mind, the institution apprises students of various employment opportunities that are available in areas of their choice through the Placement cell.

6. **Soft-Skill Development:** Apart from the attainment of knowledge and hands on skills in practical applicability of the subject, learners need to be equipped with soft-skills and values which will help them function effectively as an individual, and as a member or leader in diverse teams and in multidisciplinary groups.

7. **Science and Society:** As an outcome of the course the learners are encouraged to apply logical reasoning based on the knowledge, skills, designing solutions to assess societal, health, safety issues and the responsibilities that go along with the scientific practice.

Lists of Courses

CC:: Core Course/Papers [For Degree with Mathematics (Major), 3 years UG program]
1. **MAT-1104C:** Classical Algebra (Level: 100-199)
2. **MAT-2104C:** Calculus (including practical) (Level: 100-199)
3. **MAT-3104C:** Ordinary Differential Equations (including practical) (Level: 200-299)
4. **MAT-3204C:** Real Analysis (Level: 200-299)
5. **MAT-4104C:** Abstract Algebra (Level: 200-299)
6. **MAT-4204C:** Complex Analysis-I (including Practical) (Level: 200-299)
7. **MAT-4304C:** Analytical Geometry (Level: 200-299)
8. **MAT-5104C:** Multivariate Calculus (Level: 300-399)
9. **MAT-5204C:** Theory of Real Functions and Riemann Integration (Level: 300-399)
10. **MAT-5304C:** Numerical Analysis-I (including Practical) (Level: 300-399)
11. **MAT-5404C:** Linear Algebra
12. **MAT-6104C:** Metric Spaces and Topological Spaces (Level: 300-399)
13. **MAT-6204C:** Number Theory (Level: 300-399)
14. **MAT-6304C:** Mechanics (Level: 300-399)
15. **MAT-6404C:** Partial Differential Equations (including Practical) (Level: 300-399)

SEC:: Skill Enhancement Course/Papers
1. **MAT-1103SE:** R-Programming
2. **MAT-2103SE:** LATEX and HTML
3. **MAT-3103SE:** Programming in Python

IDC:: Interdisciplinary Course/Papers [Offered to the students of other discipline]
1. **MAT-1103ID:** Algebra and Trigonometry
2. **MAT-2103ID:** Analytical Geometry and vectors
3. **MAT-3103ID:** Introductory Calculus

CC:: Core Course/Papers [Additional Core Courses for degree with Mathematics (Honours) & Mathematics (Honours with Research)]
1. **MAT-7104C:** Mathematical Methods (Level: 400-499)
2. **MAT-7204C:** Algebra (Level: 400-499)
3. **MAT-7304C:** Mechanics and Tensor (Level: 400-499)
4. **MAT-7404C:** Real Analysis and Lebesgue Measure (Level: 400-499)
5. **MAT-8104C:** Topology (Level: 400-499)
6. **MAT-8204C:** Functional Analysis (Level: 400-499)
7. **MAT-8304C:** Complex Analysis-II (Level: 400-499)
8. **MAT-8404C:** Numerical Analysis-II (Level: 400-499)

Research Project [For Mathematics (Honours with Research)]
1. **MAT-8512C:** Research Project: In lieu of MAT-8204C, MAT-8304C, MAT-8404C, Research Project of Credit 12 has to be chosen for degree, Mathematics (Honours) with Research.

Minor Courses/Papers (For students from other discipline)

1. MAT-1104M: Algebra (Level: 100-199)

2. MAT-2104M: Calculus (Level: 100-199)

3. MAT-3104M: Differential Equations (For Single Major) (Level: 200-299)

4. MAT-3204M: Real Analysis (Additional Course to be chosen for Double Major along with MAT-3104M) (Level: 200-299)

5. MAT-4104M: Abstract Algebra (For Single Major) (Level: 200-299)

6. MAT-4204M: Complex Analysis (Additional Course to be chosen for Double Major along with MAT-4104M) (Level: 200-299)

7. MAT-5104M: Multivariate Calculus (For Single Major) (Level: 200-299)

8. MAT-5204M: Theory of Real Functions and Riemann Integration (Additional Course to be chosen for Double Major) (Level: 200-299)

9. MAT-5304M : Numerical Analysis (Additional Course again to be chosen for Double Major along with MAT-5104M & MAT-5204M) (Level: 200-299)

10. MAT-6104M: Metric Spaces and Topological Spaces (For Single Major) (Level: 200-299)

11. MAT-6204M: Number Theory (Additional Course to be chosen for Double Major) (Level: 200-299)

12. MAT-6304M: Mechanics (Additional Course again to be chosen for Double Major along with MAT-6104M & MAT-6204M) (Level: 200-299)

13. MAT-7104M: Mathematical Methods (For Single Major) (Level: 300-399)

14. MAT-7204M: Algebra-I (Additional course to be chosen for Double Major along with MAT-7104M) (Level: 300-399)

15. MAT-8104M: Topology (For Single Major) (Level: 300-399)

16. MAT-8204M: Functional Analysis (Additional Course to be chosen for Double Major along with MAT-8104M) (Level: 300-399)

Course Structure for BSc Mathematics (H) under FYUGP

Semester	CC 1	CC 2	AEC	SEC	IDC	VAC	Internship
Sem 1	Classical Algebra	To be chosen from other department Like Chemistry or Physics etc.	A common course of Cr-2	R-Programming	To be chosen from other department	A common course of Cr-2	N/A
Sem 2	Calculus (Including Practical)	To be chosen from other department like Chemistry or Mathematics etc.	A common course of Cr-2	LATEX and HTML	To be chosen from other department	A common course of Cr-2	N/A

To EXIT with a Certificate after one year, a mandatory VOC of credit 4 has to be chosen or proceed to the 2nd year.

Semester	Major/CC	Minor	AEC	SEC	IDC	VAC	Internship
Sem 3	Ordinary Differential Equations (Including Practical) Real Analysis	Course from Chemistry or Physics etc.	A common course of Cr-2	Programming in Python	To be chosen from other department	A common course of Cr-2	N/A
Sem 4	Abstract Algebra Complex Analysis-I (Including Practical) Analytical Geometry	Course from Chemistry or Mathematics □□	A common course of Cr-2	N/A	N/A	N/A	Has to be engaged in an summer internship of Cr-2

To Exit With A Diploma After One Year, A Mandatory Voc Of Credit 4 Has To Be Chosen Or Proceed To The 3rd Year.

Semester	Major/CC	Minor	AEC	SEC	IDC	VAC	Internship
Sem 5	Multivariate Calculus Theory of Real Functions and Riemann Integration Numerical Analysis-I (Including Practical) Linear Algebra	Course from Chemistry or Physics etc.	N/A	N/A	N/A	N/A	N/A
Sem 6	Metric Spaces and Topological Spaces Number Theory Mechanics Partial Differential Equations (Including Practical)	Course from Chemistry or Physics etc.	N/A	N/A	N/A	N/A	N/A

EXIT Option with a Bachelor degree after three years or Proceed to the 4th year.

Semester	Major/CC	Minor	AEC	SEC	IDC	VAC	Internship
Sem 7	Mathematical Methods Algebra Mechanics and Tensor Real Analysis and Lebesgue Measure	Course from Chemistry or Physics etc.	N/A	N/A	N/A	N/A	N/A
Sem 8	Topology Functional Analysis Complex Analysis-II Numerical Analysis-II In lieu of Functional Analysis, Complex Analysis-II & Numerical Analysis-II, a **Research Project** of Cr-12 may also be chosen	Course from Chemistry or Physics etc.	N/A	N/A	N/A	N/A	N/A

Completion of Bachelor degree with Honours/ with Honours with Research

N.B.: Whatever is the other core course opted in Semester I & Semester II, that course is to be carried on subsequent semesters as minor

Semester-I
MAT-1104C: Classical Algebra
Total marks: 100 (Theory-60, Internal Assessment-40)
Per week: 3 Lectures, 1 Tutorial, Credits 4 (3+1)

Course Learning Outcomes: This course will enable the students to:
  i)   Understand the importance of roots of real and complex polynomials and learn various methods of obtaining roots.
  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, using rank.
  iv) Find eigen values and corresponding eigenvectors for a square matrix.
  v)   Understanding matrix polynomials.

Unit 1: De Moivre's Theorem and its application, nth roots of unity, Circular functions for complex angles, Hyperbolic functions.   **Lectures: 15**

Unit2 Theory of equations, Fundamental theorem of Algebra, Relation between roots and co-efficient of nth degree equation, Symmetric functions of the roots for cubic and bi-quadratic equations.
                                                                                           Lectures: 15

Unit-3: Solution of cubic and bi-quadratic equations when some conditions on roots of the equation are given, Cardan's method to solve cubic equations, Descrate's rule of signs and its applications.
                                                                                           Lectures: 15

Unit 4: System of linear equations, Row reduction and Echelon form, Rank of a matrix, matrix equation $AX = B$, solution set of linear equation ,linear independence ,the matrix of a Linear Transformations, Characterization of invertible matrices. Determinants, Cramer's rule.
                                                                                           Lectures: 15

Text Books:
  1. S. K Mapa : Higher Algebra (Classical).
  2. Titu Andreescu and Dorin Andrica, Complex Numbers from A to Z, Birkhauser, 2006.
  3. David C. Lay, Linear Algebra and its Applications (3rd Edition), Pearson Education Asia, Indian Reprint, 2007.

Reference Books:
  1. Leonard Eugene Dickson (2009). *First Course in the Theory of Equations*. The Project Gutenberg EBook (http://www.gutenberg.org/ebooks/29785)
  2. Gilbert Strang, Linear Algebra and its Applications, Thomson, 2007.
  3. Das and Mukharjee , Higher Trigonometry .
  4. S. Barnard and J.M. Child, Higher Algebra, Arihant, 2016.
  5. Bernard Kolman & David R. Hill (2003). *Introductory Linear Algebra with Applications* (7th edition). Pearson Education Pvt. Ltd. India.
  6. Stephen and H David: Elementary Linear Algebra (5th Edn.). Academic Press, Elsevier India pvt. Ltd.
  7. Burnside, William Snow (1979). The Theory of Equations, Vol. 1 (11th ed.) S. Chand & Co. Delhi. Fourth Indian Reprint.

8. B. Das and S. R. Maiti. Higher Algebra, Asoke Prakasan, Kolkata-12.

Semester-II
MAT-2104C: Calculus (Including Practical)
Total Marks-100
Theory -42, Internal Assessment-28, Practical-30
Per week: 3 Lectures, 1 Practical, Credits 4 (3+1)

Course Learning Outcomes: This course will enable the students to:
  i) Assimilate the notions of limit of a sequence and convergence of a series of real numbers.
  ii) Calculate the limit and examine the continuity of a function at a point.
  iii) Understand the consequences of various mean value theorems for differentiable functions.
  iv) Sketch curves in Cartesian and polar coordinate systems.
  v) Apply derivative tests in optimization problems appearing in social sciences, physical sciences, life sciences and a host of other disciplines.

Unit-1: Higher order derivatives, Successive derivatives, Leibnitz rule and its application, Equations of tangent and normal (Statement only), Curvature, Asymptotes, Curve tracing (Cartesian and Polar),Concavity and Inflexion points, Indeterminate forms, L' Hospital's rule, Application in Business, Economics and Life Science, Hyperbolic Functions.   **Lectures:12**

Unit-2: Reduction Formulae, derivations and illustrations of reduction formulae of the type $\int x^n e^{ax} dx$, $\int sin^n x dx$, $\int cos^n x dx$, $\int tan^n x dx$, $\int sec^n x dx$, $\int cosec^n x dx$, $\int (logx)^n dx$, $\int x^n (logx)^n dx$, $\int x^n \sin nx dx$ $\int x^n \cos nx dx$, $\int sin^n x cos^m x\, dx$, $\int \sin mx \cos nx\, dx$, $\int \frac{1}{(x^2+a^2)^n}\, dx$, $n \neq 1$ and the corresponding definite integrals.   **Lectures: 11**

Unit-3: Line Integral, Arc length , Arc length of parametric curves, Area of surface of revolution Volumes of solids of revolution [volumes by slicing disks and washer method, volume by cylindrical shells]   **Lectures: 12**

Unit-4: Scalar and vector point functions, Limit and continuity of a vector functions, Differentiation and Integration of vector functions. Gradient of a scalar point function, Divergence and Curl of vector point functions, Directional derivative. Maximal and normal property of the gradient, Tangent planes and normal lines.   **Lectures: 11**

Practical / Lab work to be performed on a computer: **Lectures: 15**
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),

$\sqrt{ax+b},\ |ax+b|,\ c \pm |ax+b|,\ x^{2n},\ x^{1/n}$, for $n \in Z$ and $|x|/x$, $\sin(\frac{1}{x})$, $x\sin(\frac{1}{x})$, and $e^{(\pm\frac{1}{x})}$, 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 and second 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.

Text Books:
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.
2. Howard Anton, I. Bivens & Stephan Davis (2016). *Calculus* (10th edition). Wiley India.
3. George B. Thomas Jr., Joel Hass, Christopher Heil & Maurice D. Weir (2018). *Thomas' Calculus* (14th edition). Pearson Education.
4. *M. Spiegel, Vector Analysis, Schaums Outline Series.*
   Referrence Books:
1. B.C.Das and B.N.Mukherjee, Differential Calculus, U.N.Dhur & Sons Pvt. Ltd.
2. B.C.Das and B.N.Mukherjee, Integral Calculus, U.N.Dhur & Sons Pvt. Ltd.

Semester-III
MAT-3104C: Ordinary Differential Equations (Including practical)
Total Marks: 100: (Theory 42, Practical 30, Internal assessment 28)
Per week: 3 Lectures, 1 Practical, Credits 4 (3+1)

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

Course Learning Outcomes: The course will enable the students to:
 i) Learn basics of differential equations and mathematical modelling.
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.
v) Formulate mathematical models in the form of ordinary differential equations to suggest possible solutions of the day to day problems arising in physical, chemical and biological disciplines.

Unit-I: Differential equations and mathematical models. General, particular, explicit, implicit and

singular solutions of a differential equation. Exact differential equations and integrating factors and special cases, Linear differential equations and equations reducible to linear form (Bernoulli equations). **Lecture: 12**

Unit 2: First order higher degree equations solvable for *x*, *y* and *p*. Clairaut's form and singular solutions. **Lecture: 8**

Unit 3: Introduction to compartmental model, exponential decay model, lake pollution model (case study of Lake Burley Griffin), Drug assimilation into the blood of a single cold pill, Exponential growth of population, Limited growth of population, Limited growth with harvesting.
Lecture: 10

Unit 4: 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. **Lecture: 15**

List of Practical (using any software) **Lecture:15**

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.
3. B. Rai, D. P. Choudhury & H. I. Freedman (2013). *A Course in Ordinary Differential Equations* (2nd edition). Narosa.
4. M. D. Raishinghania (2013).*Ordinary and Partial Differential Equations*. S. Chand & Company Ltd.
5. H. I. Freedman (1980). *Deterministic Mathematical Models in Population Ecology*. Marcel Dekker Inc.
6. Daniel A. Murray (2003). *Introductory Course in Differential Equations*, Orient.
7. George F. Simmons (2017). *Differential Equations with Applications and Historical Notes* (3rd edition). CRC Press. Taylor & Francis.

Semester-III

MAT-3204C: Real Analysis
Total marks: 100 (Theory: 60 Internal Assessment: 40)
Per week: 3 Lectures, 1 Tutorial, Credits 4 (3+1)

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 the real line R and its properties 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 and use of convergent sequences in Numerical Analysis.
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 of a real number; Bounded above and bounded below sets, Supremum and infimum of a nonempty subset of R, The completeness property of R, Archimedean property, Density of rational numbers in R, Definition and types of intervals, Nested intervals property.   **Lecture: 10**
Unit-2: Neighborhood of a point in R, Open, closed and perfect sets in R, Connected subsets of R, Cantor set and Cantor function, limit points of a set and its simple applications.   **Lectures:10**

Unit-3: Convergence of real sequence, Limit of a sequence, Bounded sequence, Limit theorems, Monotone sequences, Monotone convergence theorem, Subsequences, Bolzano-Weierstrass theorem for sequences, Limit superior and limit inferior of a sequence of real numbers, Cauchy sequence, Cauchy's convergence criterion, properly divergence sequences.   **Lectures: 20**

Unit-4: Convergence and divergence of infinite series of positive real numbers, Necessary condition for convergence, Cauchy criterion for convergence; Tests for convergence of positive term series**;** Basic comparison test, Limit comparison test, D'Alembert's ratio test, Cauchy's nth root test, Integral test; Alternating series, Leibniz test, Absolute and conditional convergence, Rearrangement of series and Riemann's theorem.   **Lectures: 20**

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.

Semester-IV
MAT-4104C: Abstract Algebra
Total Marks: 100 (Theory 60, Internal assessment 40)
Per week 3 Lectures 1 Tutorial Credits, Credits 4 (3+1)

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: Definition and examples of groups and its elementary properties, examples of abelian and non-abelian groups, the group $\mathbb{Z}_n$ of integers under addition modulo n and the group U(n) of units under multiplication modulo n.The general linear group $GL_n(n, R)$, groups of symmetries of (i) an isosceles triangle, (ii) an equilateral triangle, (iii) a rectangle and (iv) a square, the permutation groups, the Klein-4 groups, the Dihedral groups, the quaternion groups. Subgroups and examples of subgroups, centralizer, normalizer, center of a group, product of two subgroups. Cyclic groups from number system, properties of cyclic groups, classification of subgroups of cyclic groups.

Lectures: 20

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. **Lectures: 15**

Unit-3: Group homomorphisms, properties of homomorphisms, Cayley's theorem, properties of isomorphisms, First, Second and Third isomorphism theorems. **Lectures: 10**

Unit4: Ring, Integral Domain, Field, Subring and their elementary properties, Ideals, Quotient ring, Maximal and Prime Ideals, Ring homomorphism, Fundamental theorem of ring homomorphism, Quotient field. **Lectures: 15**

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

Semester-IV

MAT-4204C: Complex Analysis-I (Including Practical)
Total marks: 100: (Theory: 42, Internal Assessment: 28, Practical 30)
Per week: 3 Lectures, 1 Practical, and Credits 4 (3+1)

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

Course Learning Outcomes: The completion of the course will enable the students to:
i) Understand the significance of differentiability of complex functions leading to the understanding of Cauchy-Riemann equations.
ii) Evaluate the contour integrals and understand the role of Cauchy-Goursat theorem and the Cauchy integral formula.
iii) 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: Analytic Functions and Cauchy-Riemann Equations
Functions of complex variable, Mappings; Mappings by the exponential function, Limits, Theorems on limits, Limits involving the point at infinity, Continuity, Derivatives, Differentiation formulae, Cauchy-Riemann equations, Sufficient conditions for differentiability; Analytic functions and their examples. **Lectures: 13**

Unit 2: Elementary Functions and Integrals
Exponential function, Logarithmic function, Branches and derivatives of logarithms, Trigonometric function, Derivatives of functions, Definite integrals of functions, Contours, Contour integrals and its examples, Upper bounds for moduli of contour integrals. **Lectures: 12**

Unit 3: Cauchy's Theorems and Fundamental Theorem of Algebra
Anti derivatives, Proof of anti derivative theorem, Cauchy-Goursat theorem (Statement only), Cauchy integral formula; An extension of Cauchy integral formula, Consequences of Cauchy integral formula, Liouville's theorem and the fundamental theorem of algebra. **Lectures: 10**

Unit 4: Series
Power series, Zeros and singularities of analytic functions, Convergence of sequences and series, Taylor series and its examples; Laurent series and its examples, Absolute and uniform convergence of power series. **Lectures: 10**

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

Reference Books:

1. Bak, Joseph & Newman, Donald J. (2010). *Complex Analysis* (3rd ed.). Undergraduate Texts in Mathematics, Springer. New York.
2. Zills, Dennis G., & Shanahan, Patrick D. (2003). *A First Course in Complex Analysis with Applications*. Jones & Bartlett Publishers, Inc.
3. Mathews, John H., & Howell, Rusell W. (2012). *Complex Analysis for Mathematics and Engineering* (6th ed.). Jones & Bartlett Learning. Narosa, Delhi. Indian Edition. (For practicals: Sample materials of files in the form Mathematica/ Maple 2011. zip, www.jblearning.com/catalog/9781449604455/).
4. Murray Spiegel, Seymour Lipschutz, John J. Schiller. Complex Variables (Schaum's Outlines) Revised 2nd Edition

LAB WORK TO BE PERFORMED ON A COMPUTER   Lectures: 15

(*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., $\oint \operatorname{Sin} z \ dz$, along the contour C which is a straight line path from -1+ i to 2 - i.
5. To perform contour integration., e.g.,

   (i) $\oint (z^! - 2z + 1) dz$ along the Contour C given by $x = y^2 + 1; -2 \le y \le 2$. (ii) $(z^! + 2z^! + 1) dz$ along the contour C given by $x^! + y^! = 1$, 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 $z = 0$.

Semester-IV

MAT-4304C: Analytical Geometry

Total Marks: 100 (Theory 60, Internal assessment 40)

Per week 3 Lectures, 1 Tutorial, Credits 4 (3+1)

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) Understand the importance of concept of frame of reference.

ii) Understand the geometrical interpretation of second degree equation.

iii) Recognize and understand the polar equations of conics.

iv) Have a rigorous understanding of the concept of three dimensional coordinates systems

v) Explain the properties of three dimensional shapes.

vi) Recognize and understand interpretation of special operators in vector calculus.

vii) Understand the application of vector integration.

Unit1-: Transformation of co-ordinate, Pair of straight lines.   **Lectures: 10**

Unit-2: General equation of 2nd degree, Tangent, Normal, Pole, Polar, Conjugate diameters with properties, condition of tangency, Equation of pair of tangents, reduction to standard form, Asymptotes, Polar co-ordinates, Central Conics, Equation of the axes and length of the axes.

                                                        Lectures: 20

Unit3: Sphere, Cone, Cylinder, Central Conicoids , Ellipsoid, Paraboloid and Hyperboloids of one and two sheets, diametral planes, tangent lines, director sphere enveloping cone and cylinder.

                                                        Lectures: 15

Unit 4: Vector integration, line, surface and volume integrals.   **Lectures: 15**

Reference:

1. R. M. Khan, Analytical Geometry of two and three dimension and vector analysis. New Central Bookagency 2012.

2. R. J. T. Bell, Coordinate Solid Geometry, Macmillan, 1983.

3. Shanti Narayan, Analytical Solid Geometry, S.Chand& Co. Pvt. Ltd.

4. Analytical Coordinate Geometry and Vector Analysis, Orient Book Company, Kolkata-7

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

Semester-V

MAT-5104C: Multivariate Calculus
Total Marks: 100 (Theory-60, Internal Assessment-40)
Per week: 3 Lectures, 1 Tutorial, Credits 4 (3+1)

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 conceptual variations while advancing from one variable to several variables in calculus.

ii) Apply multivariable calculus in optimization problems.

iii) Inter-relationship amongst the line integral, double and triple integral formulations.

iv) Applications of multivariable calculus tools in physics, economics, optimization, and understanding the architecture of curves and surfaces in plane and space etc.

v) Realize importance of Green, Gauss and Stokes' theorems in other branches of mathematics.

Unit-I: Calculus of Functions of Several Variables

Functions of several variables, Level curves and surfaces, Limits and continuity, Partial differentiation, Higher order partial derivative, Tangent planes, Total differential and differentiability, Jacobians, Change of variables, Taylor's theorem for functions of two variables and more variables Chain rule. **Lectures: 16**

Unit-II: Extrema of Functions and Vector Field

Extrema of functions of two and more variables, Method of Lagrange multipliers, constrained optimization problems.
Lectures: 12

Unit-III: Double and Triple Integrals

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 double and triple integrals, Dirichlet integral. **Lectures**: 16

Unit-IV: Green's, Stokes' and Gauss Divergence Theorem

Vector Integration, 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. **Lectures: 16**

Text Books:

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.
2. James Stewart (2012). *Multivariable Calculus* (7th edition). Brooks/Cole. Cengage.

Reference Books:

1. Jerrold Marsden, Anthony J. Tromba & Alan Weinstein (2009). *Basic Multivariable Calculus*, Springer India Pvt. Limited.
2. George B. Thomas Jr., Joel Hass, Christopher Heil & Maurice D. Weir (2018). *Thomas' Calculus* (14th edition). Pearson Education.

Semester-V

MAT-5204C: Theory of Real Functions and Riemann Integration
Total marks: 100 (Theory-60 Internal Assessment-40)
Per week: 3 Lectures, 1 Tutorial, Credits 4 (3+1)

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 learn:
i) To have a rigorous understanding of the concept of limit of a function.
ii) The geometrical properties of continuous functions on closed and bounded intervals. iii) The applications of mean value theorem and Taylor's theorem.
iii) Learn about some of the classes and properties of Riemann integrable functions, and the applications of the Fundamental theorems of integration.
iv) Know about improper integrals including, beta and gamma functions.

Unit-I: Limit of a function (c—ö approeh), Theorems on limit, one sided limit, Infinite limits and limits at infinity. Continuous function, sequential criterion for continuity, properties of continuous function, intermediate value theorem, preservation of intervals theorem, classification of discontinuity, uniform continuity. **Lectures: 15**

Unit-2: Differentiability of a function, Caratheodory's theorem, Relative extrema, Interior extretna, Monotone functions, Darboux's theorem, Rolle's theorem, 'Lagrange's Mean Value Theorem, Cauchy's Mean Value Theorem on derivatives and their applications. **Lectures: 15**

Unit-3: Taylor's theorem with Lagrange's form of remainder, Cauchy's form of remainder, Young's form of remainder. Jensen's inequality. Taylor's and Maclaurin's infinite series. Indeterminate form, L' Hospital theorem. **Lectures: 15**

Unit 4: Riemann Integration
Riemann integration: upper and lower sums; Darboux integrability, 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, Fundamental theorems (I and II) of calculus, and the integration by parts, Improper integrals of Type-I, Type-II and mixed type, Convergence of Beta and Gamma functions, and their properties. **Lectures: 15**

Text 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. Ross, Kenneth A. (2013). *Elementary Analysis*: *The Theory of Calculus* (2nd ed.). Undergraduate Texts in Mathematics, Springer.

Reference Books:
1. Ajit Kumar and S. Kumaresan, A Basic Course in Real Analysis, CRC Press, Indian Edn. 2014.
2. Denlinger, Charles G. (2011). *Elements of Real Analysis*. Jones & Bartlett (Student Edition). First Indian Edition. Reprinted 2015.
3. Ghorpade, Sudhir R. & Limaye, B. V. (2006). *A Course in Calculus and Real Analysis*. Undergraduate Texts in Mathematics, Springer (SIE). First Indian reprint.
4. 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.
5. S. R. Ghorpade and B.V Limay : A Course in Calculus and Real Analysis, Springer 2006.

6. A. Mattuk : Introduction to Real Analysis, Prantic Hall 1999.
7. S. C. Malik and Savita Arora : Mathematical analysis, New Age International Publisher.

Semester-V

MAT-5304C: Numerical Analysis-I (Including Practical)
Total marks: 100: (Theory: 42, Internal Assessment: 28, Practical 30)
Per week: 3 Lectures, 1 Practical, and Credits 4 (3+1)

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. **Lectures: 11**

UNIT 2: Lagrange and Newton interpolation: linear and higher order, finite difference operators.
Lectures: 12

UNIT 3: Numerical differentiation: forward difference, backward difference and central difference.
Lectures: 11

UNIT-4: Integration: trapezoidal rule, Simpson's rule, Euler's method. **Lectures: 11**

Note: Emphasis is to be laid on the algorithms of the above numerical methods.

***Practical / Lab work to be performed on a computer*:** **Lecture: 15**
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. C. F. Gerald and P. O. Wheatley, *Applied Numerical Analysis*, Pearson Education, India,7th edition, 2008

References Books:

1. M. K. Jain, S. R. K. Iyengar and R. K. Jain, *Numerical Methods for Scientific and Engineering Computation*, New age International Publisher, India, 5th edition, 2007.

Semester-V

MAT -5404C: Linear Algebra
Total Marks: 100: (Theory-60, Internal Assessment-40)
Per week: 3 Lectures, 1 Tutorial. Credits 4(3+1)

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: Introduction of Vector Spaces

Vector spaces and subspaces, null space and column space of a matrix, linear transformations, kernel and range, linearly independent sets, Linear span, bases, coordinate systems, dimension of a vector space, rank, change of basis. **Lectures: 15**

Unit 2: Linear Transformations
Linear transformations, Null space, Range, Rank and nullity of a linear transformation, Matrix representation of a linear transformation, Algebra of linear transformations. Isomorphisms, Isomorphism theorems, Invertibility and the change of coordinate matrix. **Lectures: 15**

Unit 3: Dual Spaces and Diagonalizable Operators
Dual spaces, Double dual, Dual basis, Transpose of a linear transformation and its matrix in the dual basis, Annihilators; Eigen values, Eigen vectors, Eigen spaces and characteristic polynomial of a linear operator; complex eigen values, Diagonalizability, Invariant subspaces and Cayley-Hamilton theorem; The minimal polynomial for a linear operator. **Lectures: 15**

Unit 4: Inner Product Spaces
Inner product, length, and orthogonality, orthogonal sets, orthogonal projections,Inner product spaces and norms, Orthonormal basis, Gram-Schmidt orthogonalization process, Diagonalization of symmetric matrices, the Spectral Theorem , Orthogonal complements, Bessel's inequality.
Lectures: 15

Text Books:
1. David C. Lay, Linear Algebra and its Applications (3rd Edition), Pearson Education Asia, Indian Reprint, 2007.
2. Gilbert Strang, Linear Algebra and its Applications, Thomson, 2007.
3. Lang, Serge (1987). *Linear Algebra* (3rd ed.). Springer.

References:
1. Stephen H. Friedberg, Arnold J. Insel, Lawrence E. Spence, *Linear Algebra* (4th Edition), Prentice-Hall of India Pvt. Ltd., New Delhi, 2004.
2. S. Kumaresan, Linear Algebra- A Geometric Approach, Prentice Hall of India,1999.
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.
5. Friedberg, Stephen H., Insel, Arnold J., & Spence, Lawrence E. (2003). *Linear Algebra* (4th ed.). Prentice-Hall of India Pvt. Ltd. New Delhi.

Semester-VI
MAT-6104C: Metric Spaces and Topological Spaces
Total Marks: 100: (Theory- 60, Internal Assessment- 40)
Per week: 3 Lectures, 1 Tutorial, Credits 4 (3+1)

Course Objectives: To understand the 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 various natural and abstract formulations of distance on the sets of usual or unusual entities. Become aware one such formulations leading to metric spaces.
ii) Analyse how a theory advances from a particular frame to a general frame.
iii) Appreciate the mathematical understanding of various geometrical concepts, viz. Balls or connected sets etc. in an abstract setting.
iv) Know about continuity in metric spaces and properties of continuous mappings in metric space.
v) 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.
vi) Know about topologies and properties topological spaces.
vii) Learn about the important topological properties, namely connectedness of metric spaces.

Unit-1: 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, Derived set, Closure of a set, dense sets, separable spaces. Convergence and completeness. Subspace, Cantor's theorem.   **Lectures: 20**

UNIT 2: Continuity in Metric Spaces
Continuous mappings, sequential criterion and other characterizations of continuity. Uniform continuity. Contraction mappings, Banach contraction mapping principle.   **Lectures: 10**

Unit-3: Connectedness in metric spaces: Connectedness, connected subsets of **R,** connectedness and continuous mappings.   **Lectures: 10**

Unit4: Topological Spaces: Definition of topological space, Discrete and indiscrete topologies, Co-finite and Co-countable topologies, The usual topology for R, Weakest and strongest topologies, Lower limit topology and upper limit topology, Metrizable space, Union and intersection of topological spaces, Open and closed sets in topological space.   **Lectures: 20**

Text Books:
1. Topology, by James R. Munkres, Pearson
2. Introduction oa Topology and Modern Analysis, by- George F. Simmons, Robert E. Krieger Publishing Company, Malabar, Florida

Semester-VI
MAT-6204C: Number Theory
Total Marks: 100 (Theory-60, Internal Assessment-40)
Per week: 3 lectures, 1 Tutorial Credits 4(3+1)

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.   **Lectures: 15**

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.   **Lectures: 15**

Unit-3: Euler's phifunction, Euler's theorem, reduced set of residues, some properties of Euler's phi-function. Primitive roots.   **Lectures: 15**

Unit-4: Algebraic number theory: Algebraic numbers, number fields, norm, trace, discriminants. Valuations, algebraic integers and integral bases.   **Lectures: 15**

Text Books:
1. David M. Burton, *Elementary Number Theory,* 6th Ed., Tata McGrawHill, Indian reprint,2007.
2. GA. Jonesand J. Mary   Jones,*Elementary NumberTheo*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

Semester-VI
MAT-6304C: Mechanics
Total Marks: 100: (Theory-60, Internal Assessment-40)
Per week: 3 Lectures, 1 Tutorial, Credits 4 (3+1)

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. **Lectures: 15**

Unit-2: Friction, C.G of an arc, plane area, surface of revolution, solid of revolution.

Lectures: 15

Unit 3: 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. Work, Energy and momentum, Conservative forces-Potential energy, Impulsive forces, Motion in resisting medium. **Lectures: 15**

Unit-4: Dynamics of Particles: Central orbit, Planetary motion, Kepler's laws. **Lectures: 15**

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, Schaum's Outlines, 2010.
4. Das and Mukharjee,Statics, U. N. Dhur & Sons Private Ltd.
5. Das and Mukharjee,Dynamics, U. N. Dhur & Sons Private Ltd.

Semester-VI
MAT-6404C: Partial Differential Equations (Including Practical)
Total marks: 100: (Theory-42, Internal Assessment-28, Practical-30),)
Per week: 3 Lectures, 1 Practical, Credits 4 (3+1)

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 partial differential equations into canonical form.
ii) Solve linear and non-linear partial differential equations using various methods; and apply these methods in solving some physical problems.

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

Lectures: 8

Unit-2: Lagrange's Method of solution, Integral surfaces passing through a given curve, Non linear partial differential equations of the first order, Cauchy's method of characteristics, Charpit's method,

some special type of equation which can be solved easily by methods other than the general method, Solutions satisfying given conditions, Jocobi's method. **Lectures: 15**

Unit 3: Canonical form of first order PDE, Method of separation of variables for first order PDE.
Lectures: 11

Unit 4: Reduction to canonical forms, Equations with constant coefficients, General solution.
Lectures: 11

Text Books:
1. Sneddon, I. N. (2006). *Elements of Partial Differential Equations*, Dover Publications. Indian Reprint.

Reference Books:
1. Tyn Myint-U and LokenathDebnath**,** *Linear Partial Differential Equation for Scientists and Engineers*, Springer, Indian reprint, 2006.
2. Stavroulakis, Ioannis P &Tersian, Stepan A. (2004). *Partial Differential Equations*: *An Introduction with Mathematica and* MAPLE (2nd ed.). World Scientific.

Practical /Lab work to be performed in a Computer Lab: **Lecture: 15**

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

(a) $\square(\square, 0) = \square(\square), \quad \square(\square, 0) = \square(\square), \square \in \mathbb{R}, \square > 0$
(b) $\square(\square, 0) = \square(\square), \square_\square(\square, 0) = \square(\square), \quad \square(0, \square) = 0, \square > 0 \ \square > 0$
(c) $\square(\square, 0) = \square(\square), \square_\square(\square, 0) = \square(\square), \square_\square(0, \square) = 0, \quad \square > 0, \square > 0$
(d) $\square(\square, 0) = \square(\square), \quad \square(\square, 0) = \square(\square), \quad \square(0, \square) = 0, \square(\square, \square) = 0, 0 < \square < \square, \square > 0$

5. Solution of one-Dimensional heat equation $\square_\square =$, for a homogeneous rod of length $\square$.
   That is - solve the IBVP:
$$\square_\square = \square \ \square_{\square\square}, 0 < \square < \square, \square > 0$$
$$(0, \square) = 0, (\square, \square) = 0, \square \geq 0$$
$$(0, \square) = (\square), 0 \leq \square \leq \square$$

6. Solving systems of ordinary differential equations.

Semester-VII
MAT-7104C: Mathematical Methods
Total Marks: 100 (Theory-60, Internal Assessment-40)
Per week: 3 lectures, 1 Tutorial, Credits 4 (3+1)

Course outcome:

i) The main objective of introducing this paper in the PG syllabus is that number theory is extensively used in the financial and defence sector of a country whereas Graph theory serves as an Mathematical model in any system involving a binary relation. Both Number and Graph Theory are used in computer application

ii) Students can use the concept of primitive roots and indices for solvability of congruence of higher order. The students can explain the quadratic reciprocity law using Legendere's and Jacobi's symbol.

iii) Students can explain Fibonacci numbers and related identities. Students can also explain partition functions, its graphical representations and generative functions.

iv) The students acquire basic knowledge of graphs to model some practical situation by using graphs.

v) Students can analyze their social networks using graph theory and able to view social network.

vi) Students are able to use a combination of theoretical knowledge and independent thinking in creative investigation of questions in graph theory.

Unit-I : Fredholm Integral Equations: Definition of Integral Equation, Reduction of ordinary differential equations into integral equations. Fredholm integral equations with separable kernels, Eigen values and Eigen functions, Method of successive approximation, Iterative scheme for Fredholm Integral equationsof second kind. **Lectures: 15**

Unit-II: Volterra Integral Equations: Volterra Integral Equations of second kind, Resolvent kernal of Volterra equation and its results, Application of iterative scheme to Volterra equation of the second kind, Convolution type kernals. **Lectures: 15**

Unit-II: Laplace Transform: Basic properties of Laplace Transform, Convolution theorem and properties of convolution, Inverse Laplace Transform. Application of Laplace Transform to solution of ordinary and partial differential equations of initial and boundary value problems, Evaluation of definite integrals. **Lectures: 15**

Unit IV: Calculus of variations: Calculus of variation with one independent variable: Basic ideas of calculus of variations, Euler's equation with fixed boundary of the functional Containing only the first order derivative of the only dependent variable with respect to one independent variable, Variational problems with functional having higher order derivatives of the only dependent variable, general case of Euler's equation, applications.

Calculus of Variation with several independent variables: Variational problems with functional dependent on functions of several independent variables having first order derivatives. Variational problems in parametric form, Variational problems with subsidiary condition: Isoperimetric problems, Applications. **Lectures: 15**

Text Books:
1. R. P. Kanwal, Linear Integral Equations, Theory and Techniques, Academic Press, New York,1971
2. M. R. Spiegel, Schaum's Outline Series: Theory and Problems of Laplace Transforms, McGraw-Hill Book Company, 1965

Reference Books:
1. S. G. Mikhlin, Linear Integral Equations (Translated from Russia), Hindustan Book Agency,1960
2. F. B. Hilderbrand, Methods of Applied Mathematics, Dover Publications, 1992
3. R. Courant and D. Hilbert, Methods of Mathematical Physics- Vol- I, Wiley Interscience, NewYork 1953.

4. A. S. Gupta, Calculus of variation with Applications : Prentice Hall of India, 1999

Semester-VII
MAT-7204C: Algebra

Total Marks: 100 (Theory-60, Internal Assessment-40)
Per week: 3 lectures, 1 Tutorial, Credits 4 (3+1)

Course outcome:

i) Based on the UGC Syllabus the paper 1016 (Algebra) for 1st semester is prepared in a logical and systematic and simple way so that the students can compare the studies of different algebraic systems called groups, rings, fields and vector spaces.

ii) The students can justify the concept of relations, mappings and composition in the study of algebraic systems called groups and rings. The concept of groups and rings play a significant role in the development of geometry and number theory in recent times.

iii) The syllabus contains a detailed study of field extension and its application to geometry, so that the students are able to solve some antique unsolved problems of geometry by the theory of field extension.

iv) The students are able to explain that the study of vector spaces is nothing but the generalization of the analytical geometry and mechanics.

Unit 1: Direct product and Direct sums of Groups. Decomposable groups. Normal and Subnormal series of groups, composition series, Jordan Holder theorem, solvable groups.   **Lectures: 15**

Unit 2: Divisibility in commutative rings, PID, UFD and their properties. Eisentein's irreducibility criterion.   **Lectures: 15**

Unit 3: Field theory – Extensions of fields. Algebraic and Transcendental elements, Algebraic extensions of Splitting field perfect Fields, Finite field (Moore's theorem etc.), Construction by ruler and compass, elements of Galois theory.   **Lectures: 15**

Unit 4: Canonical forms, similarity of linear transforms, Invariant subspaces, Reduction to triangular forms, nilpotent transformations, Primary decomposition theorem, Jordan blocks and Jordan canonical form, quadratic forms, reduction and classification of quadratic forms.   **Lectures: 15**

Text Books:
1. I. N.Herstein, Topics in Algebra, John Wiley& Sons, 1975.
2. K. Hoffman and R. Kunz, Linear Algebra, Prentice Hall, 1965

Reference Books:
1. C. Musili, Introduction to Rings and Modules, Narosa Publishing House, 1994
2. D. S. Malik, J.M. Mordeson and M. K. Sen, Fundamentals of Abstract Algebra, McGrawHill Company, 1997
3. K. B. Datta, Matrix and linear algebra, PHI Pvt. Limited, 2004
4. Seymour Lipschutz, Schaum's Outline of Linear Algebra, The McGraw-Hill Companies, Inc., 2013.
5. S. Singh and Q. Zameruddin, Modern Algebra, Vikash Publishing House, 2006

Semester-VII
MAT-7304C: Mechanics and Tensor
Total Marks: 100 (Theory-60, Internal Assessment-40)
Per week: 3 lectures, 1 Tutorial Credits 4 (3+1)

Course outcome:

Students will have knowledge:To differentiate the properties of motion in various coordinate systems viz. cylindrical,spherical,conical surfaces.

i) To apply various tools of vector algebra as well as vector calculus, calculus of variations to discuss the motion of rigid bodies under certain constraints.

ii) To handle various physical laws of motion viz. Carnot's theorem, Kelvin's theorem,Hamiltonian's principle etc with mathematical tools.

iii) To construct mathematical models viz. rigid body to describe motions under certainconstraints or no constraints which are able to analyse the physical scenario.

iv) To understand Tensors. They will be able to derive transformation laws of covariant tensors, contravariant tensors and mixed tensors and to find their ranks.

v) To perform algebraic operations on tensors, to obtain covariant derivatives of various tensors and to express Laplacian in tensor form.

vi) To identify that application of tensors is invaluable to most of the branches of Mathematics, Engineering and Theoretical Physics such Mechanics, Elasticity, Electrodynamics, Relativity etc.

Unit1: Idea of Moment of Inertia, Product of Inertia, D' Alembert's Principle, Motion of a rigid body under finite forces. Motion in three dimensions: Velocity and acceleration in cylindrical and spherical polar coordinates, motion on cylindrical, spherical and conical surfaces.
Lectures: 15

Unit 2: Motion of a rigid body about a fixed point: Euler's Geometrical and Dynamical systems, Motion under no external forces, Impulsive motions: Carnot's theorem, Kelvin's theorem and Bertrand's theorem. **Lectures: 15**

Unit 3: Generalized coordinates: Lagrange's equation of motion for finite forces in holonomic systems, Case of conservative forces and theory of small oscillation, Hamiltonian Theory: Hamilton's equation of motion, Variational methods, Hamilton's principle,and Principle of least action. **Lectures: 15**

Unit 4: Transformation laws of covariant and contravariant tensors, Mixed tensor, Rank of tensors, Kronecker delta. Algebraic operations on tensors: contraction, inner and outer product of tensors, Quotient law, Group property of tensors, symmetric and anti-symmetric tensors. Related theorems. Riemannian metric and Fundamental tensors. Christoffel symbols of the first and second kinds and their properties. Transformation laws of Christoffel symbols. Covariant derivatives of tensorsA_i ,A^i, A_{ij}, A^{ij} and A^i , Generalizations. Covariant derivatives of fundamental tensors and scalar invariant function, Application in problems. Angle between two vectors and orthogonal condition. Gradient of an invariant function. Divergence and curl of vectors. Laplacian in tensor form. **Lectures: 15**

Text Books:
1. S L Loney, An Elementary Treatise on the Dynamics of a Particle and Rigid Bodies, CambridgeUniversity Press, 2017
2. Murray Spiegel, Theory & problems of theoretical mechanics (Schaum's outline series),McGrawHill Education, 2017
3. C. E. Weatherburn, An Introduction to Riemannian Geometry and the Tensor Calculus, Cambridge University Press, Paperback, 2008

Reference Books:
1. S. L. Loney, The Elements of Statics & Dynamics, Part-II Dynamics, 2016
2. F. Chorlton, Text Books of Dynamics,John Wiley & Sons, 1983
3. L. P. Eisenhart, Riemannian Geometry, Princeton University Press, 1997
4. B. C. Kalita,Tensor Calculus and Applications: Simplified Tools and Techniques, CRC Press,2019.

Semester-VII
MAT-7404C: Real Analysis and Lebesgue Measure
Total Marks: 100 (Theory-60, Internal Assessment-40)
Per week: 3 lectures, 1 Tutorial Credits 4 (3+1)

Course outcome: After completing this course, the student will

i) understand how Lebesgue measure on R is defined, how measures may be used to construct integrals, know the basic convergence theorems for the Lebesgue integral, the relation between series and the Hilbert space of square integrable functions.

ii) have familiarity with common examples and counterexamples, knowledge of the content of the major theorems, understanding of the ideas in their proofs, and ability to make direct applicationof those results to related problems.

iii) get the knowledge in sequences of functions and their uniform convergence and get the idea about how to find out the region of convergence of power series.

iv) Develop the core skills of the subject and research skills in this areas.

Unit 1: Uniform convergence of sequence of functions at an interval, Cauchy's criterion, Test for uniform convergence, properties of uniformly convergent sequences and series of functions, results related to uniform convergence with continuity, integration and differentiation, Weirstrass's approximation theorem, Power series, radius of convergence, Abel's and Tauber's theorem, Fundamental properties.   **Lectures: 15**

Unit 2: Vector valued function, continuity, differentiation, Functions of bounded variation, their continuity, and monotonicity, Definition, existence of R-S integral, Properties of R-S integral, integration and differentiation, Fundamental theorem of calculus, Integration of vector valued functions.   **Lectures: 15**

Unit 3: Lebesgue outer measure, Measurable sets and properties, Borel sets and their measurability, Characterization of measurable sets, Non-measurable sets, Measurable functions and their properties, Operations of measurable functions, Sets of measure zero, Sequence of measurable functions, Convergence in measure.   **Lectures: 15**

Unit 4: Lebesgue integral, Lebesgue integral of a bounded function, Comparison of Riemann integral and Lebesgue integral, Integral of a non-negative measurable function, General Lebesgue integral, Convergence of Lebesgue integral, Bounded convergence theorem, Monotone convergence theorem, Lebesgue convergence theorem.   **Lectures: 15**

Text Books:
1. W. Rudin, Principles of Mathematical Analysis, McGraw-Hill Education, 1976
2. H. L. Royden, Real Analysis, Prentice Hall of India, 2011
3. P.K. Jain and V.P. Gupta, Lebesgue Measure and Integration, Anshan Ltd., 2012

Reference Books:
1. S. C. Malik and SavitaArora, Mathematical Analysis, New Age International Private Limited, 2017
2. R.R. Goldberg, Methods of Real Analysis, Oxford and IBH Publishing, 2012.

Semester-VIII
MAT-8104C: Topology
Total Marks: 100 (Theory-60, Internal Assessment-40)
Per week: 3 lectures, 1 Tutorial Credits 4 (3+1)

Course outcome:

Students will have knowledge:

i) to identify topological spaces and will be familiar with different types of subsets like open sets, closed sets, neighbourhoods, interior, boundary, derived sets, etc ., together with the ideas of bases, sub bases, relative topology, continuous functions and homeomorphisms. They can be able to classify different spaces like first countable, second countable, separable spaces and give the characterization of these spaces using some important results like Urysohn's lemma , Tietze extension theorem.

ii) To use the idea of compactness and connectedness and give their different characterizations.

iii) To explain the product topology and its relationship with compactness, connectedness, countability, etc. They can also provide examples of metrizable spaces, and can explain the relationship between embedding and metrization.

Unit:I Closed sets, closure, Dense subsets, Neighbourhood, Interior, Exterior and Boundary, Accumulation Points and Derived sets, Bases and sub- bases. Subbase and Relative Topology, Continuous Functions and Homeomorphism.   **Lectures: 15**

Unit 2: Countable and uncountable sets, First and second Countable spaces, Lindelof's theorem, Separable spaces, Second Countability and Separability, Separation Axioms T_0, T_1, T_2, $T_{31/2}$, T_4 ; their characterizations and basic properties, Urysohn's lemma, Tietze Extension Theorem.
                                                                                                Lectures: 15

Unit 3: Compactness and Connectedness: continuous functions and compact sets. Basic properties of compactness, Compactness and finite intersection property, Sequentially and Countably compact sets, Local Compactness and one point compactification. Stone-Cech Compactification, Compactness in metric spaces, Equivalence of compactness, Countable

compactness and sequential compactness in metric spaces. Connected spaces, connectedness on the real line, components, totally disconnected spaces, Locally connected spaces.   **Lectures: 15**

Unit 4: Tychonoff product topology in terms of standard subbase and its characterizations, Project Maps, Separation Axioms and Product Spaces, Connectedness and Product spaces, Compactness and Product Spaces (Tychonoff's) Theorem, Countability and Product Spaces, Embedding and Metrization, Urysohn Metrization theorem.   **Lectures: 15**

Text Books:
1. J. R. Munkres, Topology: A first course, Prentice Hall of India, 1974
2. G. F. Simmons, Introduction to Topology and Modern Analysis, McGraw Hill, 2017

Reference Books:
1. K.D. Joshi, Introduction to General Topology, New Age International Private Limited, 2017
2. J. Dugundji, Topology, Allyn and Bacon, 1966 (Reprinted in India By PHI)
3. J. Hocking and G. Young, Topology, Addison Wiley Reading, 1961
4. L. A. Steen and J. A. Seebach, Counter Examples in Topology, Dover Publications, 1995.

Semester-VIII
MAT-8204C: Functional Analysis
Total Marks: 100 (Theory-60, Internal Assessment-40)
Per week: 3 lectures, 1 Tutorial Credits 4 (3+1)

Course outcome:

Students will have knowledge:

i)   To identify normed linear spaces and Banach spaces and can provide and construct examples of these spaces. They will be familiar with different types of convergence of series in normed linear spaces and various types of subsets like absorbing, balanced, convex sets, convex hull, linear hull of a subset etc. They can be able to classify finite dimensional spaces and can provide different characteristics of such spaces.

ii) To explain the fundamental theorems on normed linear spaces, Hahn-Banach theorem, separation theorem and can give their different applications. They will be familiar with dual spaces of different normed linear spaces and can explain the concepts of reflexivity, separability, weak and weak topology.

iii) To identify inner product spaces, Hilbert spaces and can provide examples of such spaces. They can classify different types of operators like normal, unitary, self adjoint, positive, compact operators with examples and characteristics. They will also be able to explain the underlying idea of fixed point theorem, extreme points and Krein Milman theorem.

Unit 1: Normed linear spaces, Banach spaces and examples, First properties of normed linear spaces, Different types of convergence of series in a normed linear space, Absorbing, balance and convex subsets of a normed linear space, Convex hull, closed convex hull, linear hull and closed linear hull of subsets of normed linear spaces, Continuous and bounded linear operators between normed spaces, Banach space of bounded linear operators, Normed space isomorphism and isometric isomorphism, properties of finite dimensional normed linear space.   **Lectures: 15**

Unit 2: Fundamental theorems on normed linear spaces: Open Mapping Theorem,   Closed

Graph Theorem and Uniform Boundedness Principle, Quotient space, three space property, first isomorphism theorem for Banach spaces, vector space version and normed space version of Hahn Banach extension theorem, some applications, Minkowski functional, separation theorem

Lectures: 15

Unit 3: Dual space X^* as a Banach space, dual space of R^n, C_0, l_1, l_2 l_p. Adjoint operator of a bounded linear operator, annihilators, dual space of subspace and quotient space, second dual, reflexivity, separability. **Lectures: 15**

Unit 4: Hilbert space, Examples and first properties, Bounded operators and adjoint operator in a Hilbert space, Normal, unitary, self-adjoint and positive operator, Spectrum and numerical range, Compact self adjoint operator, Fixed point theorem andits applications. **Lectures: 15**

Text Books:
1. E. Kreyszig, Introductory Functional Analysis with applications, Wiley Classics Lib. Ed. 2007.
2. B.V. Limaye, Functional Analysis, New Age International, 2014
3. **R.E. Megginson, An introduction to Banach space theory, Springer, 1998**

Semester-VIII
MAT-8304C: Complex Analysis-II
Total Marks: 100 (Theory-60, Internal Assessment-40)
Per week: 3 lectures, 1 Tutorial Credits 4(3+1)

Course outcome:

i) It is common to encounter an integral that seems impossible to evaluate but with the knowledge ofResidue theorem and its consequences students can make it possible.

ii) Holonomic functions have the property that they can be uniquely analytically continued to (almost) the entire complex plane. Using the analytic continuation students can understand the behavior of a function at much larger scale by just knowing how the function behaves at a teenie-weenie open discin the complex plane. This section has a tremendous use in physics and engineering.

iii) Power series expansions are largely used in every branch of physics. An important application ofpower series in the field of engineering is spectrum analysis. Power series is used extensively you have to solve complicated differential equations. Students having knowledge of power series can solve many complicated equations arising in physics, finance and engineering.

iv) Conformal mapping is an important technique used in complex analysis and has many applications in different physical situations. If the physical problem can be represented by complex functions but the geometric structure becomes inconvenient then by appropriate mapping it can be converted to a problem of convenient geometry. With the help of conformal mapping students can solve boundary value problems that arise in heat conduction, electrostatic potential and fluid flow.

Unit 1: Complex Integration: Cauchy-Goursat Theorem, Cauchy's integral formula, Higher order derivatives. Morera's theorem, Cauchy's inequality and Liouville's Theorem, The fundamental theorem of Algebra, Gauss's Mean Value Theorem Maximum Modulus principle,

Schwarz lemma, Open mapping theorem, the Argument Principle, Rouche's theorem.

Lectures: 15

Unit 2: Theory of Residues: Residue, Calculation of Residues, Cauchy's residue theorem, Evaluation of definite integrals. Special theorems used in evaluating integrals, Mittag-Leffer's theorem.

Lectures: 15

Unit 3: Analytic functions as mappings: Isogonal and Conformal Transformation, Necessary and sufficient condition of conformal transformation, Bilinear transformations, Geometrical inversion, Invariance of cross ratio, Fixed points of a bilinear transformation, some special bilinear transformation e.g. Real axis on itself, unit circle on itself, real axis on unit circle etc. Branch point and Branch line, Concept of the Riemann surface.

Lectures: 15

Unit 4: Analytic Continuation: Analytical continuation, Schwarz's reflection principle, Infinite products, Gamma Function and its properties

Lectures: 15

Text Books:
1. M.R. Spiegel, Complex Variables. Schaum's Outlines series, McGraw Hill Education, 2017
2. E. G. Philips, Functions of a complex variables with applications, Oliver and Boyd, 1957

Reference Books:
1. Walter Rudin, Real and Complex Analysis, McGraw Hill Education, 2017
2. L. V. Ahlfors, Complex Analysis, McGraw Hill., 2000
3. H. A. Priestly, Introduction to Complex Analysis, Clarendon Press Oxford, 1990
4. Mark J. Ablowitz and A.S. Fokas, Complex Variables, Introduction and Application, CUP, 1998.
5. John B Conway, Functions of Complex Variable, Springer, 1872.

Semester-VIII
MAT-8404C: Numerical Analysis-II
Total Marks: 100 (Theory-60, Internal Assessment-40)
Per week: 3 lectures, 1 Tutorial Credits 4 (3+1)

Course outcome:
i) The students learn to solve any algebraic equations when no analytical method is applicable
ii) Students can find the approximate solutions of boundary value problems by using numericaltechnique
iii) Students can identify different types of approximation functions such as trigonometric functions,exponential functions etc.
iv) Students are now able to apply the numerical technique in physical and engineering problems.

Unit 1: System of linear equations and eigenvalue problem: Operational counts for direct methods of solving system linear algebraic equations. Gaussian operational count for inversion of a matrix. Eigenvalue problem. General iterative method. Jacobi and Gauss. Seidel method. Relaxation method. Necessary and sufficient conditions for convergence. Speed of convergence. S.O.R. and S.U.R. methods. Gerschgorin'scircle theorem. Determination of eigenvalue by iterative methods. Ill conditioned system.

Lectures: 15

Unit 2: System of non-linear method equations: Solution of Non-linear Equations: Single Equation: Modified Newton-Raphson method (for real roots-simple or repeated). Aitken's δ^2-method and Steffensen's iteration. Bairstow's method of quadratic factors, Graeffe's root squaring method. Non- Linear Systems of Equations: Newton's method, Quasi-Newton's method.

Lectures: 15

Unit 3: Polynomial Interpolation: Weirstrass's approximation theorem (Statement only), Runge's phenomena, Divergence of sequences of interpolation polynomials for equi-spaced interpolation points, piecewise polynomial interpolation – Hemite interpolation, Error term, Cubic spline interpolation, Convergence properties (statement only), Inverse interpolation, Numerical differentiation using equi- spaced points. **Lectures: 15**

Unit 4: Numerical Integration: Gauss- Legendre and Gauss-Chebyshev quadratures, Euler-Maclaurin summation formula, Richardson extrapolation, Romberg integration, Simpson's adaptive quadrature, Numerical Solution of Initial Value Problems for ODE: Picard, Euler, modified Euler and Runge-Kutta methods, Multistep predictor-corrector methods – Adams-Bashforth method, Adams- Moulton method, Milne's method, shooting method, Convergence and stability. **Lectures: 15**

Text Books:
1. C. F. Gerald and P. O. Wheatley, Applied Numerical Analysis, Pearson, 7th Edition, 2004
2. M. K. Jain, S. R. K. Iyengar, R.K. Jain, Numerical Methods for Scientific and EngineeringComputation, New Age International, 2005

Reference Books:
1. A. Ralston, A First Course in Numerical Analysis, McGraw Hill, N.Y. ,1965.
2. A. Ralston and P. Rabinowitz, A First Course in Numerical Analysis, McGraw Hill, N.Y., 1978.
3. S. D. Conte and C. De Boor, Elementary Numerical Analysis: An Algorithmic Approach, McGraw Hill, N.Y., 1980.
4. K. E. Atkinson, An Introduction to Numerical Analysis, John Wiley and Sons, 1989.
5. C. E. Fröberg, Introduction to Numerical Analysis, Addison-Wesley Publishing Company, 1969.
6. E. K. Blum, Numerical Analysis and Computation Theory and Practice, Addison-Wesley Publishing Company, Inc., London, 1972.
7. C. Pozrikidis, Numerical Computation in Science and Engineering, Oxford University Press, Inc.,N.Y., 1998.

Skill Enhancement Courses

Semester-I

MAT-1103SE: R Programming (Including Practical)
Total marks: 50 (Theory-35, Practical-15)
Per week: 2 Lectures, 1 Practical, Credits 3 (2+1)

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. **Lectures: 8**

Unit 2: **Descriptive Statistics and Tabulation**
Summary commands**:** Summary statistics for vectors, Data frames, Matrices and lists; Summary tables. **Lectures: 7**

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. **Lectures: 8**

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. **Lectures: 7**

Practical to be done in the Computer Lab using Statistical Software R: **Lecture: 15**
[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

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. Gardener, M.(2012). *Beginning* **R:** *The Statistical Programming Language*, Wiley Publications.

Semester-II
MAT-2103SE: LaTeX and HTML (Including Practical)
Total marks: 50 (Theory-35, Practical-15)

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 web pages

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.	**Lectures: 8**
Unit-2: Graphics in LaTeX; PS Tricks; Beamer presentation.	**Lectures: 7**
Unit 2: HTML, creating simple web pages, images and links.	**Lectures: 8**
Unit-4: Design of web pages.	**Lectures: 7**

Practical: Six practical should be done by each student. The teacher can assign practical from the exercises from [1]. **Lecture: 15**

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

Semester-III
MAT-3103SE: Programming in Python (Including Practical)
Total marks: 50 (Theory-35, Practical-15)
Per week: 2 Lectures, 1 Practical, Credits 3 (2+1)

Course Objectives: The purpose of this course is to help using **Python**, 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 Python syntax and to use Python as a calculator.
ii) Understand the concepts of objects, vectors and data types.
iii) Know about summary commands and summary table in Python.
iv) Visualize distribution of data in Python and learn about normality test.
 v) Plot various graphs and charts using Python.

Unit 1: **Planning and Technique of problem solving:**

Concept of problem solving, Problem definition, Program design, Debugging, Types of errors in programming, Documentation, Flowcharting, decision table, algorithms, Structured programming concepts, Programming methodologies viz. top-down and bottom-up programming

Lectures: 8

Unit 2: 4: **Introduction to Python:**
Structure of a Python Program, Elements of Python, Introduction to Python, Python Interpreter, Using Python as calculator, Python shell, Indentation, Atoms, Identifiers and keywords, Literals, Strings, Operators (Arithmetic operator, Relational operator, Logical or Boolean operator, Assignment, Operator, Ternary operator, Bit wise operator, Increment or Decrement operator).

Lectures: 7

Unit 3: **Creating Python Programs**
Input and Output Statements, Control statements (Branching, Looping, Conditional Statement, Exit function, Difference between break, continue and pass.), Defining Functions, Default arguments.

Lectures: 8

Unit 4: **Python File Operations**
Understanding read functions, read(), readline() and readlines(), Understanding write functions, write() and writelines(), Programming using file Operations, Reading config files in python, Writing log files in python. **Lectures: 7**

Practical / Lab work to be performed: **Lectures: 15**
Section: A (Simple programs)
(*N.B: Student has to perform any four of the following experiments*)

1. Write a menu driven program to convert the given temperature from Fahrenheit to Celsius and vice versa depending upon user's choice.
2. WAP to calculate total marks, percentage and grade of a student. Marks obtained in each of the three subjects are to be input by the user. Assign grades according to the following criteria:
   Grade A: Percentage $>= 80$
   Grade B: Percentage $>= 70$ and < 80
   Grade C: Percentage $>= 60$ and < 70
   Grade D: Percentage $>= 40$ and < 60
   Grade E: Percentage < 40
3. Write a menu-driven program, using user-defined functions to find the area of rectangle, square, circle and triangle by accepting suitable input parameters from user.
4. Write a program to display the first n terms of Fibonacci series.
5. Write a program to find factorial of the given number.
6. Write a program to find sum of the following series for n terms:
$$1 - (2/2!) + (3/3!) - ... + (-1)n - 1\,(n/n!)$$
7. Write a program to calculate the sum and product of two compatible matrices.

Section: B (Visual Python)
(*N.B: Student has to perform any four of the following experiments*)

All the programs should be written using user defined functions, wherever possible.
1. Write a menu-driven program to create mathematical 3D objects
   (i) Curve, (ii) Sphere (iii) Cone (iv) Arrow (v) Ring (vi) Cylinder.
2. Write a program to read n integers and display them as a histogram.

3. Write a program to display sine, cosine, polynomial and exponential curves.

4. Write a program to plot a graph of people with pulse rate p vs. height h. The values of p and h are to be entered by the user.

5. Write a program to calculate the mass m in a chemical reaction. The mass m (in gram) disintegrates according to the formula $m = 60/(t + 2)$, where t is the time in hours. Sketch a graph for t corresponds to m, where $t \geq 0$.

6. A population of 1000 bacteria is introduced into a nutrient medium. The population p grows as follows: $P(t) = (15000(1 + t))/(15 + e)$ where the time t is measured in hours. WAP to determine the size of the population at given time t and plot a graph for P corresponding to t for the specified time interval.

7. Input initial velocity and acceleration, and plot the following graphs depicting equations of motion:

   (i) velocity w.r.t time ($v = u + at$)
   (ii) distance w.r.t time ($s = u * t + 0.5 * a * t * t$)
   (iii) distance w.r.t velocity ($s = (v * v - u * u)/2 * a$)

8. Write a program to show a ball bouncing between 2 walls. (Optional)

Text Books:

1. T. Budd, Exploring Python, TMH, 1st Ed, 2011

2. Allen Downey, Jeffrey Elkner, Chris Meyers , How to think like a computer scientist: learning with Python , Freely available online.2012

Reference Books:

1. Python Tutorial/Documentation www.python.or 2015

2. http://docs.python.org/3/tutorial/index.html

3. http://interactivepython.org/courselib/static/pythonds

4. http://www.ibiblio.org/g2swap/byteofpython/read/

Interdisciplinary Courses (IDC)

Semester-I
MAT-1103ID: Algebra and Trigonometry

Course Objectives: The purpose of this course is to acquaint students with the basic knowledge of algebra and trigonometry.

Course Learning Outcomes: After studying this course the student will be able to:
 i) Know complex number system, idea of complex plane, geometrical interpretation of complex numbers.
ii) Array of numbers i.e. matrices, determinants,
iii) Learn about trigonometric angles, Trigonometrical ratios in terms of circular functions.
iv) Determine height of towers, distances of objects.
v) Know relations, mappings, sequences and progressions and idea of infinite series.

Unit-1: Complex Numbers and Quadratic Equations:
Complex Numbers, Algebra of Complex Numbers, Modulus and argument, Conjugate of a Complex Number, Polar Representation of a complex number, Argand Plane and geometrical representation of complex numbers, geometrical interpretation of the sum, difference, product and quotient of two complex numbers in Argand plane, Quadratic equation and solutions of quadratic equations, simultaneous quadratic equations, Relation between roots and coefficients of a quadratic equation, symmetric functions of roots.   **Lectures: 12**

Unit-2: Matrices
Matrix, Types of Matrices, Sum, difference and product of Matrices, Transpose of a Matrix, Symmetric and Skew Symmetric Matrices, Harmitian and Skew Harmitian Matrices, Invertible Matrices, Determinants and their properties, Area of a Triangle, Minors and Cofactors, Adjoint and Inverse of a square Matrix, Applications of Determinants   and Matrices, Rank of a Matrix, Echelon form.   **Lectures: 11**

Unit-3: Trigonometric Functions
Trigonometrical angles, Trigonometric Functions, Circular functions, Trigonometric functions of Sum and Difference of Two Angles, Multiple and sub-multiple angles, Inverse Trigonometric Functions, Properties of Inverse trigonometric functions.   **Lectures: 11**

Unit-4: Functions, Principles of counting and progressions:
Relations, Functions, Various types of functions, Composite functions, Fundamental Principle of Counting, Permutations, Combinations, Binomial Theorem, Sequences, Series, Arithmetic Progression (A.P.), Geometric Progression   (G.P.),   Relationship   between Arithmetic and Geometric Progression, Infinite series and idea of their convergence.
        Lectures: 11

Text Books:
1. Higher Algebra by B. Das and S. R. Maity
2. Intermediate Trigonometry, by B. C. Das and B. N. Mukharjee
3. College Algebra, by P. L. Ganguli
Reference Books:

1. Algebra, by R. K. Chakraborty

Semester-II
MAT-2103ID: Analytical Geometry and Vectors
Total marks: 50
Per week: 2 Lectures, 1 Tutorial, Credits 3 (2+1)

Course Objectives: The purpose of this course is to acquaint students with the basic knowledge of analytic geometry and vectors.

Course Learning Outcomes: After studying this course the student will be able to:

 i) know equations of straight lines, distance of a point from a line,

ii) have knowledge of conic sections, circle, parabola, ellipse, hyperbola,

iii) know the basic concepts of scalar and vector quantities, addition, difference, product of vectors.

iv) know to find distance between two lines using vectors.

v) learn the position of an object in space, distance between two points in space, shortest distance between two lines in space, angle between two lines in space, direction of a line in space.

Unit-I: Straight Lines

Gradient of a Line, Equations of Straight lines and its various forms, Distance of a point from a line. Transformation of Co-ordinates, Invariants, Pair of Straight lines.

Lectures: 11

Unit-II: Conic Sections

 Sections of a Cone; Circle, Parabola, Ellipse, Hyperbola.   **Lectures: 11**

Unit-III: Vector Algebra

Some Basic Concepts, Scalars and Vectors, Types of Vectors, Addition of Vectors, Multiplication of a vector by a Scalar, Product of Two Vectors. Triple product of vectors.

Lectures: 11

Unit-IV: Three Dimensional Geometry

Coordinate Axes and Coordinate Planes, Three Dimensional space, Coordinates of a Point in Space, Distance between Two Points, Direction Cosines and Direction Ratios of a Line, Equation of a Line in Space, General and symmetric equations of a line, Angle between Two Lines, Shortest Distance between Two Lines.   **Lectures: 12**

Text Books:

1. Analytical Co-ordinate Geometry, by- B. Das
2. Analytical Geometry, By- R. M. Khan

Semester-III
MAT-3103ID: Introductory Calculus
Total marks: 50
Per week: 2 Lectures, 1 Tutorial, Credits 3 (2+1)

Course Objectives: The purpose of this course is to acquaint students with the basic knowledge of calculus.

Course Learning Outcomes: After studying this course the student will be able to:
 i) Gain idea of limit and continuity of a function,
ii) Know rate of change of a variable w. r. t. another variable, differentiation,
iii) Find extreme values of functions; get idea of increasing and decreasing functions,
iv) Learn integration, various methods of integration, integrals of elementary functions,
v) Get idea of differential equations, its origin and solution of differential equations.

Unit-1: Limit and Continuity
Functions of a single variable, Limit of a function of a single variable, $\varepsilon - \delta$ definition of limit, Limits of Trigonometric Functions, Continuity, $\varepsilon - \delta$ definition of Continuity at a point, Continuity in an interval. **Lectures: 11**

Unit-2: Differentiability:
Derivatives, Differentiability, Derivatives of some elementary functions, Derivative of Exponential and Logarithmic Functions, Logarithmic Differentiation, Derivatives of Functions in Parametric Forms, Derivatives of the sum, difference, product and quotient of two functions, Second Order Derivative, Application of Derivatives; Rate of Change of Quantities, Increasing and Decreasing Functions, Maxima and Minima. **Lectures: 11**

Unit-3: Integration:
Introduction, Integration as an Inverse Process of Differentiation (Antiderivatives), Methods of Integration, Integrals of Some elementary functions, Integration by Partial Fractions, Integration by Parts, Standard integrals, Definite Integral, Fundamental Theorem of integral Calculus, method of substitution, Properties of definite integrals. **Lectures: 11**

Unit-4: Application of integrals and Differential Equations
Application of Integrals, Area of a region bounded by simple curves, Differential equations, degree and order of a differential equation, Origin of differential equation, General and particular solutions of ordinary differential equation, Methods of Solution of first order and first degree ordinary differential equations, method of separation of variables, homogeneous differential equations, exact differential equations, linear differential equations, Bernoulli's equation. **Lectures: 12**

Text Books: 1. Differential Calculus, by- B. C. Das and B. N. Mukharjee
2. Integral Calculus, by- B. C. Das and B. N. Mukharjee
3. Ordinary and Partial Differential Equations, by- M. D. Raishinghania.

<u>Minor Courses/Papers (For students from other discipline):</u>

Semester-I

MAT-1104M: Algebra

Total marks: 100 (Theory-60, Internal Assessment-40)
Per week: 3 Lectures, 1 Tutorial, Credits 4 (3+1)

Course Learning Outcomes: This course will enable the students to:
i) Understand the importance of roots of real and complex polynomials and learn various methods of obtaining roots.
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, using rank.
iv) Find eigen values and corresponding eigenvectors for a square matrix.
v) Understanding matrix polynomials.

Unit 1: De Moivre's Theorem and its application, nth roots of unity, Circular functions for complex angles, Hyperbolic functions. **Lectures: 15**
Unit2 Relation between roots and co-efficient of nth degree equation, Symmetric functions of the roots for cubic equations. **Lectures: 15**
Unit-3: Solution of cubic and bi-quadratic equations when some conditions on roots of the equation are given, Cardan's method to solve cubic equations. **Lectures: 15**
Unit 4: System of linear equations, Row reduction and Echelon form, Rank of a matrix, matrix equation $AX = B$, solution set of linear equation , Determinants, Cramer's rule. **Lectures: 15**

Text Books:
1. S. K Mapa : Higher Algebra (Classical).
2. Titu Andreescu and Dorin Andrica, Complex Numbers from A to Z, Birkhauser, 2006.
3. David C. Lay, Linear Algebra and its Applications (3rd Edition), Pearson Education Asia, Indian Reprint, 2007.

Reference Books:
1. Leonard Eugene Dickson (2009). *First Course in the Theory of Equations*. The Project Gutenberg EBook (http://www.gutenberg.org/ebooks/29785)
2. Gilbert Strang, Linear Algebra and its Applications, Thomson, 2007.
3. Das and Mukharjee , Higher Trigonometry .
4. S. Barnard and J.M. Child, Higher Algebra, Arihant, 2016.
5. Bernard Kolman & David R. Hill (2003). *Introductory Linear Algebra with Applications* (7th edition). Pearson Education Pvt. Ltd. India.
6. Stephen and H David: Elementary Linear Algebra (5th Edn.). Academic Press, Elsevier India pvt. Ltd.
7. Burnside, William Snow (1979). The Theory of Equations, Vol. 1 (11th ed.) S. Chand & Co. Delhi. Fourth Indian Reprint.
8. B. Das and S. R. Maiti. Higher Algebra, Asoke Prakasan, Kolkata-12.

Semester-II

<div align="center">

MAT-2104M: Calculus
Total Marks-100
Theory -60, Internal Assessment-40
Per week: 3 Lectures, 1 Tutorial, Credits 4 (3+1)

</div>

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

i) Assimilate the notions of limit of a sequence and convergence of a series of real numbers.

ii) Calculate the limit and examine the continuity of a function at a point.

iii) Understand the consequences of various mean value theorems for differentiable functions.

iv) Sketch curves in Cartesian and polar coordinate systems.

v) Apply derivative tests in optimization problems appearing in social sciences, physical sciences, life sciences and a host of other disciplines.

Unit-1: Higher order derivatives, Successive derivatives, Leibnitz rule and its application, Equations of tangent and normal (Statement only), Curvature, Indeterminate forms, L' Hospital's rule.
Lectures: 15

Unit- 2: Reduction Formulae, derivations and illustrations of reduction formulae of the type $\int x^n e^{ax} dx$, $\int sin^n x dx$, $\int cos^n x dx$, $\int tan^n x dx$, $\int sec^n x dx$, $\int cosec^n x dx$, the corresponding definite integrals. **Lectures: 15**

Unit-3: Line Integral, Arc length, Arc length of parametric curves, Area of surface of revolution Volumes of solids of revolution [volumes by slicing disks and washer method] **Lectures: 15**

Unit-4: Scalar and vector point functions, Limit and continuity of a vector functions, Differentiation of vector point functions. Gradient of a scalar point function, Divergence and Curl of vector point functions, Directional derivative. **Lectures: 15**

Text Books:
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.
2. Howard Anton, I. Bivens & Stephan Davis (2016). *Calculus* (10th edition). Wiley India.
3. George B. Thomas Jr., Joel Hass, Christopher Heil & Maurice D. Weir (2018). *Thomas' Calculus* (14th edition). Pearson Education.
4. *M. Spiegel, Vector Analysis, Schaums Outline Series.*

Reference Books:
1. B.C.Das and B.N.Mukherjee, Differential Calculus, U.N.Dhur & Sons Pvt. Ltd.
2. B.C.Das and B.N.Mukherjee, Integral Calculus, U.N.Dhur & Sons Pvt. Ltd.

<div align="center">

Semester-III

MAT-3104M: Differential Equations
Total Marks: 100: (Theory 60, Internal Assessment 40)
Per week: 3 Lectures, 1 Practical, Credits 4 (3+1)

</div>

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

Course Learning Outcomes: The course will enable the students to:
i) Learn basics of differential equations.
ii) Solve first order linear and non-linear differential equations and linear differential equations of higher order using various techniques.
iii) Apply these techniques to solve and analyze various mathematical models.
iv) Formulate mathematical models in the form of ordinary differential equations to suggest possible solutions of the day to day problems arising in physical, chemical and biological disciplines.

Unit-I: General solution of a differential equation of first order and first degree. Method of separation of variables, Homogeneous differential equations, exact differential equations and integrating factors and special cases.   **Lecture: 18**

Unit 2: Linear differential equations and equations reducible to linear form (Bernoulli equations). First order higher degree equations solvable for x, y and p. Clairaut's form and singular solutions.
Lecture: 15

Unit 3: General solution of homogeneous equation of second order, principle of super position for homogeneous equation, Linear differential equations of higher order with constant coefficients, Cauchy-Euler's equation, method of undetermined coefficients.   **Lecture: 15**

Unit-4: Orthogonal Trajectories, application of differential equation to some geometrical and physical problems.   **Lecture: 12**

Text Books:
4. Ross, Shepley L. (2004). *Differential Equations* (3rd ed.). John Wiley & Sons. India
Reference Books:
   8. B. Rai, D. P. Choudhury & H. I. Freedman (2013). *A Course in Ordinary Differential Equations* (2nd edition). Narosa.
   9. M. D. Raishinghania (2013).*Ordinary and Partial Differential Equations*. S. Chand & Company Ltd.
   10. H. I. Freedman (1980). *Deterministic Mathematical Models in Population Ecology*. Marcel Dekker Inc.
   11. Daniel A. Murray (2003). *Introductory Course in Differential Equations*, Orient.
   12. George F. Simmons (2017). *Differential Equations with Applications and Historical Notes* (3rd edition).CRC Press. Taylor & Francis.

Semester-III
MAT-3204M: Real Analysis
Total marks: 100 (Theory: 60 Internal Assessment: 40)
Per week: 3 Lectures, 1 Tutorial, Credits 4 (3+1)

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 the real line R and its properties 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 and use of convergent sequences in Numerical Analysis.
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 of a real number; Bounded above and bounded below sets, Supremum and infimum of a nonempty subset of R, The completeness property of R, Archimedean property, Density of rational numbers in R, Definition and types of intervals, Nested intervals property.   **Lecture: 15**
Unit-2: Neighborhood of a point in R, Open, closed and perfect sets in R, Connected subsets of R, Cantor set and Cantor function, limit points of a set and its simple applications.   **Lectures: 15**

Unit-3: Convergence of real sequence, Limit of a sequence, Bounded sequence, Limit theorems, Monotone sequences, Monotone convergence theorem, Cauchy sequence, Cauchy's convergence criterion, properly divergence sequences.   **Lectures: 15**

Unit-4: Convergence and divergence of infinite series of positive real numbers, Necessary condition for convergence, Cauchy criterion for convergence; Tests for convergence of positive term series**;** Basic comparison test, Limit comparison test, D'Alembert's ratio test, Cauchy's nth root test, Alternating series, Leibniz test.   **Lectures: 15**

Text Book:
  1. R.G. Bartle and D. R. Sherbert, Introduction to Real Analysis, 3rd Ed., John Wiley and Sons, 2002.
Reference Books:
4. Gerald G. Bilodeau , Paul R. Thie, G.E. Keough, An Introduction to Analysis, Jones & Bartlett, Second Edition, 2010.
5. A. Kumar and S. Kumaresan, Basic Course in Real Analysis, CRC Press, 2014.
6. K. A. Ross, Elementary Analysis: The Theory of Calculus, Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.

Semester-IV
MAT-4104M: Abstract Algebra
Total Marks: 100 (Theory 60, Internal assessment 40)
Per week: 3 Lectures, 1 Tutorial, Credits 4 (3+1)

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: Definition and examples of groups and its elementary properties, examples of Abelian and non-Abelian groups, the group Z_n of integers under addition modulo n and the group U(n) of units under multiplication modulo n. Order of group and order of element of group, The permutation groups. Subgroups properties of subgroups and examples, Cyclic groups, properties of cyclic groups,.

Lectures: 20

UNIT-2: Cycle notation for permutations, properties of permutations, even and odd permutations, alternating group, properties of cosets, Lagrange's theorem. Normal subgroups, factor groups.

Lectures: 15

UNIT-3: Group homomorphisms, properties of homomorphisms, Isomorphism of groups, Fundamental theorem of group homomorphism.   **Lectures: 10**

Unit4: Ring, Integral Domain, Field, Subring and their elementary properties, Quotient ring, Ring homomorphism, Fundamental theorem of ring homomorphism.   **Lectures: 15**

Text Book:

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

Reference Books:

6. John B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.
7. G. Santhanam, Algebra, Narosa Publishing House, 2017.
8. Joseph J. Rotman, An Introduction to the Theory of Groups, 4th Ed., Springer Verlag, 1995.
9. David S. Dummit and Richard M. Foote, Abstract Algebra (2nd Edition), John Wiley and Sons (Asia) Pvt. Ltd, Singapore, 2003.
10. M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.

Semester-IV

MAT-4204M: Complex Analysis
Total marks: 100: (Theory-60, Internal Assessment-40)
Per week: 3 Lectures, 1 Practical, and Credits 4 (3+1)

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

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

i) Understand the significance of differentiability of complex functions leading to the understanding of Cauchy-Riemann equations.

ii) Evaluate the contour integrals and understand the role of Cauchy- Goursat theorem and the Cauchy integral formula.

iii) 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: Analytic Functions and Cauchy-Riemann Equations
Functions of complex variable, Mappings; Mappings by the exponential function, Limits, Theorems on limits, Limits involving the point at infinity, Continuity, Derivatives, Differentiation formulae, Cauchy-Riemann equations, Sufficient conditions for differentiability; Analytic functions and their examples. **Lectures: 20**

Unit 2: Elementary Functions and Integrals
Exponential function, Logarithmic function, Branches and derivatives of logarithms, Trigonometric function, Derivatives of functions, Definite integrals of functions, Contours, Contour integrals and its examples, Upper bounds for moduli of contour integrals. **Lectures: 15**

Unit 3: Cauchy's Theorems and Fundamental Theorem of Algebra
Anti derivatives, Proof of anti derivative theorem, Cauchy-Goursat theorem (Statement only), Cauchy integral formula; an extension of Cauchy integral formula, Consequences of Cauchy integral formula.
Lectures: 15

Unit 4: Series
Power series, Zeros and singularities of analytic functions, Convergence of sequences and series, Taylor series and its examples; Laurent series and its examples. **Lectures: 10**

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

Reference Books:
5. Bak, Joseph & Newman, Donald J. (2010). *Complex Analysis* (3rd ed.). Undergraduate Texts in Mathematics, Springer. New York.
6. Zills, Dennis G., & Shanahan, Patrick D. (2003). *A First Course in Complex Analysis with Applications*. Jones & Bartlett Publishers, Inc.
7. Mathews, John H., & Howell, Rusell W. (2012). *Complex Analysis for Mathematics and Engineering* (6th ed.). Jones & Bartlett Learning. Narosa, Delhi. Indian Edition. (For practicals: Sample materials of files in the form Mathematica/Maple 2011.zip, www.jblearning.com/catalog/9781449604455/).
8. Murray Spiegel, Seymour Lipschutz, John J. Schiller. Complex Variables (Schaum's Outlines) Revised 2nd Edition

Semester-V

<div align="center">

MAT-5104M: Multivariate Calculus

Total Marks: 100 (Theory 60, Internal assessment 40)

Per week: 3 Lectures, 1 Tutorial, Credits 4 (3+1)

</div>

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 conceptual variations while advancing from one variable to several variables in calculus.

ii) Apply multivariable calculus in optimization problems.

iii) Inter-relationship amongst the line integral, double and triple integral formulations.

iv) Applications of multivariable calculus tools in physics, economics, optimization, and understanding the architecture of curves and surfaces in plane and space etc.

v) Realize importance of Green, Gauss and Stokes' theorems in other branches of mathematics.

Unit-I: Functions of several variables, Limits and continuity, Partial differentiation, Higher order partial derivative, Tangent planes, Total differential and differentiability, Jacobians, Change of variables, Taylor's theorem for functions of two variables.   **Lectures: 16**

Unit-II: Extrema of functions of two and more variables, Method of Lagrange multipliers.

<div align="right">

Lectures: 12

</div>

Unit-III: 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 double and triple integrals, Dirichlet integral.   **Lectures: 16**

Unit-IV: Vector Integration, Line integrals, Applications of line integrals: Mass and Work, Green's theorem, Surface integrals, Stokes' theorem (Statement only) and related examples, The Gauss divergence theorem (Statement only) and related examples.   **Lectures: 16**

Text Books:

3. Strauss, Monty J., Bradley, Gerald L., & Smith, Karl J. (2007). *Calculus* (3rd ed.). Dorling Kindersley (India) Pvt. Ltd. (Pearson Education). Delhi. Indian Reprint 2011.
4. James Stewart (2012). *Multivariable Calculus* (7th edition). Brooks/Cole. Cengage.

Reference Books:

3. Jerrold Marsden, Anthony J. Tromba & Alan Weinstein (2009). *Basic Multivariable Calculus*, Springer India Pvt. Limited.
4. George B. Thomas Jr., Joel Hass, Christopher Heil & Maurice D. Weir (2018). *Thomas' Calculus* (14th edition). Pearson Education.

<div align="center">

Semester-V

MAT-5204M: Theory of Real Functions and Riemann Integration

</div>

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 learn:
i) To have a rigorous understanding of the concept of limit of a function.
ii) The geometrical properties of continuous functions on closed and bounded intervals. iii)   The applications of mean value theorem and Taylor's theorem.
iii) Learn about some of the classes and properties of Riemann integrable functions, and the applications of the Fundamental theorems of integration.
iv) Know about improper integrals including, beta and gamma functions.

Unit-I: Limit of a function (ε—δ approach), Theorems on limit, one sided limit, Infinite limits and limits at infinity. Continuous function, sequential criterion for continuity, properties of continuous function, intermediate value theorem.   **Lectures: 15**

Unit-2: Differentiability of a function, Monotone functions, Darboux's theorem, Rolle's theorem, 'Lagrange's Mean Value Theorem, Cauchy's Mean Value Theorem on derivatives and their applications.   **Lectures: 15**

Unit-3: Taylor's theorem with Lagrange's form of remainder, Cauchy's form of remainder, Taylor's and Maclaurin's infinite series. Indeterminate form, L' Hospital theorem.   **Lectures: 15**

Unit 4: Riemann Integration
Riemann integration: Riemann sum and Riemann integrability, Riemann integrability of monotone and continuous functions on intervals, mean value theorems for integrals, Fundamental theorem of integral calculus and the integration by parts.   **Lectures: 15**

 Text Books:
4. R.G. Bartle D.R. Sherbert, Introduction to Real Analysis, 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.
5. Charles G. Denlinger, Elements of Real Analysis, Jones & Bartlett (Student Edition), 2011.
6. Ross, Kenneth A. (2013). *Elementary Analysis*: *The Theory of Calculus* (2nd ed.). Undergraduate Texts in Mathematics, Springer.

Reference Books:
8. Ajit Kumar and S. Kumaresan, A Basic Course in Real Analysis, CRC Press, Indian Edn. 2014.
9. Denlinger, Charles G. (2011). *Elements of Real Analysis*. Jones & Bartlett (Student Edition). First Indian Edition. Reprinted 2015.
10. Ghorpade, Sudhir R. & Limaye, B. V. (2006). *A Course in Calculus and Real Analysis*. Undergraduate Texts in Mathematics, Springer (SIE). First Indian reprint.
11. 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.
12. S. R. Ghorpade and B.V Limay : A Course in Calculus and Real Analysis, Springer 2006.

13. A. Mattuk : Introduction to Real Analysis, Prantic Hall 1999.
14. S. C. Malik and Savita Arora : Mathematical analysis, New Age International Publisher.

Semester-V

MAT-5304M: Numerical Analysis
Total marks: 100: (Theory-60, Internal Assessment-40)
Per week: 3 Lectures, 1 Practical, and Credits 4 (3+1)

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.   **Lectures: 15**

UNIT 2: Lagrange and Newton interpolation: linear and higher order, finite difference operators.
                                                                                    Lectures: 15
UNIT 3: Numerical differentiation: forward difference, backward difference and central difference.
                                                                                    Lectures: 15
UNIT-4: Integration: trapezoidal rule, Simpson's rule.   **Lectures: 15**

Note: Emphasis is to be laid on the algorithms of the above numerical methods.

Practical / Lab work to be performed on a computer: **Lecture: 15**
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. C. F. Gerald and P. O. Wheatley, *Applied Numerical Analysis*, Pearson Education, India,7th edition, 2008

References Books:
1. M. K. Jain, S. R. K. Iyengar and R. K. Jain, *Numerical Methods for Scientific and Engineering Computation*, New age International Publisher, India, 5th edition, 2007.

Semester-VI
MAT-6104M: Metric Spaces and Topological Spaces
Total Marks: 100: (Theory- 60, Internal assessment- 40)
Per week: 3 Lectures, 1 Tutorial, Credits 4 (3+1)

Course Objectives: To understand the 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 various natural and abstract formulations of distance on the sets of usual or unusual entities. Become aware one such formulations leading to metric spaces.
ii) Analyse how a theory advances from a particular frame to a general frame.
iii) Appreciate the mathematical understanding of various geometrical concepts, viz. Balls or connected sets etc. in an abstract setting.
iv) Know about continuity in metric spaces and properties of continuous mappings in metric space.
v) 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.
vi) Know about topologies and properties topological spaces.
vii) Learn about the important topological properties, namely connectedness of metric spaces.

Unit-1: Metric spaces:
Definition and examples of Metric spaces, 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, Derived set, Closure of a set, dense sets, separable spaces. Convergence and completeness, Subspace.   **Lectures: 20**

UNIT 2: Continuity in Metric Spaces: Continuous mappings, sequential criterion and other characterizations of continuity. Uniform continuity.   **Lectures: 10**

Unit-3: Connectedness in metric spaces: Connectedness, connected subsets of **R,** connectedness and continuous mappings.   **Lectures: 10**

Unit4: Topological Spaces: Definition of topological space, Discrete and indiscrete topologies, Co-finite and Co-countable topologies, The usual topology for R, Weakest and strongest topologies, Lower limit topology and upper limit topology, Metrizable space, Union and intersection of topological spaces, Open and closed sets in topological space.   **Lectures: 20**

Text Books:
1. Topology, by James R. Munkres, Pearson
2. Introduction oa Topology and Modern Analysis, by- George F. Simmons, Robert E. Krieger Publishing Company, Malabar, Florida

Semester-VI
MAT-6204M: Number Theory
Total Marks: 100 (Theory-60, Internal assessment-40)
Per week: 3 lectures, 1 Tutorial Credits 4(3+1)

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.   **Lectures: 15**

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.   **Lectures: 15**

Unit-3: Euler's phi function, Euler's theorem, reduced set of residues, some properties of Euler's phi-function.   **Lectures: 15**

Unit-4: Algebraic number theory: Algebraic numbers, number fields, norm, trace, discriminants. Valuations, algebraic integers and integral bases. **Lectures: 15**

Text Books:
3. David M. Burton, *Elementary Number Theory,* 6th Ed., Tata McGrawHill, Indian reprint,2007.
4. GA. Jonesand J. Mary Jones, *Elementary NumberTheo*ry. Undergraduate Mathematics Series (SUMS). First Indian Print. 2005

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

Semester-VI
MAT-6304M: Mechanics
Total Marks: 100: (Theory 60, Internal assessment 40)
Per week: 3 Lectures, 1 Tutorial, Credits 4 (3+1)

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 centre 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. **Lectures: 15**

Unit-2: Friction, C.G of an arc, plane area, surface of revolution, solid of revolution.
Lectures: 15

Unit 3: 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. Work, Energy and momentum, Conservative forces-Potential energy, Impulsive forces, Motion in resisting medium. **Lectures: 15**

Unit-4: Dynamics of Particles: Central orbit, Planetary motion, Kepler's laws. **Lectures: 15**

Text Book:
3. S. L. Loney, The elements of Statics and Dynamics (Vol I & II) Publisher Arihant, 4th Edition 2014.
4. F. Chorlton, Textbook of Dynamics, CBS, Publications 2nd Edition, 1985

Reference books:
6. A. S. Ramsay, Statics, Cambridge University Press, publication year:2009
7. A. S. Ramsay, Dynamics, Cambridge University Press,publication year:2009
8. M. R. Spiegel, Theoretical Mechanics, Schaum's Outlines, 2010.
9. Das and Mukharjee,Statics, U. N. Dhur & Sons Private Ltd.
10. Das and Mukharjee,Dynamics, U. N. Dhur & Sons Private Ltd.

Semester-VII

MAT-7104M: Mathematical Methods
Total Marks: 100 (Theory-60, Internal Assessment-40)
Per week: 3 lectures, 1 Tutorial, Credits 4 (3+1)

Course outcome:

vii) The main objective of introducing this paper in the PG syllabus is that number theory is extensively used in the financial and defence sector of a country whereas Graph theory serves as an Mathematical model in any system involving a binary relation. Both Number and Graph Theory are used in computer application

viii) Students can use the concept of primitive roots and indices for solvability of congruence of higher order. The students can explain the quadratic reciprocity law using Legendere's and Jacobi's symbol.

ix) Students can explain Fibonacci numbers and related identities. Students can also explain partition functions, its graphical representations and generative functions.

x) The students acquire basic knowledge of graphs to model some practical situation by using graphs.

xi) Students can analyze their social networks using graph theory and able to view social network.

xii) Students are able to use a combination of theoretical knowledge and independent thinking in creative investigation of questions in graph theory.

Unit-I: Fredholm Integral Equations: Definition of Integral Equation, Reduction of ordinary differential equations into integral equations. Fredholm integral equations with separable kernels, Eigen values and Eigen functions, Method of successive approximation, Iterative scheme for Fredholm Integral equationsof second kind. **Lectures: 15**

Unit-II: Volterra Integral Equations: Volterra Integral Equations of second kind, Resolvent kernal of Volterra equation and its results, Application of iterative scheme to Volterra equation of the second kind, Convolution type kernals. **Lectures: 15**

Unit-II: Laplace Transform: Basic properties of Laplace Transform, Convolution theorem and properties of convolution, Inverse Laplace Transform. Application of Laplace Transform to solution of ordinary and partial differential equations of initial and boundary value problems. **Lectures: 15**

Unit IV: Calculus of variations: Calculus of variation with one independent variable: Basic ideas of calculus of variations, Euler's equation with fixed boundary of the functional Containing only the first order derivative of the only dependent variable with respect to one independent variable, Variational problems with functional having higher order derivatives of the only dependent variable, general case of Euler's equation, applications. **Lectures: 15**

Text Books:

3. R. P. Kanwal, Linear Integral Equations, Theory and Techniques, Academic Press, New York , 1971
4. M. R. Spiegel, Schaum's Outline Series: Theory and Problems of Laplace Transforms, McGraw-Hill Book Company, 1965

Reference Books:

5. S. G. Mikhlin, Linear Integral Equations (Translated from Russia), Hindustan Book Agency,1960
6. F. B. Hilderbrand, Methods of Applied Mathematics, Dover Publications, 1992
7. R. Courant and D. Hilbert, Methods of Mathematical Physics- Vol- I, Wiley Interscience, NewYork 1953.
8. A. S. Gupta, Calculus of variation with Applications : Prentice Hall of India, 1999

Semester-VII

MAT-7204M: Algebra-I

Total Marks: 100 (Theory-60, Internal Assessment-40)
Per week: 3 lectures, 1 Tutorial, Credits 4 (3+1)

Course outcome:

i) Based on the UGC Syllabus the paper 1016 (Algebra) for 1st semester is prepared in a logical and systematic and simple way so that the students can compare the studies of different algebraic systems called groups, rings, fields and vector spaces.

ii) The students can justify the concept of relations, mappings and composition in the study of algebraic systems called groups and rings. The concept of groups and rings play a significant role in the development of geometry and number theory in recent times.

iii) The syllabus contains a detailed study of field extension and its application to geometry, so that the students are able to solve some antique unsolved problems of geometry by the theory of field extension.

iv) The students are able to explain that the study of vector spaces is nothing but the generalization of the analytical geometry and mechanics.

Unit 1: Direct product and Direct sums of Groups. Decomposable groups. Normal and Subnormal series of groups, composition series, Jordan Holder theorem.   **Lectures: 15**

Unit 2: Divisibility in commutative rings, PID, UFD and their properties. Eisentein's irreducibility criterion.   **Lectures: 15**

Unit 3: Field theory – Extensions of fields. Algebraic and Transcendental elements, Algebraic extensionsof Splitting field perfect Fields, Finite field (Moore's theorem etc.).   **Lectures: 15**

Unit 4: Canonical forms, similarity of linear transforms, Invariant subspaces, Reduction totriangular forms, nilpotent transformations, Primary decomposition theorem, Jordan blocks and Jordan canonical form.   **Lectures: 15**

Text Books:

3. I. N.Herstein, Topics in Algebra, John Wiley& Sons, 1975.
4. K. Hoffman and R. Kunz, Linear Algebra, Prentice Hall, 1965

Reference Books:

6. C. Musili, Introduction to Rings and Modules, Narosa Publishing House, 1994
7. D. S. Malik, J.M. Mordeson and M. K. Sen, Fundamentals of Abstract Algebra, McGrawHill Company, 1997
8. K. B. Datta, Matrix and linear algebra, PHI Pvt. Limited, 2004
9. Seymour Lipschutz, Schaum's Outline of Linear Algebra, The McGraw-Hill Companies, Inc., 2013.
10. S. Singh and Q. Zameruddin, Modern Algebra, Vikash Publishing House, 2006

Semester-VIII

MAT-8104M: Topology

Total Marks: 100 (Theory-60, Internal Assessment-40)
Per week: 3 lectures, 1 Tutorial Credits 4 (3+1)

Course outcome: Students will have knowledge:

i) to identify topological spaces and will be familiar with different types of subsets like open sets, closed sets, neighbourhoods, interior, boundary, derived sets, etc ., together with the ideas of bases, sub bases, relative topology, continuous functions and homeomorphisms. They can be able to classify different spaces like first countable, second countable, separable spaces and give the characterization of these spaces using some important results like Urysohn's lemma , Tietze extension theorem.

ii) To use the idea of compactness and connectedness and give their different characterizations.

iii) To explain the product topology and its relationship with compactness, connectedness, countability, etc. They can also provide examples of metrizable spaces, and can explain the relationship between embedding and metrization.

Unit:I: Closed sets, closure, Dense subsets, Neighbourhood, Interior, Exterior and Boundary, Accumulation Points and Derived sets, Bases and sub- bases. Subbase and Relative Topology, Continuous Functions and Homeomorphism.   **Lectures: 15**

Unit 2: Countable and uncountable sets, First and second Countable spaces, Lindelof's theorem, Separable spaces, Second Countability and Separability, Separation Axioms T_0, T_1, T_2, T_3, T_4 ; their characterizations and basic properties.   **Lectures: 15**

Unit 3: Compactness and Connectedness: continuous functions and compact sets. Basic properties of compactness, Compactness and finite intersection property, Sequentially and Countably compact sets, Local Compactness and one point compactification. Stone-Cech Compactification, Compactness in metric spaces, Equivalence of compactness, Countable compactness and sequential compactness in metric spaces. Connected spaces, connectedness on the real line, components, totally disconnected spaces, Locally connected spaces.   **Lectures: 15**

Unit 4: Tychonoff product topology in terms of standard subbase and its characterizations, Project Maps, Separation Axioms and Product Spaces, Connectedness and Product spaces, Compactness and Product Spaces (Tychonoff's) Theorem. **Lectures: 15**

Text Books:
3. J. R. Munkres, Topology: A first course, Prentice Hall of India, 1974
4. G. F. Simmons,Introduction to Topology and Modern Analysis, McGraw Hill, 2017

Reference Books:
5. K.D. Joshi,Introduction to General Topology, New Age International Private Limited, 2017
6. J. Dugundji,Topology, Allyn and Bacon, 1966 (Reprinted in India By PHI)
7. J. Hocking and G. Young,Topology, Addison Wiley Reading, 1961
8. L. A. Steen and J. A. Seebach,Counter Examples in Topology, Dover Publications, 1995.

Semester-VIII
MAT-8204M: Functional Analysis
Total Marks: 100 (Theory-60, Internal Assessment-40)
Per week: 3 lectures, 1 Tutorial Credits 4 (3+1)

Course outcome: Students will have knowledge:
i) To identify normed linear spaces and Banach spaces and can provide and construct examples of these spaces. They will be familiar with different types of convergence of series in normed linear spaces and various types of subsets like absorbing, balanced, convex sets, convex hull, linear hullof a subset etc. They can be able to classify finite dimensional spaces and can provide different characteristics of such spaces.
ii) To explain the fundamental theorems on normed linear spaces, Hahn-Banach theorem, separation theorem and can give their different applications. They will be familiar with dual spaces of different normed linear spaces and can explain the concepts of reflexivity, separability, weak and weak topology.
iii) To identify inner product spaces, Hilbert spaces and can provide examples of such spaces. They can classify different types of operators like normal, unitary, self adjoint, positive, compact operators with examples and characteristics. They will also be able to explain the underlying idea of fixed point theorem, extreme points and Krein Milman theorem.

Unit 1: Normed linear spaces, Banach spaces and examples, First properties of normed linear spaces, Different types of convergence of series in a normed linear space, Absorbing, balance and convex subsets of a normed linear space, Convex hull, closed convex hull, linear hull and closed linear hull of subsets of normed linear spaces, Continuous and bounded linear operators between normed spaces, Banach space of bounded linear operators. **Lectures: 15**

Unit 2: Fundamental theorems on normed linear spaces: Open Mapping Theorem, Closed Graph Theorem and Uniform Boundedness Principle, Quotient space, three space property, first isomorphism theorem for Banach spaces, vector space version and normed space version of Hahn Banach extension theorem, some applications. **Lectures: 15**

Unit 3: Dual space X* as a Banach space, dual space of R^n, C_0, l_1, l_2 l_p. Adjoint operator of a bounded linear operator, annihilators, dual space of subspace and quotient space.   **Lectures: 15**

Unit 4: Hilbert space, Examples and first properties, Bounded operators and adjoint operator in a Hilbert space, Normal, unitary, self-adjoint and positive operator.   **Lectures: 15**

Text Books:
4. E. Kreyszig, Introductory Functional Analysis with applications, Wiley Classics Lib. Ed. 2007.
5. B.V. Limaye, Functional Analysis, New Age International, 2014
6. R.E. Megginson, An introduction to Banach space theory, Springer, 1998

****
****