Department of Mathematics

School of Mathematics and Computer Sciences

# Outcome Based Education

# Syllabus for Integrated M.Sc. Mathematics

**(For students of I and III year Int. M. Sc. in 2020-2021)**

**Central University of Tamil Nadu**

**Thiruvarur - 610005**

**Department of Mathematics**
**School of Mathematics and Computer Sciences**
**Central University of Tamil Nadu**

## A. Vision

To be an internationally acclaimed Department of Mathematics for its teaching and research that also caters to the educational and occupational needs of the local community.

## B. Mission

**M1** - To provide a world class teaching and research infrastructure.
**M2** - To promote professional working environment that supports innovative thinking and teamwork.
**M3** - To inculcate the art of asking questions, formulating the problem, solving the problem and interpreting the solution for possible applications.

## C. Programme Outcomes (PO)

PO1: Acquire basic knowledge on logic, tools and techniques for formulating problems in to a model.
PO2: Motivate the students to develop problem solving skills.
PO3: Ability to work in teams via group discussion and class room interaction.
PO4: Acquire skills to qualify competitive exams.
PO5: Enhance skills to develop critical thinking
PO6: Develop innovative skills, team work, leadership quality and ethical values
PO7: Students are directed towards lifelong learning through reading course and project

## D. PO to Mission Statement Mapping

| | **PO1** | **PO2** | **PO3** | **PO4** | **PO5** | **PO6** | **PO7** |
|---|---|---|---|---|---|---|---|
| **M1** | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **M2** | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **M3** | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

## E. Programme Specific Outcomes (PSO)

PSO1: Understand the abstract concepts in Algebra, Analysis and Geometry.
PSO2: Inculcate critical and analytical thinking to solve problems.
PSO3: Students are motivated towards inter disciplinary research.
PSO4: Focus on examinations like CSIR, GATE and NBHM etc through assignments.
PSO5: Students are encouraged to do research in reputed institutions.
PSO6: Capable of solving real world problems independently.
PSO7: Communicate Mathematical concepts efficiently.
PSO8: Develop programming skills and problem solving skills to study the mathematical concepts effectively

**F. PO to PSO Mapping**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **PO1** | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 |
| **PO2** | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 |
| **PO3** | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 |
| **PO4** | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 |
| **PO5** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **PO6** | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 |
| **PO7** | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 |

**G: Course Structure**

| Semester | Course code | Course title | Type | Credits |
|---|---|---|---|---|
| I | MAT111 | Mathematics I | Core | 4 |
| I | – | *Physics 1** | Core | 5 |
| I | – | *Chemistry 1** | Core | 5 |
| I | – | *English 1** | AECC | 3 |
| I | – | *AECC 1** | AECC | 2 |
| II | MAT121 | Mathematics II | Core | 4 |
| II | – | *Physics 2** | Core | 5 |
| II | – | *Chemistry 2** | Core | 5 |
| II | – | *English 2** | AECC | 3 |
| II | – | *AECC 2** | AECC | 2 |
| III | MAT211 | Mathematics III | Core | 4 |
| III | MAT212 | Scientific Computing Lab I | Core | 2 |
| III | – | *Physics 3** | Core | 5 |
| III | – | *Chemistry 3** | Core | 5 |
| III | – | *II Language 1** | AECC | 3 |
| III | – | *AECC 3** | AECC | 2 |
| IV | MAT221 | Probability and Statistics | Core | 4 |
| IV | MAT222 | Scientific Computing Lab II | Core | 2 |
| IV | – | *Physics 4** | Core | 5 |
| IV | – | *Chemistry 4** | Core | 5 |
| IV | – | *II Language 2** | AECC | 3 |
| IV | – | *AECC 4** | AECC | 2 |
| V | MAT311 | Algebra I | Core/DSE** | 4 |
| V | MAT312 | Analysis I | Core/DSE** | 4 |
| V | MAT313 | Ordinary Differential equations | Core/DSE** | 4 |
| V | MAT314 | Linear Programming | Core/DSE** | 4 |
| V | MAT315 | Number theory | Core/DSE** | 4 |
| VI | MAT321 | Algebra II | Core/DSE** | 4 |
| VI | MAT322 | Elementary Complex Analysis | Core/DSE** | 4 |
| VI | MAT323 | Basic Graph Theory | Core/DSE** | 4 |
| VI | MAT324 | Numerical analysis | SEC | 3 |
| VI | MAT325 | Numerical analysis - Lab | SEC | 2 |

| Semester | Course code | Course title | Type | Credits |
|---|---|---|---|---|
| VII | MAT411 | Analysis II | Core | 5 |
| VII | MAT412 | Linear Algebra | Core | 5 |
| VII | MAT413 | Probability theory | Core | 5 |
| VII | – | Elective 1* | Elective | 4 |
| VII | – | Elective 2* | Elective | 4 |
| VIII | MAT421 | Measure and Integration | Core | 5 |
| VIII | MAT422 | Topology | Core | 5 |
| VIII | MAT423 | Partial Differential Equations | Core | 5 |
| VIII | – | Elective 3* | Elective | 4 |
| VIII | – | Elective 4* | Elective | 4 |
| IX | MAT511 | Advanced Complex Analysis | Core | 5 |
| IX | – | Elective 5* | Elective | 5 |
| IX | MAT51R | Reading course* | Elective | 2 |
| X | MAT521 | Functional Analysis | Core | 5 |
| X | – | Elective 6* | Elective | 5 |
| X | MAT52P | Project | Elective | 12 |

*The course titles and course codes will be given based on the choice.
**For Int. M.Sc. programme, types of these papers will be Core. For B.Sc. degree by exit option, type of these papers will be mentioned as DSE.

| **Credits/Programmes** | **B.Sc.** | **Int. M.Sc.** | **Core** | **Elective** | **AECC** | **SEC** |
|---|---|---|---|---|---|---|
| *Range of credits by CBCS/UGC* | *Min 120* | *Min 196* | *124 - 132* | *36 - 48* | *20* | *4 - 8* |
| Actual credits | 121 | 197 | 132 | 40 | 20 | 5 |

**List of elective courses.**

| Sl. No. | Course code | Course title | Credits |
|---|---|---|---|
| 1 | MAT01E | Computational Mathematics | 3+2 |
| 2 | MAT02E | Mathematical Methods | 4 or 5 |
| 3 | MAT03E | Fluid Dynamics | 4 or 5 |
| 4 | MAT04E | Transformation Groups | 4 |
| 5 | MAT05E | Design & Analysis of Algorithms | 4 |
| 6 | MAT06E | Number Systems | 4 |
| 7 | MAT07E | Nonlinear Programming | 4 or 5 |
| 8 | MAT08E | Introduction to Lie Algebras | 4 or 5 |
| 9 | MAT09E | Algebraic Number Theory | 4 |
| 10 | MAT10E | Non-linear Partial Differential Equations | 4 or 5 |
| 11 | MAT11E | Advanced Partial Differential Equations | 5 |
| 12 | MAT12E | Differential Geometry | 4 |
| 13 | MAT13E | Delay Differential equations | 4 |
| 14 | MAT14E | Foundations of Geometry | 4 |
| 15 | MAT15E | Commutative algebra | 5 |
| 16 | MAT16E | Discrete Mathematics | 4 or 5 |
| 17 | MAT17E | Advanced graph theory | 4 |
| 18 | MAT18E | Hyperbolic Geometry | 4 or 5 |
| 19 | MAT21E | Discrete Dynamical systems | 4 |

**Generic electives.**

| Sl.No. | Course code | Course title | Credits |
|---|---|---|---|
| 1 | MAT01G | Python for Sciences | 4 |
| 2 | MAT02G | Game theory | 4 |
| 3 | MAT03G | History of Mathematics | 3 |

**H: Evaluation Procedure**

Evaluation is based on Internal Assessment and End Semester Examination. The Internal Assessment consists of the following components: Written tests, Assignments, Practical, Project works, Quiz, seminar, open-book tests, viva voce and online tests via platforms Moodle, MOOCs, Google Classroom, etc.,.

| | Internal Marks | End Semester Marks | Total |
|---|---|---|---|
| **Theory Courses** | 40 | 60 | 100 |
| **Lab Courses** | 60 | 40 | 100 |
| **Project** | 60 | 40 | 100 |
| **Reading Course** | 40 | 60 | 100 |

Internal Assessment evaluation pattern will differ from course to course for each semester. This will have to be declared to the students at the beginning of each semester.

**SEMESTER – I**

**Course Code: MAT111** **Credit: 4**

**Mathematics I**

**Course Outcome (CO)**

On completion of the course the students will be able to

| | Course Outcome | Level |
|---|---|---|
| **CO 1** | understand the concept of convergence, limits, eigen values and eigen vectors. | Remember Understand |
| **CO 2** | solve systems of linear equations including Gauss elimination method and rate related problems | Apply |
| **CO 3** | examine the convergence and divergence of sequences and series using various tests | Analyze |
| **CO 4** | find inverse of matrices using determinants and Cayley-Hamilton theorem, limits of quotient of functions using L'Hospital's rule and limits of convergence sequences, local extremums and Taylor series expansions of functions. | Evaluate |
| **CO 5** | investigate the increasing, decreasing, concavity and convexity of functions | Create |

**Syllabus**

| Units | Content | Hrs. |
|---|---|---|
| **I** | Systems of linear equations, Gauss elimination, and consistency. Subspaces of $R^n$and their dimensions; matrices, systems of linear equations as matrix equations, row-reduced echelon matrices, row-rank, and using these as tests for linear dependence. | 12 |
| **II** | Inverse of a Matrix. Equivalence of row and column ranks. Equivalence and canonical form. Determinants. Eigenvalues, eigenvectors, and the characteristic equation of a matrix. Cayley-Hamilton theorem and its applications. | 12 |
| **III** | Limit of a function motivation and examples, L'Hospital's rule, problems on limits, convergent sequences and their properties, bounded, Cauchy, monotonic sequences, convergent series, tests of convergence of series. | 12 |
| **IV** | (Review of differential calculus), related rate problems, implicit differentiation, tangent of a curve (given in parametric form and in implicit form), motion on a straight Line, local extremums, increasing, decreasing Functions. | 12 |
| **V** | Higher order derivatives, Taylor's series expansion of sin x, cos x, $e^x$ , log(1+x), $(1+x)^m$ (with m is a negative integer or a rational number), Leibnitz rule and its applications to problems of type $e^{ax+b}sin(x)$, $e^{ax+b}cos(x)$, $(ax+b)^n sin(x)$, and $(ax+b)^n cos(x)$, convex and concave functions, curve tracing. | 12 |
| | **References:** 1. G.B. Thomas and R.L. Finney, Calculus and Analytic Geometry, 9th Edition, Pearson, Noida, 2019. 2. B.S. Grewal, Higher Engineering Mathematics, 42nd edition, Khanna Publisher, 2012. | |

| | | |
|---|---|---|
| | 3. E. Kreyszig, Advanced Engineering Mathematics, 8th Edition, JohnWiley & Sons, Singapore, 2006. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO2** | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 |
| **CO3** | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 |
| **CO4** | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 |
| **CO5** | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 |

**Semester II**

**Subject Code: MAT121** **Credits: 4**

**Mathematics II**

**Course Outcome (CO)**

On completion of the course the students will be able to

| | **Course Outcome** | **Level** |
|---|---|---|
| **CO 1** | understand the concepts of vectors, derivatives and integration | Remember Understand |
| **CO 2** | solve problems on vector differentiation and integration in two and three dimensional spaces | Apply |
| **CO 3** | examine the extreme values of functions of two variables, solenoidality, irrotationality, conservativeness of a given vector field and verify Gauss, Green's and Stokes theorems | Analyze |
| **CO 4** | determine Hessian matrix, area, arc length, surface area and volume of surface of revolution, and evaluate double and triple integrals | Evaluate |
| **CO 5** | compile the application of line, surface and volume integrals | Create |

**Syllabus**

| **Units** | **Content** | **Hrs.** |
|---|---|---|
| **I** | Differentiability, total differential, chain rule. Directional derivative, gradient of a scalar field, geometrical meaning, tangent plane, Hessian matrix, extreme values and saddle point for function of two variables. | 12 |
| **II** | Divergence and curl of a vector field, solenoidal field, irrotational field and conservative field, scalar and vector potentials, Laplacian of a scalar field, standard identities involving curl, divergence, gradient and Laplacian operators. | 12 |
| **III** | (Review of Integral Calculus) Area Under Curves, Applications of integrals to find Area, Arc Length, Surface Area and Volumes of Surface of Revolution, Reduction formulae for powers of trigonometric functions, Differentiation under integral sign by Leibnitz rule, Improper integrals. | 12 |
| **IV** | Double integrals, Change of order of integration, Double integrals in polar form, Jacobian determinant, Change of variables, Triple integrals in rectangular co-ordinates, Triple integrals in cylindrical and spherical coordinates. | 12 |
| **V** | ine Integral, Surface integral, Volume Integral. Gauss, Green and Stokes theorems (without proof) and their applications. | 12 |
| | **References:**<br>1. G.B. Thomas and R.L. Finney, Calculus and Analytic Geometry, 9th<br>Edition, Pearson, Noida, 2019.<br>2. B.S. Grewal, Higher Engineering Mathematics, 42nd edition, Khanna Publisher, 2012.<br>3. E. Kreyszig, Advanced Engineering Mathematics, 8th Edition, Johnv Wiley & Sons, Singapore, 2006. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| CO / PSO | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| **CO2** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO3** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| **CO4** | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 |
| **CO5** | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 |

**Semester III**

**Subject Code: MAT211** **Credits: 4**

**Mathematics III**

**Course Outcome (CO)**

On completion of the course the students will be able to

| | **Course Outcome** | **Level** |
|---|---|---|
| **CO 1** | Motivation and understandings towards the origin of ODE's, properties and solutions of first order ordinary differential equations | Remember Understand |
| **CO 2** | Applications of various methods in finding the solutions spaces of ODE's, PDE's and Laplace transforms. | Apply |
| **CO 3** | Analysis of the properties of the ODE's, PDE's and Laplace transforms. | Analyze |
| **CO 4** | Obtains the solutions of first and $2^{nd}$ order ODE's, PDE's using the existing methods in the syllabus. | Evaluate |
| **CO 5** | For the given differential equations, discussion about the types of solutions and the application of Laplace transform method. | Create |

**Syllabus**

| **Units** | **Content** | **Hrs** |
|---|---|---|
| I | Motivation for ODE with some simple models, Definition of Linearity, classifications of ODEs: Linear and nonlinear, homogeneous and non-homogeneous, order and degree. Notion of solution: General, particular and singular solution. First order ODE: Separable equations, Exact equations: Integrating factors and Homogeneous. | 12 |
| II | Homogeneous: Solution space, Linear dependence & independence and their Wronskian, solution of constant coefficient equation. Non-homogeneous: Complimentary solution and particular solutions, method of variation of parameters. | 12 |
| III | Laplace transform, Laplace transforms of standard functions, properties of Laplace transforms, inverse Laplace transform and its properties. | 12 |
| IV | Applications of Laplace transform in solving linear ODE with constant coefficients, system of linear ODE's with constant coefficients. | 12 |
| V | Introduction, Formation of PDEs, Methods for First order PDEs: Lagrange's method and Charpit's Method. Linear PDEs with constant coefficients, Classification of second order PDEs. | 12 |
| | **References**<br>1. E. Kreyszig Advanced Engineering Mathematics, 9th Edition, John Wiley and Sons, Singapore, 2006.<br>2. K.A. Stroud, Advanced Engineering Mathematics, Fourth Edition, Palgrave, London, 2003.<br>3. M. Braun, Differential Equations and their applications, Fourth Edition, Springer, 1993.<br>4. I.N. Sneddon, Elements of Partial Differential Equations, Dover, 2006.<br>5. T. Myint-U. L. Debnath, Linear Partial Differential Equations for Scientists and Engineers, Birkhäuser, Boston, 2014. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| CO / PSO | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| **CO2** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO3** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| **CO4** | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 |
| **CO5** | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 |

**Course Code: MAT212** **Credit: 2**

## Scientific Computing Lab I

**Course Outcome (CO)**

On completion of the course the students will be able to

| | Course Outcome | Level |
|---|---|---|
| **CO 1** | To comfortably use Linux command line, VI editor and necessary basic commands of Linux. | Remember & Understand |
| **CO 2** | To use Python shell as a calculator and to use standard Mathematical functions available in Python. | Apply |
| **CO 3** | To write basic Python programs and functions. | Analyze |
| **CO 4** | To use lists, loops in a program to iterate some well known Numerical methods in Mathematics. | Evaluate |
| **CO 5** | To format the output and use functions from the Numpy and Scipy libraries. | Create |

**Syllabus**

| Unit s | Content | Hrs . |
|---|---|---|
| **I** | (Review)Linux commands; File management and permissions; Using VI editor; Introducing a programming language, syntax, basic tools, simple programmes, etc. | 12 |
| **II** | Basic Tools; First Program file; Handling complex numbers; Functions and loops; Standard math functions; Conditionals; Python keywords and function names; Defining Names; | 12 |
| **III** | Lists in Python; Defining and accessing lists; Loops with lists; Range function; for loop with lists for sorting; Built-in sort functions; else class in loops; slicing lists; lists as stacks; using lists as queues; new lists from old; | 12 |
| **IV** | Data types; Numeric Types; Tuples; Accepting tuple inputs; sorting iterables; the lambda function; Sets; Dictionaries; | 12 |
| **V** | Input and output; Output formatting; Format specifiers; align, sign, width, precision, type; File operations; Functions from Numpy and Scipy libraries. Some mathematical problems for practice and is not limited to the following:<br>(a) Finding GCD of two or more integers;<br>(b) Primality checking; Finding primes upto a given integer;<br>(c)Plottingcurves;<br>(d)Area of a triangle;<br>(e) Angle between vectors;<br>(f) Convert a number in decimal to a given base *n*.<br>(g) Transpose of a matrix; Product of two matrices;<br>(h) Finding the mean; median; mode; standard deviation etc., of a given data; | 12 |
| | **References:**<br>1. M. Lutz and D. Ascher, Learning Python: Powerful Object-Oriented | |

| | | | |
|---|---|---|---|
| | Program- ming, 4th edition, O'Reilly, 2009.<br>2. R. Thareja, Python Programming: Using Problem Solving Approach, Oxford HED, 2017.<br>3. H.P. Langtangen, A Primer on Scientific Programming with Python, Springer- Verlag, Berlin, 2016.<br>4. Y. Zhang, An Introduction to Python and Computer Programming, Springer, Singapore, 2015.<br>5. K.V.Namboothiri, Python for Mathematics Students, Version2.1, March2013. (https://drive.google.com/le/d/0B27RbnD0q6rgZk43akQ0MmRXNG8/view) | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 |
| **CO2** | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 |
| **CO3** | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 |
| **CO4** | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 |
| **CO5** | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 |

**Semester IV**

**Course Code: MAT221** **Credit: 4**

**Probability & Statistics**

**Course Outcome (CO)**

On completion of the course the students will be able to

| | Course Outcome | Level |
|---|---|---|
| **CO 1** | To quantify the uncertainness in various real life situations using the knowledge of probability. | Remember & Understand |
| **CO 2** | To model and predict various events as discrete random variables. | Apply |
| **CO 3** | To model and predict various events as continuous random variables. | Analyze |
| **CO 4** | To estimate the basic statistics in a practical situation and to give a conclusive inference from the available resources. | Evaluate |
| **CO 5** | To test different hypothesis and to establish the validity of the proposed hypothesis with statistical evidence. | Create |

**Syllabus**

| Units | Content | Hrs. |
|---|---|---|
| **I** | Probability, Random experiment; Sample point, Event and Probability; Rules of Probability; Conditional Probability; Independence of Events; Bayes' Rule. Applications. | 12 |
| **II** | Discrete Random variables Definition; sum and linear composite of random variables; Mean and variance; Bernoulli, Binomial, geometric and negative binomial distributions; hypergeometric distribution; Poisson distribution. Applications. | 12 |
| **III** | Continuous Random Variables. Definition; Uniform and exponential distributions; Normal distribution and its properties; Standard normal distribution; Transformation from a general normal distribution to standard normal; Checking for normality of data; Applications. | 12 |
| **IV** | Point Estimation and Confidence Intervals Point estimation of the population mean and standard deviation of a normal distribution; Estimation of proportion; Confidence intervals; Large sample methods; Applications. | 12 |
| **V** | Hypothesis Testing Hypothesis - simple and composite; Null and alternative; Test of Hypothesis; Type I and Type II errors; Level and power of a test; p-value; Tests for mean and standard deviation; Test for proportion; one tail or two tails. Applications. | 12 |
| | **References:**<br>1. A.D. Aczel, and J. Sounderpandian Complete Business Statistics, 7th Edition, McGraw-Hill, Irwin, 2008.<br>2. S.C. Gupta, V.K. Kapoor, Fundamentals of Mathematical Statistics (A Modern Approach), 10th Edition, Sultan Chand and Sons, 2000.<br>3. M.L. Samuels and J.A. Witmer, Statistics for the life sciences, 3rd | |

| | | |
|---|---|---|
| | Edition, Prentice Hall, 2003.<br>5. H. E. Van Emden, Statistics for terrified Biologists, Blackwell Publishing, 2008.<br>6. 5. R. Barlow, Statistics - A guide to the use of statistical methods in the Physical Sciences, Wiley, 1999. | |

**Mapping of Program Outcomes Course Outcomes**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| **CO2** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| **CO3** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| **CO4** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| **CO5** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |

**Course Code: MAT222** **Credit: 2**

## Scientific Computing Lab II

**Course Outcome (CO)**

On completion of the course the students will be able to

| | Course Outcome | Level |
|---|---|---|
| **CO 1** | To use Python and SageMath's built-in commands/functions in a Jupyter notebook. | Remember & Understand |
| **CO 2** | To define functions and run several numerical methods in SageMath. | Apply |
| **CO 3** | To create and manipulate data structures like lists and dictionaries in SageMath. | Analyze |
| **CO 4** | To visualize graphs and other objects in two and three dimensions in SageMath. | Evaluate |
| **CO 5** | To perform basic statistical analysis of a given data using SageMath. | Create |

**Syllabus**

| Units | Content | Hrs. |
|---|---|---|
| **I** | Review of Python commands, Python variables, Symbolic Variables, First computations; Elementary functions and Usual constants; Auto completion; Simple plotting.<br>Symbolic Expressions and Simplification; Transforming expressions; Usual Mathematical functions; Assumptions and pitfalls; Explicit solving of Equations; Equation with no explicit solution; Sums; Limits; Sequences; Power Series Expansions; Series; Derivatives; Partial Derivatives; Integrals; Solving linear systems; Vector Computations; Matrix Computations; Reduction of a Square Matrix | 12 |
| **II** | Programming with Sage; Python language keywords; Sage Keywords; Special symbols in Sage and their uses; Function Calls; Algorithms - Loops; Approximation of Sequence Limits; Conditionals; Procedures and functions; Iterative and recursive methods; Input and Output | 12 |
| **III** | Lists and Other Data Structures; List creation and access; Global list operations; Main methods on lists; Examples of list manipulations; Character Strings; Shared or Duplicated Data Structures; Mutable and Immutable Data Structures; Finite sets; Dictionaries; | 12 |
| **IV** | 2D Graphics Graphical representation of a function; Parametric Curve; Curves in Polar Coordinates; Curve Defined by an implicit function; Data Plot; Displaying solutions of differential equations; Evolute of a curve; 3D Graphics | 12 |
| **V** | Statistics with Sagemath: Basic functions random, mean, median, mode, moving average, std, variance; C Int Stats - stats.IntList, min, max, plot, histogram, product, sum; Distributions - norm, uniform, expon, bernoulli, poisson; Statistical functions - stats.gmean, stats.hmean, stats.skew, stats.histogram2, stats.kurtosis, stats.linregress; Statistical model - linear fit - stats.glm | 12 |
| | **References:**<br>1. P. Zimmermann et.al., Mathematical Computation with Sage, | |

| | | |
|---|---|---|
| | SIAM, Philadelphia, 2018. (http://sagebook.gforge.inria.fr/english.html)<br>2. R. A. Mezei, An Introduction to SAGE Programming: With Applications to SAGE Interacts for Numerical Methods, John Wiley & Sons, 2015.<br>3. G. A. Anastassiou, R. A. Mezei, Numerical Analysis Using Sage, Springer, 2015.<br>4. R. A. Beezer, A First Course in Linear Algebra, University Press of Florida, 2009.<br>6. A. Kumar & S. G. Lee, Linear Algebra with Sage, Kyobo Books,2015. (http://matrix.skku.ac.kr/2015-Album/Big-Book-LinearAlgebra-Eng-2015.pdf )<br>7. https://docs.scipy.org/doc/scipy/reference/stats.html | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 |
| **CO2** | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 |
| **CO3** | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 |
| **CO4** | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 |
| **CO5** | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 |

**SEMESTER – V**

**Course Code: MAT311** **Credit: 4**

**Algebra I**

**Course Outcome (CO)**

On completion of the course the students will be able to

| | Course Outcome | Level |
|---|---|---|
| **CO 1** | understand the basic concept groups and subgroups and rings, integral domain, fields | Remember & Understand |
| **CO 2** | solve problems using properties of groups and rings | Apply |
| **CO 3** | examine the converse part of Lagrange's Theorem and characterization of fields | Analyze |
| **CO 4** | find the irreducible polynomial over the field of rational numbers and given an ideal is maximal or not in a commutative ring. | Evaluate |
| **CO 5** | investigate the given natural number can be written as the product of prime factors (unique up to isomorphism) | Create |

**Syllabus**

| Units | Content | Hrs. |
|---|---|---|
| **I** | Groups: definition and examples: finite, infinite, abelian, cyclic groups; Subgroups: existence of smallest subgroups of a group G containing a subset $S \subset G$;order of an element; Cosets of subgroups; Lagrange's theorem | 12 |
| **II** | Normal subgroups - properties, the subgroup of the form HK and O(HK) - quotient groups, homomorphisms of groups, kernel, image, fundamental theoremof homomorphism | 12 |
| **III** | Automorphisms, Cayley's theorem, permutation groups | 12 |
| **IV** | Rings, commutative ring, integral domain, division ring, field (definitions), finiteintegral domain is a field, ring homomorphism, ideals, quotient rings,maximalideals & prime ideals and their characterizations, quotient field of an integraldomain. | 12 |
| **V** | Euclidean rings: division algorithm, GCD and unique factorization theorem ina Euclidean ring, Principal Ideal domain and Unique factorization domain,Polynomial rings. | 12 |
| | **References:**<br>1. I.N. Herstein, Topics in Algebra, 2nd Edition, John-Wiley & Sons, 1975.<br>2. J.B. Fraleigh, A First course in Abstract Algebra, 7th edition, Pearson Education, 2003.<br>3. D.S. Dummit and R.M. Foote, Abstract Algebra, Third edition, Wiley, 2004.<br>4. M. Artin, Algebra, Prentice-Hall of India, 1994.<br>5. C. Lanski, Concepts in Abstract Algebra, American Math. Society, Indian Edtion,by Universities Press, 2010.<br>6. E. Kreyszig, Advanced Engineering Mathematics, 8th Edition, John Wiley & Sons, Singapore, 2006. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| **CO2** | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 |
| **CO3** | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 |
| **CO4** | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| **CO5** | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 |

**Course Code: MAT312** **Credit: 4**

## Analysis I

**Course Outcome (CO)**

On completion of the course the students will be able to

| | Course Outcome | Level |
|---|---|---|
| **CO 1** | explain the concepts of infimum, supremum and metric spaces | Remember & Understand |
| **CO 2** | demonstrate the convergence of series and power series using various tests | Apply |
| **CO 3** | analyze the topological properties of continuous functions | Analyze |
| **CO 4** | determine the interior point, limit point, closure of subsets of various metric spaces and also the limits of functions, sequences and subsequences | Evaluate |
| **CO 5** | construct functions that have various combination of the properties continuity, uniform continuity and differentiability | Create |

**Syllabus**

| Units | Content | Hrs. |
|---|---|---|
| **I** | Ordered set, ordered field, infimum and supremum, least upper bound property, Archimedian property in $R$, $Q$ is dense in $R$, existence of $n^{th}$ root of unity. | 12 |
| **II** | Metric space, interior point, limit point, open set, closed set, interior, closure, perfect set, Cantor set, compact set, Bolzano's theorem, Heine Borel theorem, connected set, characterization of connected subsets of $R$. | 12 |
| **III** | Subsequential limits, limit infimum and limit supremum, and their properties, convergent series, examples, series of non-negative terms, the number $e$, Root test and ratio test, power series, summation by parts, absolute convergence, addition and multiplication of series, rearrangements of series. | 12 |
| **IV** | Limits functions between metric spaces, continuous functions, uniform continuous functions, examples of continuous but not uniformly continuous functions, continuity and compactness, continuity and connectedness, discontinuities, monotone functions, infinite limits and limit at infinity. | 12 |
| **V** | Differentiable functions, local extremums, mean-value theorems, continuity of derivatives, L'Hospital's rule, Derivatives of higher order and Taylor's theorem, derivatives of vector valued functions. | 12 |
| | **References:**<br>1. W. Rudin, Principles of Mathematical Analysis, Wiley International Edition, 1985.<br>2. T. Apostol, Mathematical Analysis, 2nd Edition, Narosa Publishing House, 1985.<br>3. R.G. Bartle and D.R. Sherbert, Introduction to Real Analysis, 3rd Edition, Wiley International Student edition, 2001. | |

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|---|---|---|
| | 4. A. Kumar, S.Kumaresan, A Basic Course in Real Analysis, CRC Press, 2014.<br>5. K.A. Ross, Elementary Analysis: The theory of Calculus, Springer International Edition, Indian Reprint, New Delhi, 2004. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 |
| **CO2** | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 |
| **CO3** | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 |
| **CO4** | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 |
| **CO5** | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 |

**Subject Code: MAT313** **Credits: 4**

## Ordinary Differential Equations

**Course Outcome (CO)**

On completion of the course the students will be able to

| | Course Outcome | Level |
|---|---|---|
| **CO 1** | recognize the relation between linear algebra, analysis and differential equations | Remember Understand |
| **CO 2** | Apply various methods to solve ordinary differential equations | Apply |
| **CO 3** | analyze the qualitative properties of solutions of differential equations | Analyze |
| **CO 4** | Evaluate the solutions using separation of variables and Fourier series | Evaluate |
| **CO 5** | Develop a method to distinguish singular and ordinary points in the higher order ordinary differential equations | Create |

**Syllabus**

| Units | Content | Hrs. |
|---|---|---|
| **I** | First order differential equations: Introduction, Separable equations, Exact equations: Integrating factors, Orthogonal trajectories, Existence and uniqueness theorem: Picard iteration. | 12 |
| **II** | Second order differential equations: Linear equations with constant coefficients, Non-homogeneous equations, Method of variation of parameters, Method of judicious guessing, Series solution: Singular points, regular singular points; the method of Frobenius, Equal roots, and roots differing by an integer. The method of Laplace transforms, properties of Laplace transforms, Dirac delta function, convolution integral, Higher order equations. | 12 |
| **III** | System of differential equations: The eigenvalue-eigenvector method of finding solutions, Complex roots, Equal roots, Fundamental matrix solutions, the non-homogeneous system of equations: Method of variation of parameters, solving systems by Laplace transforms. | 12 |
| **IV** | Qualitative theory: Stability of linear system of ODEs, Stability of equilibrium solutions, qualitative properties of orbits, Phase portraits of linear systems. | 12 |
| **V** | Separation of variables and Fourier series method: Sturm-Liouville problems.Fourier series, separation of variables, Heat, wave and Laplace equation. | 12 |
| | **References:**<br>1. M. Braun, Differential Equations and their applications, Fourth Edition, Springer, 1993.<br>2. S.L. Ross, Differential Equation, Fourth Edition, JohnWiley& Sons, 1984.<br>3. A.K. Nandakumaran, P.S. Datti and R.K. George, Ordinary Differential Equations: Principles and Applications, Cambridge University Press, 2017.<br>4. T.Myint-U, Ordinary Differential Equations, Elsevier, North-Holland, 1978. | |

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|---|---|---|
| | 5. G.F. Simmons & S.G. Krantz, Differential Equations: Theory, Technique, and Practice, TataMc-Graw Hill, 2012.<br>6. E.A. Coddington, An Introduction to Ordinary Differential Equations, Dover, 1961.<br>7. L. Perko,Differential Equations andDynamical Systems, Third Edition, Springer, 2006.<br>8. M.W. Hirsch, S. Smale, R.L. Devaney, Differential Equations, Dynamical Systems, and an Introduction to Chaos, Third edition, Academic Press, 2013. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| CO / PSO | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8+ |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 |
| **CO2** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO3** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO4** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO5** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Subject Code: MAT314** **Credits: 4**

## Linear Programming

**Course Outcome (CO)**

On completion of the course the students will be able to

| | Course Outcome | Level |
|---|---|---|
| **CO 1** | Understand the history, properties and principles of operations research and linear programming. | Remember Understand |
| **CO 2** | Improve the problems solving skills related to the scientific methods of Operations Research. | Apply |
| **CO 3** | learn the modeling and solutions of linear programming problem | Analyze |
| **CO 4** | Model the assignment and transportation problems and their methods of solutions. | Evaluate |
| **CO 5** | model the real life sequencing problems, theoretical models and their solutions | Create |

**Syllabus**

| Units | Content | Hrs |
|---|---|---|
| I | The Linear programming problem. Problem formulation. - Graphical Method-Definitions of bounded, unbounded and optimal solutions, Linear programming in matrix notation. Definitions of Basic, non-basic variables - basic solutions-slack variables, surplus variables and optimal solution, Simplex method of solution of a linear programming problem, Big M-technique. | 12 |
| II | Two phase simplex method. Degeneracy and Cycling. Revised Simplex Method, Duality Theory Formulation of Dual Problem. Duality theorems. Primal Dual Method and Dual Simplex Method. Sensitivity Analysis. | 12 |
| III | Balanced and unbalanced Transportation problems. Feasible solution-Basic feasible solution - Optimum solution - degeneracy in a Transportation problem. - Mathematical formulation - North West Corner rule - Vogell's approximation method Method of Matrix minima - algorithm of Optimality test. | 12 |
| IV | Balanced and unbalanced assignment problems -restrictions on assignment problem - Mathematical formulation -formulation and solution of an assignment problem (Hungarian method) - degeneracy in an assignment problem. | 12 |
| V | Sequencing problem-n jobs through 2 machines-n jobs through 3 machines -two jobs through m machines - n jobs through m machines. Definition of network, event, activity, critical path, total float and free float - difference between CPM and PERT - Problems. | 12 |
| | **References:**<br>1. K. Swarup, P.K. Gupta, Man Mohan, Operations Research, 9th edition, Sultan Chand & Sons, Chennai, 2001.<br>2. S.I. Gauss, Linear Programming, Second Edition, McGraw-Hill Book Company, New York, 1964.<br>3. A. Ravindran, D.T. Phillips, and J.J. Solberg, Operation research: Principles and Practice, Second Edition, John Wiley & Sons, | |

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|---|---|---|
| | 1987.<br>4. F.S. Hillier and G.J. Lieberman, Introduction to Operations Research, McGrawHill, 8th Edition, 2001. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| CO / PSO | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO2** | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 |
| **CO3** | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 |
| **CO4** | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 |
| **CO5** | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 |

**Subject Code: MAT315** **Credits: 4**

## Number Theory

**Course Outcome (CO)**

On completion of the course the students will be able to

| | Course outcome | Level |
|---|---|---|
| **CO 1** | Understand the concepts of divisibility of integers, fundamental theorem of arithmetic. | Remember Understand |
| **CO 2** | Apply the notion of congruence, and its properties. | Apply |
| **CO 3** | Examine the Dirichlet product of two arithmetic functions, Bell series and their properties. | Analyze |
| **CO 4** | Solve problems on number theory. | Evaluate |
| **CO 5** | Find the properties of Euler's totient function, Mobius function, Mangoldt function, Liouville's function, multiplicative functions, and completely multiplicative functions. | Create |

**Syllabus**

| Units | Content | Hrs. |
|---|---|---|
| **I** | Divisibility, greatest common divisor and its properties, Euclidean algorithm, primes, Unique factorization theorem. Mobius function $\mu$, and Euler's totient function $\varphi$, relation between $\mu$ and $\varphi$, product formula for $\varphi$, properties of $\varphi$. | 12 |
| **II** | Dirichlet product of arithmetical functions, Dirichlet inverses, and Mobius inversion formula, Mangoldt function and its properties, multiplicative functions and Dirichlet product, inverse of completely multiplicative function. | 12 |
| **III** | Liouville's function $\lambda(n)$, divisor functions $d_a(n)$, Generalized convolution, Generalized Mobius inversion formula, Bell series of arithmetic function, Bell series and Dirichlet product, Derivative of arithmetic function, Selberg identity | 12 |
| **IV** | Definition and basic properties of congruences, residue classes and complete residue system, linear congruences, reduced residue systems, Euler-Fermat theorem, Little Fermat theorem, Polynomial congruence modulo $p$, Lagrange's theorem, Applications of Lagrange's theorem, Wilson's theorem, Wolstenholme's theorem | 12 |
| **V** | Simultaneous linear congruences, Chinese remainder theorem, Applications of Chinese remainder theorem, polynomial congruences with prime power moduli, Principle of cross classification and its applications. | 12 |
| | **References.** 1. T. M. Apostal, Analytic Number Theory, Springer Verlag, New York, 1976. 2. I. Niven, H.S. Zukerman, H.L. Montgomery, An Introduction to Theory of Numbers, Fifth Edition, John Wiley & Sons inc., New York, 1991. 3. D. M Burton, Elementary Number Theory, Sixth Edition, McGraw-Hill, NewYork, 2007. | |

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|---|---|---|
| | 4. S.G. Telang, Number Theory, Tata McGraw-Hill, 2003 | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| CO / PSO | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 |
| **CO2** | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 |
| **CO3** | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| **CO4** | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 |
| **CO5** | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 |

**Semester VI**
**Subject Code: MAT321** **Credits: 4**

**Algebra II**

**Course Outcome (CO)**
On completion of the course the students will be able to

| | Course Outcome | Level |
|---|---|---|
| **CO 1** | have a thorough introduction to the subject | Understand |
| **CO 2** | appreciate Sylow's theorems and its applications | Apply |
| **CO 3** | solve problems on conjugacy classes, Sylow's theory, field extensions and solvable groups | Analyze |
| **CO 4** | Find the dimension of the constructed extension fields | Evaluate |
| **CO 5** | have a detailed knowledge on Galois theory | Create |

**Syllabus**

| Units | Content | Hrs. |
|---|---|---|
| **I** | Conjugacy classes, class equations, Cauchy's theorem for abelian groups, Sylow's theorem for abelian groups, Cauchy's theorem, number of conjugacy classes in S n , conjugate of a subgroup. | 12 |
| **II** | Sylow's theorem, three parts of Sylow's theorem, applications of Sylow' theorem, Structure theorem for finite abelian groups (without proof). | 12 |
| **III** | Fields, Field extensions, finite extension, algebraic extension, roots of polynomials, splitting field. | 12 |
| **IV** | More about roots, simple extension, splitting field of a polynomial, elements of Galois theory, Galois group, fixed field, theorem on symmetric polynomials, normal extension, | 12 |
| **V** | Fundamental theorem of Galois theory, Solvable group, solvable by radicals, Abel's theorem. | 12 |
| | **References:**<br>1. I.N. Herstein, Topics in Algebra, 2nd Edition, John-Wiley & Sons, 1975.<br>2. D.S. Dummit and R.M. Foote, Abstract Algebra, Third edition, Wiley, 2004.<br>3. N. Jacobson, Basic Algebra I, Second Edition, Dover, 2009.<br>4. M. Artin, Algebra, Prentice Hall India, 1996.<br>5. J. Rotman, Galois Theory, Springer, 1998. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| CO / PSO | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| **CO2** | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| **CO3** | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| **CO4** | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| **CO5** | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |

**Subject Code: MAT322** **Credits: 4**

## Elementary complex analysis

**Course Outcome (CO)**

On completion of the course the students will be able to

| | Course outcome | Level |
|---|---|---|
| **CO 1** | learn and understand the basics of analytic functions. | Remember Understand |
| **CO 2** | solve problems using Cauchy's integral formula and Cauchy's residue theorem. | Apply |
| **CO 3** | check the analyticity of a given function, to apply C-R equations to find the harmonic conjugate, to find the radius of convergence of a power series. | Analyze |
| **CO 4** | compute Laurent series expansion and classify the types of singularities, the number of zeroes of a polynomial in an annulus with centre zero. | Evaluate |
| **CO 5** | find a linear fractional transform with a given values at three specific points, cross ratios, and to check if the given three points are on a line or a circle. | Create |

**Syllabus**

| Units | Content | Hrs. |
|---|---|---|
| **I** | (Quick Review: Complex numbers and geometrical representations - Cauchy-Schwarz Inequality and Schwarz's inequality - principal argument of a complex number -nth root of a complex number) - Sequences and series of complex numbers, limit and continuity of complex valued functions of a complex variable, Extended complex numbers and stereographic projection. | 12 |
| **II** | Complex and partial differentiability - Cauchy-Riemann equations – Harmonic function - Harmonic conjugate - Problems on finding harmonic conjugates, finding analytic functions from a given harmonic function as its real(or imaginary) part . | 12 |
| **III** | Radius of convergence of a Power series, differentiability and uniqueness of power series -problems on finding radius convergence of power series - Polynomial and rational functions, Lucas' theorem, existence of partial fraction expansion of rational functions - Linear fractional transforms / Mobius transforms - Mobius transform maps circles and lines to circles and lines - Cross ratios - Symmetric points with respect to circle or straight line. | 12 |
| **IV** | Piece-wise smooth curve - Line Integrals and their properties - Cauchy's theorem (without proof)- Cauchy's integral formula - Evaluation of integrals using Cauchy's integral formula (problems only), Types of singularities, characterization of removable singularity - Taylor's theorem - Laurent series (without proof)- Zeros, poles and singularities-problems on expanding Laurent series - characterization of singularities using Laurent series. | 12 |
| **V** | Residue definition -Problems on finding residues of functions at isolated singularities - Cauchy's residue theorem (without proof) - Evaluation of integrals using Cauchy's residue theorem- Evaluation of real integrals (problems only) - Evaluating number of zeroes of polynomials using Rouche's theorem. | 12 |

**References**

1. J.W. Brown and R.V. Churchill, Complex Variable and Applications, McGraw Hill, 2008.
2. J.B. Conway, Functions of one complex variable, 2nd edition, Springer-Verlag, 1978.
3. S. Ponnusamy, Foundations of Complex Analysis, 2nd edition, Narosa
   Publishing House, 2005.
4. L.V. Ahlfors, Complex Analysis, 2nd edition, McGraw-Hill, New York, 1966.

**Mapping of Program Specific Outcomes with Course Outcomes**

| CO / PSO | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 |
| **CO2** | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 |
| **CO3** | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 |
| **CO4** | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 |
| **CO5** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Course Code: MAT323** **Credit: 4**

## Basic Graph Theory

**Course Outcome (CO)**

On completion of the course the students will be able to

| | Course Outcome | Level |
|---|---|---|
| **CO 1** | understand the concept of graphs, subgraphs and graph isomorphisms | Remember & Understand |
| **CO 2** | demonstrate Cayleys's formula to count the spanning trees of $K_n$ | Apply |
| **CO 3** | distinguish between connectivity and edge connectivity, between vertex coloring and edge coloring | Analyze |
| **CO 4** | determineEulerian graphs, planar graphs and chromatic polynomial of a given graph | Evaluate |
| **CO 5** | translate real-world problems in to graph theoretic models | Create |

### Syllabus

| Units | Content | Hrs. |
|---|---|---|
| **I** | Graphs, subgraphs, isomorphism of graphs, degrees of vertices, paths and connectedness, trees, counting the number of spanning trees and Cayley's Formula. | 12 |
| **II** | Vertex cuts, edge cuts, connectivity, edge-connectivity, blocks and Eulerian graphs. | 12 |
| **III** | Hamilton graphs - Necessary conditions - Dirac's theorem - closure of a graph - a criterion for Hamilton graphs using closure of a graph and Chvatal's theorem. | 12 |
| **IV** | Edge colourings, vertex colourings, critical graph, properties of critical graphs and chromatic polynomials. | 12 |
| **V** | Planar and nonplanar graphs, Euler's Formula and its consequences, $K_n$ and $K_{3,3}$ are Nonplanar graphs, dual of a plane graph, The Four Color Theorem (without proof) and the Heawood Five-Color Theorem and Kuratowski's Theorem (without proof). | 12 |
| | **References:**<br>1. J.A. Bondy and U.S.R. Murty, Graph Theory with Applications, North-Holland, 1982.<br>2. G. Chartrand, L. Lesniak and P. Zhang, Graphs and Digraphs, Fifth Edition, CRC press, 2011.<br>3. D.B. West, Introduction to Graph Theory, Second Edition, PHI Learning Private Ltd, New Delhi, 2011.<br>4. R. Balakrishnan and K. Ranganathan, A Textbook of Graph Theory, Second Edition, Springer, 2012. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 |
| **CO2** | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 |
| **CO3** | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 |
| **CO4** | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 |
| **CO5** | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 |

**Subject Code: MAT324** **Credits: 3**

## Numerical Analysis

**Course Outcome (CO)**

On completion of the course the students will be able to

| | Course Outcome | Level |
|---|---|---|
| **CO 1** | demonstrate the theory about polynomials and accuracy about numerical methods. | Remember Understand |
| **CO 2** | solve algebraic and transcendental equations and study the rate of convergence | Apply |
| **CO 3** | Analyze the properties about polynomials to develop methods to perform integration and differentiations. | Analyze |
| **CO 4** | Evaluate numerically the approximate solution of ordinary differential equations | Evaluate |
| **CO 5** | formulate numerical procedure when real world problems are modelled by the system and understand how the iteration gives approximate solution to the system. | Create |

**Syllabus**

| Units | Content | Hrs. |
|---|---|---|
| **I** | Algebraic and transcendental equations: Bisection method, Iteration method, Regula-Falsi method, Secant method, Newton-Raphson's method, Error analysis, Rate of convergence. | 12 |
| **II** | System of Equations: Linear system (Direct methods): Gauss elimination, Pivoting strategies, Vector and matrix norms, Error estimates and condition number, LU decomposition. Linear system (Iterative methods): Gauss-Jacobi and Gauss-Seidel - Convergence analysis; Eigenvalue problem: Power method – Jacobi for a real symmetric matrix. | 12 |
| **III** | Interpolation: Lagrange's interpolation - Error analysis - Newton's divided differences - Newton's finite difference interpolation - Optimal points for interpolation - Piecewise polynomial Interpolation: Piecewise linear and Spline interpolation | 12 |
| **IV** | Numerical differentiation and Integration: Numerical differentiation based on interpolation, finite differences. Numerical integration: Newton Cotes formulae, Gaussian quadrature, Trapezoidal and Simpson's rules, Error analysis. Quadrature rules for Multiple integrals. | 12 |
| **V** | Ordinary Differential Equations: Single-Step methods: Euler's method and Modified Euler's method, Taylor series method - Runge-Kutta method of fourth order -Multistep methods: Adams-Bashforth -Moulton methods - Stability analysis- Boundary value problems: Finite Difference method. | 12 |
| | **References:**<br>1. K.E. Atkinson, An Introduction to Numerical Analysis, Wiley, 1989<br>2. R.L. Burden, J.D. Faires, Numerical Analysis, 9th Edition, Cengage Learning, 2011.<br>3. D. Kincaid and W.Chenney, Numerical Analysis: Mathematics of Scientific Computing, Brooks/Cole Pub. 2nd Edition, 2002.<br>4. G.M. Phillips and P.J. Taylor, Theory and Applications of Numerical Analysis, 2nd Edition, Elsevier, New Delhi, 2006. | |

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|---|---|---|
| | 5. A. Quarteroni, F. Saleri and P. Gervasio, Scientific computing with MATLAB and Octave, Springer, 2006.<br>6. S.D. Conte, and C. de Boor, Elementary Numerical Analysis, Third Edition, McGraw-Hill Book Company, 1983.<br>7. B. Bradie., A Friendly Introduction to Numerical Analysis, 1st Edition, Pearson Education, New Delhi, 2007. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| CO / PSO | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 |
| **CO2** | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 |
| **CO3** | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 |
| **CO4** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO5** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Subject Code: MAT325** **Credits: 2**

**Numerical Analysis Lab**

**Course Outcome (CO)**

On completion of the course the students will be able to

| | Course Outcome | Level |
|---|---|---|
| **CO 1** | Remember program for simple arithmetic operations with scalars, vectors and matrices. | Remember Understand |
| **CO 2** | implement computer program to solve algebraic and transcendental equations | Apply |
| **CO 3** | Test the problem by producing two-dimensional and three-dimensional plots | Analyze |
| **CO 4** | Select computer algorithm to solve differential equations | Evaluate |
| **CO 5** | develop a computer algorithm to analyze the consistency, stability and convergence of a numerical methods. | Create |

**Syllabus**

| Units | Content | Hrs. |
|---|---|---|
| I | Laboratory Assignments (not limited to):<br>1. To find the roots of the Algebraic and Transcendental equations using Bisection method, Regula-Falsi method, Newton-Raphson method, Secant method and Iterative method<br>2. To solve the system of linear equations using Gauss elimination method, Gauss Jacobi method, Gauss-Seidal method and Gauss Jordan method<br>3. To determine the Eigen values and Eigen vectors of a Square matrix.<br>4. To find the largest eigenvalue of a matrix by power method.<br>5. To implement Numerical Integration using Trapezoidal rule.<br>6. To implement Numerical Integration using Simpson 1/3 rule.<br>7. To implement Numerical Integration Simpson 3/8 rule<br>8. To implement Newton's Forward/Backward Interpolation formula<br>9. To implement Gauss Forward/Backward Interpolation formula<br>10. To implement Newton's Divided Difference formula<br>11. To implement Langrange's Interpolation formula<br>12. To find numerical solution of ordinary differential equations by Euler's method, Runge-Kutta method and Adams-Bashforth method | 45 |
| | **References:**<br>1. K.E. Atkinson, An Introduction to Numerical Analysis, Wiley, 1989<br>2. R.L. Burden, J.D. Faires, Numerical Analysis, 9th Edition, Cengage Learning, 2011.<br>3. D. Kincaid and W. Chenney, Numerical Analysis: Mathematics of Scientific Computing, Brooks/Cole Pub. 2nd Edition, 2002.<br>4. G.M. Phillips and P.J. Taylor, Theory and Applications of Numerical Analysis, 2nd Edition, Elsevier, New Delhi, 2006. | |

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|---|---|---|
| | 5. A. Quarteroni, F. Saleri and P. Gervasio, Scientific computing with MATLAB and Octave, Springer, 2006.<br>6. S.D. Conte, and C. de Boor, Elementary Numerical Analysis, Third Edition, McGraw-Hill Book Company, 1983.<br>7. B. Bradie., A Friendly Introduction to Numerical Analysis, 1st Edition, Pearson Education, New Delhi, 2007. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| CO / PSO | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| **CO2** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO3** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO4** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO5** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Semester VII**

**Subject Code: MAT411** **Credits: 5**

## Analysis II

**Course Outcome (CO)**

On completion of the course the students will be able to

| | Course outcome | Level |
|---|---|---|
| **CO 1** | understand the concepts of Riemann-Stieltjes integrals, and their properties. | Remember<br>Understand |
| **CO 2** | solve problems using the Gauss, Stokes, and Divergence theorems | Apply |
| **CO 3** | examine the relations among the partial derivatives and total derivative, interchanging the order of the derivatives, interchanging the order of integrations. | Analyze |
| **CO 4** | discuss the proofs of Green's theorem, Stoke's theorem and Gauss divergence theorem. | Evaluate |
| **CO 5** | find examples to explain the differences between point-wise and uniform convergence of sequences of functions, to know what are the properties that are preserved under uniform convergence. | Create |

**Syllabus**

| Units | Content | Hrs. |
|---|---|---|
| **I** | Riemann integrable functions, Riemann - Stieltjes integrable functions, equivalence of Riemann integrable functions, examples, properties of Riemann-Stieltjes integrable functions, Differentiation and integration, total variation of rectifiable curves. | 12 |
| **II** | Point-wise and uniform convergence of sequence and series of functions, Examples of sequence (series) of functions for which point-wise convergence does not preserve, uniform convergence and limit, uniform convergence and Riemann-Stieltjes integral, limit and differentiation. | 6 |
| **III** | Partial derivatives and total derivative of differentiable scalar valued (and vector valued) functions on $R^n$, Chain rule, Mean-value theorem and applications, Higher order derivatives, interchanging order of derivatives; Taylor's theorem for scalar valued valued functions, Inverse mapping theorem, Implicit mapping theorem | 14 |
| **IV** | Multiple integrals, Properties of integrals, Existence of integrals, iterated integrals, change of variables. | 14 |
| **V** | Curl, Gradient, divergence, Line integrals, surface integrals, Proofs of theorems of Green, Gauss and Stokes | 14 |
| | **References.**<br>1. 1. W. Rudin, Principles of Mathematical Analysis, Wiley International Edition, 1985.<br>2. T.M. Apostol, Calculus Vol.2, Multi-Variable Calculus and Linear Algebra with Applications to Differential Equations and Probability, 2nd Edition, John Wiley & Sons, 1969.<br>3. T. Apostol, Mathematical Analysis, 2nd Edition, Narosa Publishing House, 1985. | |

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|---|---|---|
| | 4. R.G. Bartle and D.R. Sherbert, Introduction to Real Analysis, 3rd Edition, Wiley International Student edition, 2001.<br>5. K.A. Ross, Elementary Analysis: The theory of Calculus, Springer International Edition, Indian Reprint, 2004. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| CO / PSO | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 |
| **CO2** | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 |
| **CO3** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO4** | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| **CO5** | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 |

**Subject Code: MAT412** **Credits: 5**

## Linear Algebra

**Course Outcome (CO)**

On completion of the course the students will be able to

| | Course Outcome | Level |
|---|---|---|
| **CO 1** | understand the concepts of vector spaces, subspaces and linear transformations | Understand |
| **CO 2** | appreciate the geometry of vector spaces using parallelogram law, Pythagorean theorem and triangle inequality | Apply |
| **CO 3** | know the relation between matrices and linear transformations | Analyse |
| **CO 4** | know the concepts of diagonlization, Jordan form and rational canonical form | Evaluate |
| **CO 5** | know the difference between various kind of operators like self-adjoint operators, Normal operators etc. | Create |

**Syllabus**

| Units | Content | Hrs. |
|---|---|---|
| **I** | Vector Spaces and its properties; Examples; Subspaces; Smallest Subspace containing a give subset; Span and Linear Independence; Bases; Dimension; | 12 |
| **II** | Linear Maps; Null spaces and Ranges; Rank-Nullity Theorem; Matrix of a Linear Map; Invertibility; Review of polynomials with complex and real coefficients; Eigenvalues and Eigenvectors; Existence of eigenvalue; Triangularization and Diagonalization of linear transformations; Invariant subspaces. | 12 |
| **III** | Inner-product spaces; Pythagorean Theorem; Triangle Inequality; Parallelogram Law; Orthonormal Basis - Gram-Schmidt process; Orthogonal Projections and its properties; Definition of adjoint operator and its properties. | 12 |
| **IV** | Linear operators on inner-product spaces; Self-adjoint and Normal operators; Spectral Theorem. | 12 |
| **V** | Operators on complex vector spaces; Generalized eigenvectors; Characteristic polynomial and Cayley-Hamilton Theorem; Minimal polynomial; Jordan Form; Rational Canonical Form (if time permits). | 12 |
| | **References:**<br>1. S. Axler, Linear Algebra Done Right, Second edition, Springer, 1997.<br>2. S. Kumaresan, Linear Algebra - A Geometric Approach, 12th reprint, Prentice Hall of India, 2011.<br>3. G. Strang, Linear Algebra and its applications, 8th Indian reprint Indian<br>edition, Cengage Learning, 2011.<br>4. S.H. Friedberg and A.J. Insel, L.E. Spence, Linear Algebra, 4th edition, | |

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|---|---|---|
| | Prentice-Hall of India, 2003.<br>5. K. Hoffman and R. Kunze, Linear Algebra, 2nd edition, Prentice Hall of India, 2003. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| CO / PSO | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 |
| **CO2** | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 |
| **CO3** | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 |
| **CO4** | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 |
| **CO5** | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 |

**Subject Code: MAT413** **Credits: 5**

## Probability Theory

**Course Outcome (CO)**

On completion of the course the students will be able to

| | Course Outcome | Level |
|---|---|---|
| **CO 1** | understand the concept of random variables and the probability distributions | Remember Understand |
| **CO 2** | apply Poisson, Gamma, Chi-square and other distributions to solve real life problems | Apply |
| **CO 3** | compare discrete and continuous random variables | Analyze |
| **CO 4** | derive the probability density function, distribution function of various random variables, and derive the marginal and conditional distributions of bivariate random variables | Evaluate |
| **CO 5** | translate real-world problems into probability models | Create |

**Syllabus**

| Units | Content | Hrs. |
|---|---|---|
| **I** | Differentiability, total differential, chain rule. Directional derivative, gradient of a scalar field, geometrical meaning, tangent plane, Hessian matrix, extreme values and saddle point for function of two variables. Random Experiments and Probability Sample space; Sample points; Events; Axioms of Probability; Probability of union of events; Sample spaces with equally likely outcomes; Probability as a continuous set function. | 12 |
| **II** | Conditional Probability and independence of events: Motivation for conditional probability; Shrinking of sample space when it is known that a certain event occurred; Conditional probability; Independence of events; independent events and disjoint events; Bayes' Theorem and posterior probabilities. | 12 |
| **III** | Discrete Random Variables: Definition; Distribution; Examples; Probability mass function and distribution function; Properties of a distribution function; Expected value; Variance of a random variable; Bernoulli, Binomial, Geometric and negative binomial distributions; Poisson distribution and Hypergeometric distribution; Distribution functions, means and variances of various distributions mentioned above; Poisson random variable as an approximation of Binomial random variable. | 12 |
| **IV** | Continuous random variables: Probability density function and Distribution function; Examples; Expectation and variance of continuous random variables; Need they always exist (Cauchy Distribution); Uniform distribution; Normal distribution; Use of the table of probabilities of Standard normal distribution; Normal approximation of Binomial distribution; Exponential distribution; Gamma, Chi-square, Beta and F distributions; Weibull and Cauchy distributions; Chebychev's inequality and its applications. | 12 |
| **V** | Joint distribution of two or more random variables; Joint distribution | 12 |

| | | |
|---|---|---|
| | functions; Examples; Covariance between two random variables; Independence of random variables; Uncorrelatedness and independence; pairwise independence and mutual independence; Sums of independent random variables; Marginal and Conditional distributions; Conditional distribution: discrete and continuous cases; Bivariate normal distributions, Weak law of Large Numbers; Statements of Central Limit Theorem. | |
| | **References:**<br>1. S. Ross, A first Course in Probability, 6th Edition, Pearson Education, 2006.<br>2. A. Dasgupta, Fundamentals of Probability: A First Course, Springer, 2010.<br>3. W. Feller, An introduction to Probability Theory and its Applications, Volume 1, 2nd Edition, Wiley, 1969.<br>4. R.V. Hogg, J. McKean and A.T. Craig, Introduction to Mathematical Statistics, Pearson Education, sixth edition, 2005. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| CO /PSO | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO2** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO3** | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 |
| **CO4** | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 1 |
| **CO5** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Semester VIII**
**Subject Code: MAT421** **Credits: 5**

## Measure and Integration

**Course Outcome (CO)**

On completion of the course the students will be able to

| | Course Outcome | Level |
|---|---|---|
| CO 1 | to understand the concept of measure of a Lesbegue Measurable Subset of R as the generalization of length of an interval. | Remember Understand |
| CO 2 | to understand measurability of functions | Apply |
| CO 3 | to understand the definition of a Lebesgue Integral | Analyze |
| CO 4 | to understand convergence theorems | Evaluate |
| CO 5 | to understand abstract measure theory | Create |
| CO 6 | to be able to solve problems on these topics | |

**Syllabus**

| Units | Content | Hrs. |
|---|---|---|
| I | A quick review (in about 2 lectures) of Riemann integral. Definition of Lebesgue outer measure of a subset of R and its properties -Definition of a Lebesgue measurable set - The sigma-algebra of Lebesgue measurable sets. Every interval is Lebesgue measurable - Cantor (ternary) set - The inner and outer regularity of Lebesgue measurable sets - Borel sigma algebra. | 12 |
| II | Lebesgue Measurable functions on R - liminf and limsup of measurable functions - simple functions - any non-negative measurabl e function is the limit of an increasing sequence of simple functions - Existence of non-measurable sets, Lebesgue integrals of simple functions, non-negative measurable functions, any real values measurable function, complex valued functions on R and their properties. | 12 |
| III | Fatou's lemma, Monotone convergence theorem, Dominated and bounded convergence theorems, integral of series, Necessary and sufficient condition for Riemann integrability - Riemann integrability implies the Lebesgue integrability | 12 |
| IV | Abstract measure theory: $\sigma$-algebra B of subsets of a set $X$, measurable space, measure space, integral of measurable functions over abstract measure space. Signed measure, Hahn decomposition, Jordan decomposition, Lebesgue decomposition theorem - Radon-Nykodim theorem | 12 |
| V | $L^p$ spaces, for $1\leq p<\infty$ and the space $L^\infty$-space -Holder's inequality, Minkowski's inequality – $L^p$ spaces asmetric spaces - completeness of $L^p$-spaces, for $1\leq p\leq\infty$ Product measure - monotone class and sigma-algebra- Fubini's Theorem. | 12 |
| | **References.**<br>1. G. de Barra, Measure theory and integration, Wiley Eastern Ltd., 1981.<br>2. H.L. Royden and P. Fritzpatric, Real Analysis, Fourth Edition, Pearson Education, 2010.<br>3. C.D. Aliprantis and O. Burkinshaw, Principles of Real Analysis, 3rd Edition, Academic Press, 1998. | |

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|---|---|---|
| | 4. G.B. Folland, Real Analysis -Modern Techniques and their applications, 2nd Edition,Wiley,1999.<br>5. I.K. Rana, Measure theory and Integration, 2nd edition, Narosa Publishing, 2000. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| CO / PSO | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 |
| **CO2** | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 |
| **CO3** | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 |
| **CO4** | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 |
| **CO5** | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 |

**Subject Code: MAT422** **Credits: 5**

## Topology

**Course Outcome (CO)**

On completion of the course the students will be able to

| | Course outcome | Level |
|---|---|---|
| **CO 1** | understand the concepts of topology, basis, subbasis, subspace topology, open set, closed set, interior, closure, continuous function, homeomorphism, and open map. | Remember Understand |
| **CO 2** | find the applications of topology. | Apply |
| **CO 3** | identify the differences among the various separation axioms | Analyze |
| **CO 4** | discuss the proofs Urysohn's lemma, Tietze's extension theorem, Urysohn's metrization theorem, Tychnoff's theorem | Evaluate |
| **CO 5** | construct examples and counter examples of various topological properties | Create |

**Syllabus**

| Units | Content | Hrs. |
|---|---|---|
| **I** | Topological space definitions and examples, Basis and subbasis, order topology, continuous functions, product topology, subspace topology, closed sets, closures, limit points, cluster (accumulation) points, interior and boundary of a set, metric topology, quotient topology. | 12 |
| **II** | Connectedness, components, Locally connectedness, and path-connectedness and locally path-connectedness. | 12 |
| **III** | Compactness, tube lemma, compact subspaces of real line, characterization of compact metric spaces, locally compactness. | 12 |
| **IV** | Countability axioms, $T1$-spaces, Hausdorff spaces, regular spaces, completely regular spaces, Normal spaces, one-point compactification, Uryosohn's lemma and Tietze extension theorem. | 12 |
| **V** | Urysohn Metrization Theorem, Tycknoff's theorem, Stone-Cech ˇ Compactification. | 12 |
| | **References.**<br>1. J. R. Munkres, Topology, 2nd Edition, Prentice Hall of India, 2000.<br>2. G.F. Simmons, Introduction to Topology and Modern analysis, McGraw-Hill, 1963.<br>3. S. Kumaresan, Topology of Metric Spaces, 2nd Edition, Narosa Publishing, 2011.<br>4. K. D. Joshi, Introduction to General Topology, Second Edition, New Age International Publishers, 1983.<br>5. M.A. Armstong, Basic Topology, Springer International Edition, 2005. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| CO / PSO | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| **CO2** | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 |
| **CO3** | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 |
| **CO4** | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| **CO5** | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 |

**Subject Code: MAT423** **Credits: 5**

## Partial Differential Equations

**Course Outcome (CO)**

On completion of the course the students will be able to

| | Course Outcome | Level |
|---|---|---|
| **CO 1** | understand the relation between the theory and modelling in the problems arising in various fields, such as, economics, finance, applied sciences and etc | Remember Understand |
| **CO 2** | Enhance their mathematical understanding in representing solutions of partial differential equations. | Apply |
| **CO 3** | classify the partial differential equations and transform into canonical form | Analyze |
| **CO 4** | determine the solution representation for the three important classes of PDEs, such as Laplace, Heat and wave equation by various methods. | Evaluate |
| **CO 5** | Formulate fundamentals of partial differential equations, like Green's function, maximum principles, Cauchy problem, to take a research career in the area of partial differential equations | Create |

**Syllabus**

| Units | Content | Hrs. |
|---|---|---|
| **I** | First order PDE: Classification of PDEs into linear, semi-linear, quasilinear, and fully nonlinear equations. Well-posed problems in the sense of Hadamard. Geometrical Interpretation of a First-Order Equation. Solution of first order PDEs: Cauchy problem, Method of characteristics, Lagrange's method. Non-linear first order PDEs. Initial value problems. | 12 |
| **II** | Second order PDE Classification of second order PDEs in to hyperbolic, elliptic and parabolic PDEs. Canonical forms. | 6 |
| **III** | Wave Equation d'Alembert's formula, uniqueness and stability of solutions to the initial value problem for one dimensional wave equation. Parallelogram identity, domain of dependence, range of influence, finite speed of propagation. Method of spherical means. Hadamard's method of descent. Duhamel's principle for solutions of non-homogeneous wave equation. Uniqueness using energy method. | 14 |
| **IV** | Laplace equation Green's identities. Uniqueness of solutions to Dirichlet, Neumann, and mixed boundary value problems. Fundamental solutions. Mean value property. Properties of harmonic functions: Maximum principle and uniqueness, Regularity, Liouville's theorem. Green's function forDirichlet boundary value problem on upper half-space and ball. Energy method: Uniqueness, Dirichlet principle. | 14 |
| **V** | Heat equation Fundamental solution. Method of eigen function expansion for solutions. Cauchy problem for homogeneous heat equation, infinite speed of propagation. Duhamel's principle for non-homogeneous heat equation. Maximum principle and uniqueness. Energy method: Uniqueness, backward uniqueness | 14 |
| | **References:** 1. L.C. Evans, Partial Differential Equations, AMS, Second Edition, 2010. | |

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|---|---|---|
| | 2. T. Amaranath, An elementary course in partial differential equations, Narosa Publishing House, 2003.<br>3. R.Mc Owen, Partial Differential Equations: Methods and Applications, Pearson Education, 2002.<br>4. F. John, Partial differential equations, Fourth Edition, Springer-verlag, New York, 1991.<br>5. Q. Han, A Basic Course in Partial Differential Equations, AMS, 2011.<br>6. T. Myint-U, and L. Debnath, Linear Partial Differential Equations for Scientists and Engineers, Fourth Edition, Birkhauser, 2007. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| CO / PSO | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 |
| **CO2** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO3** | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 |
| **CO4** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO5** | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 |

**SEMESTER – IX**

**Subject Code: MAT511** **Credits: 5**

## Advanced Complex Analysis

**Course Outcome (CO)**

On completion of the course the students will be able to

| | Course Outcome | Level |
|---|---|---|
| **CO 1** | understand the concepts of complex integration, series expansion of a meromorphic function, infinite product expansion of an entire functions. | Remember Understand |
| **CO 2** | solve problems on complex integration. | Apply |
| **CO 3** | examine the proofs of Cauchy's theorems for rectangle for disc, Cauchy's integral formula. | Analyze |
| **CO 4** | discuss the proofs of Morera's theorem, Liouville's theorem, fundamental theorem of algebra. | Evaluate |
| **CO 5** | find the complex integrals and infinite sums and series using the Cauchy's residue theorem, Weierstrass theorem and Mittag-Leffler theorem. | Create |

**Syllabus**

| Units | Content | Hrs. |
|---|---|---|
| **I** | Quick review of complex derivative, partial derivative, C-R equations, power series. Branch of log and some other functions, Cauchy's theorem for rectangle, Rectangle theorem with exceptional points, exact differentiable form, Cauchy's theorem for disc, Winding number, Cauchy's theorem for disc with exceptional points, Cauchy's integral formula, Higher order derivatives. | 12 |
| **II** | Morera's theorem, Liouville's theorem, fundamental theorem of algebra, Removable singularities, Taylor's theorem, zeroes and poles, essential singularity, algebraic order of isolated singularity, local correspondence theorem, open mapping theorem, maximum modulus principle. | 12 |
| **III** | Simply connected region, Cauchy's theorem for simply connected region, homology, Cauchy's theorem for multiply connected region, Residues, Argument principle, Rouche's theorem, evaluation of definite integrals (theory with proof). | 12 |
| **IV** | Harmonic function, mean-value property of harmonic function, Poisson's formula, Schwartz theorem, Reflection principle, Weierstrass theorem, Taylor's series and Laurent series. | 12 |
| **V** | Partial fractions, Mittag-Leffler theorem, expansion of $\frac{\pi}{sin\pi z}$ , infinite products, canonical products, Gamma function, infinite product expressions for $\pi\cot\pi z$ and $\sin\pi z$, Jensen's formula, Poisson-Jensen's formula. | 12 |
| | **References.** | |

| | | |
|---|---|---|
| | 1. L.V. Ahlfors, Complex Analysis, 3rd edition, McGraw-Hill Inc., 1979.<br>2. J. Bak and D.J. Newmann, Complex analysis, 2nd edition, Springer Indian Edition (SIE), 2009.<br>3. H.A. Priestley, Complex analysis, 2nd edition,Oxford University Press, Indian Edition, 2006.<br>4. S. Ponnusamy and H. Silverman, Complex variables with applications,<br>Birkhauser, Boston, 2006.<br>5. T.W. Gamelin, Complex analysis, Springer, 2004.<br>6. J.B. Conway, Functions of one complex variable, 2nd edition, SISE, Narosa, 1996. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| CO / PSO | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO2** | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 |
| **CO3** | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 1 |
| **CO4** | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 |
| **CO5** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**SEMESTER – X**

**Course Code: MAT521** **Credit: 5**

## Functional Analysis

**Course Outcome (CO)**

On completion of the course the students will be able to

| | Course Outcome | Level |
|---|---|---|
| **CO 1** | explain the concepts of normed linear space (NLS), continuity of a linear map, $L_p$-space, Banach, Hilbert spaces, four pillars | Remember & Understand |
| **CO 2** | demonstrate the convergence in the different types of spaces | Apply |
| **CO 3** | analyze the properties of different types NLS | Analyze |
| **CO 4** | determine the linear functional in terms orthonormal basis | Evaluate |
| **CO 5** | Obtain the open mapping theorem from closed graph theorem and vice-versa | Create |

**Syllabus**

| Units | Content | Hrs. |
|---|---|---|
| **I** | Normed Linear spaces, Banach spaces, X is complete iff $\{x : \|x\| \leq 1\}$ is complete,direct sum of Banach spaces, quotient space, $l^n{}_p$ and $l_p$ spaces (includingthe proof of Holder's and Minkowski's inequalities), $\|.\|_p \to \|.\|_\infty$ as $p\to\infty$, thespaces of continuous bounded functions $C(X,\mathbf{R})$ and $C(X,\mathbf{C})$. | 12 |
| **II** | Bounded linear transformations, equivalences of continuous linear transformations, norm of a bounded linear transformation and its properties, the space B(X,Y) bounded linear transformations, completeness of B(X,Y ), equivalence of different norms on a space linear space - Every linear transformation from a finite dimensional normed linear space is continuous - dual space(the space of continuous linear functionals) $X^*$ - $(l^n{}_p)^* = l^n{}_q$ and $(l^n{}_1)^* = l^n{}_\infty$,$(l^n{}_\infty)^* = l^n{}_1$-$l_p$ and $(l_1)^* = l_\infty$, $(c_0)^* = l_1$ and $(l^n{}_\infty)^* \neq l_1$,Hahn-Banachextension theorem (for both real and complex cases) - applications of Hahn-Banach theorems. | 12 |
| **III** | Natural imbedding of X in $X^{**}$- reflexive spaces - $l^n{}_p$ are reflexive, $1\leq p\leq\infty$,weak topology on $X^*$, strong topology on $X^*$- a Banach space is reflexive iff its closed unit sphere is compact in the weak topology - weak¤-topology on $X^*$ -closed unit ball in a normed linear space is always compact Housdorff in the weak$^*$-topology, Open mapping theorem, projections on Banach spaces, direct sums and projections, closed graph theorem, conjugate of an operator and its properties. | 12 |
| **IV** | Inner product spaces, Hilbert spaces, Cauchy-Schwartz inequality - $l^n{}_2$ and $l_2$ spaces, parallelogram law - closed convex set has a unique vector of minimum norm - polarization identity - pythogorean theorem - orthogonal complement and its properties- best approximation of a closed subspace of a Hilbert space exists and it is in the orthogonal complement - $H = M\oplus M^\perp$, for any closed subspace M - orthonormal sets - examples, Bessel's inequality, equivalences of orthonormal basis- Fourier series - Riezs representation theorem - Gram-Schmidt's orthogonalization process - Conjugate space $H^*$ | 12 |
| **V** | Adjoint of an operator and its properties - self adjoint operator-positive | 12 |

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|---|---|---|
| | operatorsand inequality on self-adjoint operators - normal and unitary operators -projections - spectral theoremfor finite dimensional Hilbert spaces. | |
| | **References:**<br>1. G.F. Simmons, Introduction to Topology and Modern analysis, McGraw-Hill, 1963.<br>2. B.V. Limaye, Functional Analysis, 2nd edition, New Age international, 1996.<br>3. B. Bollabas, Linear Analysis, an introductory course, Cambridge University Press, 1994.<br>4. E. Kreyzig, Introductory Functional Analysis with applications, Wiley ClassicsLibrary, 2001.<br>5. M. Thamban Nair, Functional Analysis: A First Course, Prentice-Hall of India, New Delhi, 2002. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 |
| **CO2** | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 |
| **CO3** | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 |
| **CO4** | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 |
| **CO5** | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 |

## Elective Courses

**Subject Code: MAT01E** **Credits: 3+2**

## Computational Mathematics

**Course Outcome (CO)**

On completion of the course the students will be able to

| | Course Outcome | Level |
|---|---|---|
| **CO 1** | understand the theory of weak formulation of boundary value problems | Remember Understand |
| **CO 2** | Apply the basics of analysis to estimate error while solving partial differential equations numerically | Apply |
| **CO 3** | Differentiate finite difference and element method for PDEs | Analyze |
| **CO 4** | evaluate the robustness and the accuracy of the algorithms and how fast the numerical results converge to the analytical solutions. | Evaluate |
| **CO 5** | design algorithms to solve scientific problems that cannot be solved exactly | Create |

**Syllabus**

| Units | Content | Hrs. |
|---|---|---|
| I | Finite Difference Method:<br>Parabolic equations: Explicit and Crank-Nicolson Schemes for – weighted average approximation - derivative boundary conditions - Truncation errors - Consistency, Stability and convergence- Lax Equivalence theorem eigenvalues of a common tridiagonal matrix - Gerischgorin’s theorems - stability by matrix and Fourier-series method - A.D.I. method. | 10 |
| II | Hyperbolic Equations: First order quasi-linear equations and characteristics - numerical integration along a characteristic - Lax-Wendroff explicit method - second order quasi - linear hyperbolic equation - characteristics- solution by the method of characteristics - Explicit method for linear hyperbolic equations. | 10 |
| III | Elliptic Equations: Solution of Laplace and Poisson equations in a rectangular region using standard five point finite difference formula - five point finite difference formula with non uniform grid - Finite difference in Polar coordinate - Discretization error -Mixed Boundary value problems | 10 |
| IV | FINITE ELEMENT METHODS:<br>Weak formulation of Boundary Value Problems, Ritz-Galerkin approximation, Error Estimates, Piecewise polynomial spaces, Finite Element Method, Relationship to Difference Methods, Local Estimates. | 9 |
| V | Finite element methods for elliptic problems, error analysis for the finite element method, Galerkin methods for time-dependent problems, error estimates, two-dimensional problems. | 6 |
| | Laboratory Assignments (not limited to):<br>1. Explicit and Crank-Nicholson schemes for with prescribed and derivative boundary conditions<br>2. ADI method for two space dimensional parabolic PDE<br>3. Method of numerical integration along characteristics for first order hyperbolic PDE<br>4. Lax-Wendroff method<br>5. Finite difference method for Laplace and Poisson’s equations<br>6. Finite element method for Two point BVP | 45 |

| | | |
|---|---|---|
| | 7. Finite element method for one space parabolic PDE<br>8. Finite Element method for Poisson's equation. | |
| | **References:**<br>1. G.D. Smith, Numerical Solution of P.D.E., Oxford University Press, New York, 1995.<br>2. A.R. Mitchel and S.D.F. Griffiths, The Finite Difference Methods in Partial Differential Equations, John Wiley and sons, New York, 1980.<br>3. K.W.Morton, and D.F.Mayers, Numerical Solutions of Partial Differential Equations, Cambridge University Press, Cambridge, 2002.<br>4. S. Brenner and R. Scott, The Mathematical Theory of Finite Elements Methods, Springer-Verlag, New York 1994.<br>5. C. Johnson, Numerical Solutions of Partial Differential Equations by the Finite Element Method, Cambridge University Press, Cambridge 1987. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| CO / PSO | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 |
| **CO2** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO3** | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 |
| **CO4** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO5** | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 |

**Subject Code: MAT02E** **Credits: 4 or 5**

## Mathematical Methods

**Course Outcome (CO)**

On completion of the course the students will be able to

| | Course Outcome | Level |
|---|---|---|
| **CO 1** | Understanding the idea about functional and its properties | Remember Understand |
| **CO 2** | solve Fredholm, Volterra and singular integral equations | Apply |
| **CO 3** | Analyze the Fredholm theory | Analyze |
| **CO 4** | Determine the solutions of Brachistochrone problem, geodesics problems and isoperimetric problems | Evaluate |
| **CO 5** | Formulate the knowledge of calculus of variation to solve a wide range of real world problems of applied sciences | Create |

**Syllabus**

| Units | Content | Hrs. |
|---|---|---|
| **I** | Integral equation: Introduction: Types of Integral equations Â″U Integral equations with separable kernels - Reduction to a system of algebraic equations, Fredholm alternative, an approximate method, Fredholm integral equations of the first kind, method of successive approximations - Iterative scheme, Volterra integral equation, some results about the resolvent kernel, classical Fredholm theory - Fredholm's method of solution - Fredholm's first, second, third theorems (without proof). | 12 |
| **II** | Applications of Integral Equations: Application to ordinary differential equation - Reduction of Initial value problems and boundary value problems to integral equations - Green's function Approach - Singular integral equations – Abel integral equation | 12 |
| **III** | Symmetric Kernels: Introduction, Fundamental Properties of Eigenvalues and Eigenfunctions for symmetric kernels, Solution of a symmetric integral equation, Rayleigh-Ritz Method. (if time permits) | 12 |
| **IV** | Calculus of Variations: Functionals. Variation of a functional - Euler-Lagrange equation -Necessary and sufficient conditions for extrema - Functional dependent on higher-order derivatives, functional dependent on the function of several independent variables, variational problems in parametric form. Sufficient condition for weak/storing extremum. | 12 |
| **V** | Direct Methods in Variational Problems: Direct Methods, Euler's finite difference methods, The Ritz method, Kantorovich's method. | 12 |
| | **References:** 1. I.M. Gelfand and S.V. Fomin, Calculus of Variations, Prentice Hall, New Jersey, 1963. 2. F.B. Hildebrand, Methods of Applied Mathematics, Dover, New York, 1992. 3. F.G. Tricomi, Integral Equations, Dover Publications, 1985 4. L. Elsgolts, Differential Equations and the Calculus of Variations, MIR Publishers, Moscow, 1970. | |

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|---|---|---|
| | 5. Weinstock, Calculus of Variations, with Applications to Physics and Engineering, McGraw-Hill, New York, 1952.<br>6. R.P. Kanwal, Linear Integral Equations: Theory & Technique, Second Edition, Birkhäuser, 2013. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| CO / PSO | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 |
| **CO2** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO3** | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 |
| **CO4** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO5** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Subject Code: MAT03E** **Credits: 4 or 5**

**Fluid Dynamics**

**Course Outcome (CO)**

On completion of the course the students will be able to

| | Course Outcome | Level |
|---|---|---|
| **CO1** | Understand the basic properties and principles of viscous and non-viscous fluids | Remember/Understand |
| **CO2** | Derive and deduce the consequences of the governing equations of fluids | Apply |
| **CO3** | Solve kinematics problems such as finding particle paths and streamlines | Analyze |
| **CO4** | Understand the basic theorems of fluid mechanics and its applications | Evaluate |
| **CO5** | Derive the boundary layer equations of some basic flows and its solutions | Create |

**Syllabus**

| Units | Content | Hrs |
|---|---|---|
| I | KINEMATICS OF FLUIDS IN MOTION: Real and ideal fluids. Coefficient of viscosity. Steady and unsteady flows. Isotropy. Orthogonal curvilinear coordinates. Velocity of a fluid particle. Material local and convective derivative. Acceleration. Stress. Rate of strain. Vorticity and vortex line. Stress analysis. Relation between stress and rate of strain, Streamline. Path lines. Streak lines. Velocity potential. Eulerian and Lagrangian forms of Equation of continuity. Boundary conditions and boundary surfaces. | 15 |
| II | EQUATIONS OF MOTION OF A FLUID: Pressure at a point in a fluid. Euler's equations of Motion. Momentum equations in cylindrical and spherical polar coordinates. Conservative field of force. Flows involving axial symmetry. Equations of motion under impulsive forces. Potential theorems. | 15 |
| III | IN VISCID FLOWS: Energy equation. Cauchy's Integrals. Helmholtz equations. Bernoulli's equation and applications. Lagrange's hydro-dynamical equations. Bernoulli's theorem and applications. Torricelli's theorem. Trajectory of a free jet. Pitot tube. Venturi meter. | 15 |
| IV | TWO DIMENSIONAL AND IRROTATIONAL MOTION: Two-dimensional flows. Stream function. Complex potential. Irrational and incompressible flow, Complex potential for standard two-dimensional flows. Cauchy Riemann equations in polar form. Magnitude of velocity. Sources and sinks in two dimensions. Problems. Kinetic energy of liquid. Theorem of Blasius. Complex potential due to source. Doublet in two dimensions. MilneThomson circle theorem. Fflow and circulations. Stoke's theorem. Kelvin circulation theorem. Kinetic energy of infinite liquid. Kelvins minimum energy theorem. Permanence if irrotational motion. Vortex motion. Dynamical similarity. Boundary layer theory. | 15 |
| | **References**<br>1. G.K. Batchelor, An Introduction to Fluid Dynamics, Cambridge University Press, 1993.<br>2. F. Chorlton, Text book of Fluid Mechanics, CBS Publishers, New | |

| | | |
|---|---|---|
| | Delhi, 1985.<br>3. F. White, Viscous Fluid Flow, McGraw -Hill, 1991.<br>4. M.D. Raisinghania, Fluid Dynamics, S Chand, New Delhi, 2000. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| CO / PSO | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| **CO2** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO3** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| **CO4** | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 |
| **CO5** | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 |

**Subject Code: MAT04E** **Credits: 4**

**Transformation Groups**

**Course Outcome (CO)**

On completion of the course the students will be able to

| | **Course Outcome** | **Level** |
|---|---|---|
| **CO 1** | to understand Groups of bijections | Remember Understand |
| **CO 2** | to be able to prove that the isometries the plane are given by translation, rotation, reflections and glide reflections. | Apply |
| **CO 3** | to understand Affine and Projective Transformations | Analyze |
| **CO 4** | to understand the standard methods of solving ODEs with the help of symmetries | Evaluate |
| **CO 5** | to be able solve problems on these topics | Create |

**Syllabus**

| **Units** | **Content** | **Hrs.** |
|---|---|---|
| **I** | Revision of Group Theory | 15 |
| **II** | Isometries in $R^2$ | 15 |
| **III** | Affine transformations and projective transformations | 15 |
| **IV** | Symmetries of Differential Equation | 15 |
| | **References.** 1. S.V. Duzhin and B.D. Chebotarevsky, Transformation Groups for beginners, AMS, 2004 | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| **CO / PSO** | **PSO1** | **PSO2** | **PSO3** | **PSO4** | **PSO5** | **PSO6** | **PSO7** | **PSO8** |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 |
| **CO2** | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 |
| **CO3** | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 |
| **CO4** | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 |
| **CO5** | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 |

**Subject Code: MAT05E** **Credits: 4**

## Design & Analysis of Algorithms

### Course Outcome (CO)

On completion of the course the students will be able to

| | Course Outcome | Level |
|---|---|---|
| **CO 1** | study some of the basic and key techniques to analyze and design algorithms | Understand |
| **CO 2** | see the practical applications of algorithms and the impact of the same | Apply |
| **CO 3** | have hands on experience in conducting a few challenging scientific computing | Analyse |
| **CO 4** | develop real life problem solving capability | Evaluate |
| **CO 5** | connect the theory and computing | Create |

### Syllabus

| Units | Content | Hrs. |
|---|---|---|
| **I** | Introduction to Algorithms, lots of examples, Recurrent relations and closed form solution, Tools and techniques for summation, Manipulation of sum, floor and ceiling functions, Finite and infinite calculus, Problem solving using the tools | 9 |
| **II** | Number theory an applied perspective, Divisibility, Introduction to relations and functions, Mod and congruence relation, Application of congruence, Independent Residues. | 9 |
| **III** | Permutation, Permutation of Multi sets, Combination, Application of Permutation and combination, Combinatorial properties of permutations. | 9 |
| **IV** | Design and analysis of algorithms with examples like Euclid algorithm etc.., | 9 |
| **V** | Sorting - Insertion sort - Divide and Conquer approach -Merge sort - Quick sort. Asymptotics and analysis. Complexity Theory. Polynomial time - Complexity classes - class P, NP, NPC - reducibility - NP Completeness problems. | 9 |
| VI | Scientific computing with open source R. | 30 |
| | **References:**<br>1. T.H. Cormen, C.E. Leiserson, R.L. Rivest, Introduction to Algorithms, Prentice Hall of India, New-Delhi, 2004.<br>2. S. Basse, Computer Algorithms: Introduction to Design and Analysing, Addison Wesley, 1993.<br>3. A. Levitin, Introduction to the Design and Analysis of Algorithms, Pearson Eduction Pvt. Ltd, New Delhi, 2003.<br>4. S. Sedgewick, Algorithms, Addison Wesley, 2011. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| CO / PSO | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 |
| **CO2** | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 |
| **CO3** | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 |
| **CO4** | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 |
| **CO5** | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 |

**Subject Code: MAT06E** **Credits: 4**

## Number Systems

**Course Outcome (CO)**

On completion of the course the students will be able to

| | Course outcomes | Level |
|---|---|---|
| **CO 1** | understand axiomatic approach of set theory, ordered pairs, natural number system, addition, multiplication and order relation on natural numbers, finite and infinite sets, | Remember Understand |
| **CO 2** | solve problems on cardinal numbers | Evaluate |
| **CO 3** | examine the rational numbers, real numbers through Dedekind's cuts, field structure, Archimedean property, least upper bound property, | Analyze |
| **CO 4** | discuss the real numbers construction through Cantor's construction, field structure, uniqueness of real number system, decimal expansion. | Evaluate |
| **CO 5** | determine the rigorous proofs of properties of integers. | Create |

**Syllabus**

| Units | Content | Hrs. |
|---|---|---|
| **I** | Axioms of set theory, Russell's paradox, Foundation axiom, ordered pair, relation, function, Peano's postulates and natural numbers, definition and properties of addition on N, definition and properties of multiplication on N, order relation on N and its properties. Equivalence of principle of induction and well ordering property on N, finite and infinite sets, pigeon-hole principle, characterization of finite sets, Schörder-Bernstein theorem, countable sets and their properties. | 12 |
| **II** | Definition of integers as equivalence classes of pairs of natural numbers, addition, multiplication, order relation, subtraction and their properties on Z, proof of the fact that Z is an integral domain, definition of rational numbers , operations on rational numbers and their properties, Q is an ordered field satisfying Archimedian property, denseness of Q in itself, proof of Q is not having least upper bound property, absolute value on Q | 12 |
| **III** | Dedekind's construction of real numbers through cuts, addition, multiplication, and order relation on R, R is an ordered Archimedian field with least upper bound property | 12 |
| **IV** | Cantor's construction of real numbers through equivalence classes of Cauchy sequences of rational numbers, addition, multiplication, field structure, order relation, completeness of R, least upper bound property of R in Cantor's construction of real numbers, uniqueness of real number system, decimal expansion of a real number, when do two different decimal expansion represent a same real number? When does a decimal expansion represent a rational number? | 12 |
| **V** | Uncountable set, properties of uncountable sets, R is equinumerous with ever interval having at least two points, R is equinumerous with R*n*, definition of cardinality, arithmetic on cardinalities, Aleph naught, aleph and their arithmetic, [ordinals, equivalence of axiom of choice (if time permits)] | 12 |

| | | |
|---|---|---|
| | **References.**<br>1. A. G. Hamilton, Numbers, Sets and Axioms: The Apparatus of Mathematics, Cambridge University Press, Cambridge, 1983.<br>2. E. Hewitt and K. Stromberg, Real and Abstract Analysis, Springer, New York , 1975.<br>3. E. Kamke, Theory of Sets, Dover Publications Inc., New York, 1950.<br>4. W. Rudin, Principles of Mathematical Analysis, McGraw-Hill Inc., New York, 1976. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| CO / PSO | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 |
| **CO2** | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| **CO3** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO4** | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 |
| **CO5** | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |

**Course Code: MAT07E** **Credit: 4 or 5**

## Nonlinear Programming

**Course Outcome (CO)**

On completion of the course the students will be able to

| | Course Outcome | Level |
|---|---|---|
| **CO 1** | learn about Convex sets and functions; characterization of convex functions. | Remember & Understand |
| **CO 2** | study the Characterization of global optimality of a convex program. | Apply |
| **CO 3** | study the Optimality conditions of linear and nonlinear programs. | Analyze |
| **CO 4** | appreciate the beauty of Lagrangian duality; weak and strong duality theorems. | Evaluate |
| **CO 5** | understand about the Algorithmic maps and its convergence. | Create |

**Syllabus**

| Units | Content | Hrs. |
|---|---|---|
| **I** | Introduction to Optimization problems.(real life examples, constrained and unconstrained, convex and non-convex etc.,)<br>Convex sets, convex hull, Caratheodory's theorem, Separation theorem and Farka's lemma. (Standard fixed point theorems without proof after teaching Farka's lemma)<br>Convex functions, first and second derivative convexity characterizations, Euclidean(metric) projection on a convex set. | 12 |
| **II** | Necessary and sufficient conditions for local and global optimality of a feasible point, Weierstrass Theorem.<br>Definition of descent direction and a sufficient condition for descent direction. | 12 |
| **III** | Optimality conditions: Definitions of normal cone, cone of feasible directions and tangent cone. Relationship between these cones. Optimality conditions based on these cones.<br>Fritz John optimality conditions and KKT optimality conditions.<br>Different constraint qualifications (Abadie's CQ, Mangasarian-Fromovitz CQ, Slater CQ, Linear independence CQ) and their relationship with KKT optimality conditions. | 12 |
| **IV** | Lagrangian Duality: Lagrangian dual problem, Examples to find the dual of a linear as well as nonlinear programming problems, Lagrange multipliers and its relation to global optimality. Convexity of dual problem.<br>Duality gap and existence of Lagrange multipliers, Global optimality conditions in the absence of duality gap. Saddle point and global optimality.<br>Weak and strong duality theorems for convex programs. Explained how these theorems work for linear and quadratic programming problems. | 12 |

| | | |
|---|---|---|
| **V** | Definition of sub-gradient for a convex function. Example of a dual problem with non differentiable objective.<br>Sub-gradient projection algorithm for convex problems.<br>Algorithms and algorithmic maps. Examples of algorithms and algorithmic maps. Zangwill's convergence theorem. (without proof) | 12 |
| | **References**<br>1. O. Mangasarian, Nonlinear programming, Mc Graw-Hill Inc., 1969.<br>2. M. S. Bazaraa, H. D. Sherali and C. M. Shetty, Nonlinear programming, Wiley- Blackwell, 2006<br>3. N. Andreasson, A. Evgrafov and M. Patriksson, An Introduction to Continuous optimization, Springer, 2013. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO2** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO3** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO4** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO5** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Course Code: MAT08E** **Credit: 4 or 5**

## Introduction to Lie Algebras

**Course Outcome (CO)**

On completion of the course the students will be able to

| | Course Outcome | Level |
|---|---|---|
| **CO 1** | Topological groups and its properties in general. A detailed study of the group of GLn(R) and its various subgroups and their topological properties. | Remember & Understand |
| **CO 2** | The various decompositions available for different matrix classes and its applications. | Apply |
| **CO 3** | The maps like exponential and logarithm of a matrix, its properties. | Analyze |
| **CO 4** | Linear Lie groups and its Lie algebras. Campbell-Hausdorff formula. | Evaluate |
| **CO 5** | Lie algebras and its representations. Nilpotent and solvable Lie algebras. Semi-simple Lie algebras. | Create |

**Syllabus**

| Units | Content | Hrs. |
|---|---|---|
| **I** | Review of the following: exponential and logarithmic functions of real and complex variables; inverse function theorem; triangularizability, diagonalizability and simultaneous diagonalizability of matrices; Jordan Canonical Form; Topology: Hausdorff topology, continuity, compactness and connectedness; Groups: Normal groups, homomorphism between groups, nilpotent and solvable groups; total derivatives and chain rule. | 12 |
| **II** | Topological Groups; The group $GL(n,\mathrm{R})$; Examples of subgroups of $GL(n,\mathrm{R})$; Polar decomposition in $GL(n,\mathrm{R})$; The orthogonal group; Gram decomposition. | 12 |
| **III** | Exponential and Logarithm of a matrix; total derivative of the exponential. | 12 |
| **IV** | Linear Lie Groups: One parameter semigroups and subgroups; Lie algebra of a linear Lie group; Linear Lie groups as sub-manifolds; Campbell-Hausdorff formula. | 12 |
| **V** | Lie algebras: Definitions and examples; nilpotent and solvable Lie algebras; semi-simple Lie algebras. | 12 |
| | **References:** 1. J. Faraut, Analysis on Lie Groups, Cambridge Studies in Advanced Mathematics, Cambridge University Press, Cambridge, 2008. 2. B. Hall, Lie Groups, Lie Algebras, and Representations, Springer International Publishing, Switzerland, 2015. 3. A. Baker, Matrix Groups: An Introduction to Lie Group Theory, Springer-Verlag, London, UK, 2002. 4. N. J. Higham, Functions of Matrices, SIAM, Philadelphia, 2008. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 |
| **CO2** | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 |
| **CO3** | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 |
| **CO4** | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 |
| **CO5** | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 |

**Subject Code: MAT09E** **Credits: 4**

## Algebraic Number Theory

**Course Outcome (CO)**

On completion of the course the students will be able to

| | Course Outcome | Level |
|---|---|---|
| **CO 1** | know the preliminaries of Galois theory | Understand |
| **CO 2** | have knowledge on module theory and finitely generated module theory | Apply |
| **CO 3** | understand the effects of algebraic methods and analytic methods in number theory | Analyse |
| **CO 4** | understand Gauss's and Artin's conjecture on primitive roots | Evaluate |
| **CO 5** | Understand more conjectures on number theory and how to go about solving them | Create |

**Syllabus**

| Units | Content | Hrs. |
|---|---|---|
| **I** | Introduction; A quick review on concepts like Integral domain, prime ideal, maximal ideal, prime number theorem(without proof ), various estimates on π(x), module theory and finitely generated module theory | 12 |
| **II** | Number fields: Algebraic numbers, Algebraic integers, transcendental numbers, Algebraic Number Fields, Liouville's Theorem, finite extension of Q, Dedekind domain, primitive element theorem | 12 |
| **III** | Primtive roots, semi-primitive roots, Sophie Germain prime, Gauss's conjecture, Artin's generalized conjecture, various estimates around the conjecture | 12 |
| **IV** | abc conjecture, non-wieferich primes, estimates on the number of primes p ≤ x such that 2 p−1 6≡ 1 mod p 2 , Fermat's last theorem, Erdős' conjecture on square full natural numbers, Connecting these conjectures with Fermat's last theorem | 12 |
| **V** | Analytic methods, The Riemann zeta function, Dedekind Zeta Function, Zeta Functions of Quadratic Fields | 12 |
| | **References:**<br>1. D. Burton, Elementary Number Theory, 7th ed. Tata McGraw-Hill, 2012.<br>2. G. H. Hardy and E. M. Wright, An Introduction to the Theory of Numbers, Clarendon Press, Oxford, 5th edition, 1979.<br>3. Stopple, A primer of analytic number theory: from Pythagoras to Riemann, Cambridge University Press, 2003<br>4. R. Gupta, M. Ram Murty, A remark on Artin's conjecture, Inventiones Mathematicae, vol. 78, pp. 127-130 (1984).<br>5. M.E. Harold Fermat's Last Theorem: A Genetic Introduction to Algebraic Number Theory, Graduate Texts in Mathematics, Springer, 2000. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| CO / PSO | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO2** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO3** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO4** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO5** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Subject Code: MAT10E** **Credits: 4 or 5**

**Non-linear Partial Differential Equations**

**Course Outcome (CO)**

On completion of the course the students will be able to

| | Course Outcome | Level |
|---|---|---|
| **CO 1** | understand the existence theory for partial differential equations | Remember Understand |
| **CO 2** | implement various methods for solving nonlinear PDEs including the method of characteristics, similarity solutions and Riemann functions | Apply |
| **CO 3** | distinguish classical solution and weak solution | Analyze |
| **CO 4** | Determine the weak solution of scalar conservation laws | Evaluate |
| **CO 5** | Develop the relation between nonlinear partial differential equations and calculus of variations | Create |

**Syllabus**

| Units | Content | Hrs. |
|---|---|---|
| **I** | Nonlinear first-order PDEs: complete integral, new solutions from envelopes; characteristics; | 12 |
| **II** | Introduction to Hamilton-Jacobi equations: calculus of variations: First variation, Euler-Lagrange Equation, second variation, Hamilton's ODE, Legendre transform, Hopf-Lax formula, weak solutions, uniqueness; | 12 |
| **III** | Introduction to Conservation laws: shocks, entropy condition, Lax-Oleinik formula, weak solutions, uniqueness, Riemann's problem, long time behaviour. | 12 |
| **IV** | Representation of solutions: separation of variables; similarity of solutions; transform methods: Fourier, Laplace | 12 |
| **V** | Converting nonlinear PDE into ODE: Hopf-Cole transform, Asymptotics; Power series: non-characteristic surfaces, real analytic functions, Cauchy-Kovalevskaya theorem. | 12 |
| | **References:**<br>1. L.C. Evans, Partial Differential Equations, AMS, Second Edition, 2010.<br>2. F. John, Partial differential equations, Fourth Edition, Springer, 1991.<br>3. R. McOwen, Partial Differential Equations: Methods and Applications, Pearson Education, 2002.<br>4. J.D. Logan, Applied Partial Differential Equations, Second Edition, Springer, 2004.<br>5. T. Myint-U, L. Debnath, Linear Partial Differential Equations for Scientists and Engineers, Fourth Edition, Birkhauser, 2007. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| CO / PSO | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 |
| **CO2** | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 |
| **CO3** | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| **CO4** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO5** | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 |

**Subject Code: MAT11E** **Credits: 5**

## Advanced Partial Differential Equations

**Course Outcome (CO)**

On completion of the course the students will be able to

| | Course Outcome | Level |
|---|---|---|
| **CO 1** | understand the theory of weak solutions | Remember Understand |
| **CO 2** | Apply the theory of functional analysis to study weak solutions of PDEs | Apply |
| **CO 3** | analyze existence, uniqueness and regularity of solutions for PDEs | Analyze |
| **CO 4** | Determine the necessary conditions for the existence of extremals | Evaluate |
| **CO 5** | Develop the relation between nonlinear partial differential equations and calculus of variations | Create |

**Syllabus**

| Units | Content | Hrs. |
|---|---|---|
| **I** | Elliptic Equation: Weak Solution, Lax-Milgram Theorem, Energy estimates, Regularity, Maximum principles | 12 |
| **II** | Parabolic Equation: Weak Solution, Existence and uniqueness, Regularity, Maximum principles | 12 |
| **III** | Hyperbolic Equation: Weak Solution, Existence and uniqueness, Regularity, Propagation of disturbances | 12 |
| **IV** | Calculus of variation: Basic ideas, First variation, Euler-Lagrange equation, Second variation, Systems: Null Lagrangians, Brouwer's fixed point theorem | 12 |
| **V** | Existence of Minimizers: coercivity, lower semi continuity, convexity, weak solutions of Euler-Lagrange equations, systems. | 12 |
| | **References:** 1. L.C. Evans Partial Differential Equations, Second Edition, AMS, Providence, 2010. 2. S. Salsa Partial Differential Equations in Action: From Modelling to Theory, Springer, New Delhi, 2008. 3. S. Kesavan Topics in Functional Analysis and Applications, New Age International, New Delhi, 2008. 4. H. Brezis Functional Analysis, Sobolev Spaces and PDEs, Springer, New York, 2011. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| CO / PSO | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| **CO2** | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 |
| **CO3** | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 |
| **CO4** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO5** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Subject Code: MAT12E** **Credits: 4**

**Differential Geometry**

**Course Outcome (CO)**

On completion of the course the students will be able to

| | Course Outcome | Level |
|---|---|---|
| **CO 1** | to understand plane curves and their curvature | Remember Understand |
| **CO 2** | to understand surfaces , tangents and normals | Apply |
| **CO 3** | to understand Quadratic Surfaces | Analyze |
| **CO 4** | to understand concepts related to curvature of surfaces | Evaluate |
| **CO 5** | to be able to solve problems on these topics. | Create |

**Syllabus**

| Units | Content | Hrs. |
|---|---|---|
| **I** | Plane curves and Space curves- Frenet-Serret Formulae. Global properties of curves- Simple closed curves, The isoperimetric inequality, The Four Vertex theorem. | 12 |
| **II** | Surfaces in three dimensions- Smooth surfaces, Tangents, Normals and Orientability, Quadric surfaces. | 12 |
| **III** | The First Fundamental form- The lengths of curves on surfaces, Isometries of surfaces, Conformal mappings of surfaces, Surface area, Equiareal Maps and a theorem of Archimedes. | 12 |
| **IV** | Curvature of surfaces- The Second Fundamental form, The Curvature of curves on a surface, Normal and Principal Curvatures. | 12 |
| **V** | Gaussian Curvature and The Gauss' Map - The Gaussian and The mean Curvatures, The Pseudo sphere, Flat surfaces, Surfaces of Constant Mean Curvature, Gaussian Curvature of Compact surfaces, The Gauss' Map. | 12 |
| | **References.** 1. A. N. Pressley, Elementary Differential Geometry, Springer, 2010. 2. T. J.Willmore, An Introduction to Differential Geometry, Oxford University Press, 1997. 3. D. Somasundaram, Differential Geometry: A First Course, Narosa, 2005. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| CO / PSO | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 |
| **CO2** | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 |
| **CO3** | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 |
| **CO4** | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 |
| **CO5** | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 |

**Subject Code: MAT13E** **Credits: 4**

**Delay Differential Equations**

**Course Outcome (CO)**

On completion of the course the students will be able to

| | Course Outcome | Level |
|---|---|---|
| **CO 1** | To be able to solve simple Delay Differential Equations. | Remember Understand |
| **CO 2** | to be able to apply numerical techniques to Delay Differential Equations | Apply |
| **CO 3** | to understand infinite dynamical systems via the semi-group approach | Analyze |
| **CO 4** | to be able to apply Hille-Yosida Theorem to show existence of solutions to Delay Differential Equations | Evaluate |
| **CO 5** | to understand stability of Delay Differential Equations | Create |

**Syllabus**

| Units | Content | Hrs. |
|---|---|---|
| **I** | Review of system of ODEs, Solution of nonlinear system as given by groups of operators, stability and asymptotic stability. | 15 |
| **II** | Solution of Parabolic/hyperbolic equations as semigroups/ groups. Backward Euler method as a motivation for Hille-Yoshida theorem without proof, Existence for DDEs. | 15 |
| **III** | Models involving DDEs | 15 |
| **IV** | Asymptotic stability of linear DDEs | 15 |
| | **References.** <br> 1. J. Hale, Theory of Functional Differential Equations, Springer-Verlag, New York,1997. <br> 2. V. J. Arnold, Ordinary Differential Equations, Springer-Verlag, Berlin, 1982. <br> 3. S. Kesavan, Topics in Functional Analysis and Applications, John Wiley & Sons,1989. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| CO /PSO | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 |
| **CO2** | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 |
| **CO3** | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 |
| **CO4** | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 |
| **CO5** | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 |

**Subject Code: MAT14E** **Credits: 4**

## Foundations of Geometry

**Course Outcome (CO)**

On completion of the course the students will be able to

| | Course Outcome | Level |
|---|---|---|
| **CO 1** | to understand the five groups of Axioms of Geometry | Remember Understand |
| **CO 2** | to understand the compatibility and mutual independence of the Axioms | Apply |
| **CO 3** | to understand the theory of proportion | Analyze |
| **CO 4** | to understand plane areas | Evaluate |
| **CO 5** | to understand Desargues's Theorem | Create |

**Syllabus**

| Units | Content | Hrs. |
|---|---|---|
| **I** | The five group of Axioms | 12 |
| **II** | Compatibility andMutual Independence of the Axioms | 12 |
| **III** | The Theory of Proportion | 12 |
| **IV** | The theory of plane Areas | 12 |
| **V** | Desargues's Theorem | 12 |
| | **References.**<br>1. D. Hilbert, The Foundations of Geometry, MJP Publishers, 1902. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| CO / PSO | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 |
| **CO2** | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 |
| **CO3** | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 |
| **CO4** | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 |
| **CO5** | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 |

**Course Code: MAT15E** **Credit: 5**

## Commutative Algebra

**Course Outcome (CO)**

On completion of the course, the student will be able to

| | Course Outcome | Level |
|---|---|---|
| **CO 1** | understand the difference between vector space over a field and module over a commutative ring. | Remember & Understand |
| **CO 2** | Applying some operations, obtain a new module from old the old ones. | Apply |
| **CO 3** | Finding thefraction rings and fraction modules from given the rings and modules | Analyze |
| **CO 4** | Obtain a characterization for Noetherian A-module and Artinian A-module using submodules and the chain conditions. | Evaluate |
| **CO 5** | investigate the Hilbert's basis theorem for Noetherian ring of polynomials | Create |

**Syllabus**

| Units | Content | Hrs. |
|---|---|---|
| **I** | Commutative ring with unity, Zero-divisors, Nilpotent elements, Nilradical Jacobson radical, Modules, Module homomorphism. | 12 |
| **II** | Submodules, Quotient modules, Operations on submodules, Direct sum, Finitely Generated modules, Nakayama's lemma, Exact sequences | 12 |
| **III** | Rings and Modules of Fractions, local properties | 12 |
| **IV** | Chain Conditions, Noetherian A-module and its characterization, Arinian A-modules and its characterization | 12 |
| **V** | Noetherian rings, Hilbert's Basis Theorem, Artinian rings | 12 |
| | **References:**<br>1. J.W. Anderson, Hyperbolic geometry, second edition, Springer Undergraduate Mathematics Series, Springer-Verlag London, Ltd., London, 2005.<br>2. 2. L. Keen and N. Lakic, Hyperbolic geometry from a local view point, London Mathematical Society Student Texts, Cambridge University Press, Cambridge, 2007. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 |
| **CO2** | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 |
| **CO3** | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 |
| **CO4** | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 |
| **CO5** | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 |

**Subject Code: MAT16E** **Credits: 4 or 5**

## Discrete Mathematics

**Course Outcome (CO)**

On completion of the course the students will be able to

| | **Course Outcome** | **Level** |
|---|---|---|
| **CO 1** | to understand Recurrence Relations, formal languages and Grammars | Remember Understand |
| **CO 2** | to understand symbolic logic, Posets and Lattices | Apply |
| **CO 3** | to understand Boolean Algebra | Analyze |
| **CO 4** | to apply Boolean Algebra to Switching Theory | Evaluate |
| **CO 5** | to understand Finite state machines | Create |

**Syllabus**

| **Units** | **Content** | **Hrs.** |
|---|---|---|
| **I** | Recurrence Relations and Generating Functions, Some number sequences, Linear homogeneous recurrence relations, Non-homogeneous recurrence relations, Generating functions, Recurrences and generating functions, Exponential generating functions. | 12 |
| **II** | Statements Symbolic Representation and Tautologies, Quantifiers, Predicates and validity, Prepositional Logic. Lattices as partially ordered sets, their properties, Lattices as Algebraic systems. Sub lattices, Direct products and Homomorphism, Some special lattices e.g. complete, Complemented and Distributive Lattices. | 12 |
| **III** | Boolean Algebras as Lattices, Various Boolean Identities, The switching Algebra. Example, Subalgebras, Direct Products and Homomrphism, Joint-irreducible elements, Atoms and Minterms, Boolean forms and their equivalence, Minterm Boolean forms, Sum of Products, Cononical forms, Minimization of Boolean functions, Applications of Boolean Algebra to Switching Theory ( using AND, OR and NOT gates.) The Karnaugh method. | 12 |
| **IV** | Finite state Machines and their Transition table diagrams, Equivalence of Finite State, Machines, Reduced Machines, Homomorphism, Finite automata, Acceptors, Non-deterministic, Finite Automata and equivalence of its power to that of deterministic Finite automata, Moore and Mealy Machines. | 12 |
| **V** | Grammars and Language: Phrase-Structure Grammars, Requiting rules, Derivation, Sentential forms, Language generated by a Grammar, Regular, Context -Free and context sensitive grammars and Languages, Regular sets, Regular Expressions and the pumping Lemma. | 12 |
| | **References.**<br>1. J.P. Tremblay and R. Manohar, A First Course in Discrete Structures with Applications to Computer Science, McGraw Hill, 1987.<br>2. K.H. Rosen, Discrete Mathematics and its Applications, Seventh edition, McGraw Hill, 2011.<br>3. C.L. Liu, Elements of Discrete Mathematics, McGraw Hill, New York, 1978.<br>4. R.P. Grimaldi and B.V. Ramana, Discrete and Combinatorial Mathematics- An Applied Introduction, Pearson education, 2004.<br>5. T. Sengadir, Discrete Mathematics, Pearson Education India, 2009. | |

| | | |
|---|---|---|
| | 6. J.E. Hopcraft and J.D. Ullman, Introduction to Automata Theory, Languages and Computation, 2nd Edition, Addison Wesley, 2001. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| CO /PSO | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO2** | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO3** | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO4** | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO5** | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Course Code: MAT17E** **Credit: 4**

## Advanced Graph Theory

**Course Outcome (CO)**

On completion of the course, the student will be able to

| | Course Outcome | Level |
|---|---|---|
| **CO 1** | understand the concept of maximum matching and perfect matching | Remember Understand |
| **CO 2** | demonstrate Euler tour and Hamiltonian cycle in graphs using a characterization of Eulerian graph properties of Hamilton graphs | Apply |
| **CO 3** | Finding a triangle free graph with arbitrarily large chromatic number | Analyze |
| **CO 4** | determine Euler formula for a planer graph in terms of its n, m, □ | Evaluate |
| **CO 5** | Create a schedule for a tournament in a particular game using tournament of the di-connected graphs | Create |

**Syllabus**

| Units | Content | Hrs. |
|---|---|---|
| **I** | Matching-maximum matching-Berge theorem in maximum matching-Hall's Theorem-Perfect matching-Tutte theorem. | 12 |
| **II** | Eulerian graphs and its characterization - Vizing's theorem in edge colourings -independent sets - Gallai's theorem - Ramsey theory | 12 |
| **III** | Turan's theorem - Brook's theorem in vertex colourings - Hajo's conjecture -subdivision of graphs -Mycielski's construction for triangle free graphs. | 12 |
| **IV** | Kuratowski's theorem - face colouring - characterization of face colouring– Tait colouring – non hamiltonian planar graphs. | 12 |
| **V** | Directed graphs - existence of directed path - tournament - disconnected tournament-Moon theorem- Networks -Max-flow min-cut theorem. | 12 |
| | **References:**<br>1. J.A. Bondy and U.S.R. Murty, Graph Theory with Applications, North-Holland, 1982.<br>2. G. Chartrand, L. Lesniak and P. Zhang, Graphs and Digraphs, Fifth Edition, CRC press, 2011.<br>3. D.B. West, Introduction to Graph Theory, Second Edition, PHI Learning Private Ltd, New Delhi, 2011.<br>4. R. Balakrishnan and K. Ranganathan, A Textbook of Graph Theory, Second Edition, Springer, 2012. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| **CO2** | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 |
| **CO3** | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 |
| **CO4** | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 |
| **CO5** | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 |

**Course Code: MAT18E** **Credit: 4 or 5**

## Hyperbolic Geometry

**Course Outcome (CO)**

On completion of the course, the student will be able to

| | Course Outcome | Level |
|---|---|---|
| **CO 1** | understand the models of hyperbolic plane viz., the Riemann sphere and the upper half plane | Remember<br>Understand |
| **CO 2** | demonstrate the transitivity properties and geometry of action of the Mobius group | Apply |
| **CO 3** | distinguish hyperbolic area and ordinary area | Analyze |
| **CO 4** | find out the hyperbolic distance formula in the upper half plane and the disc | Evaluate |
| **CO 5** | investigate the trigonometry in the hyperbolic plane | Create |

**Syllabus**

| Units | Content | Hrs. |
|---|---|---|
| **I** | A model for the hyperbolic plane, Riemann sphere, boundary at infinity of the upper half plane, the group of Mobius transformations Mob $^+$ ,the transitivity properties of Mob $^+$ and cross ratio. | 12 |
| **II** | Classification of elements in Mob$^+$ , matrix representations, reflections, conformality of elements of Mob $^+$ , transitivity properties and the geometry of action of Mob $^+$ . | 12 |
| **III** | Paths and elements of arc-length, the element of arc-length on $H$, path metric spaces, arc-length to metric, formulae for the hyperbolic distance in $H$ and isometries. | 12 |
| **IV** | Metric properties of (H, $d_H$) Poincare disc model, a general construction, convexity and hyperbolic polygons. | 12 |
| **V** | Definition of hyperbolic area, Gauss-Bonnet formula with applications and trigonometry in the hyperbolic plane. | 12 |
| | **References:**<br>1. J.W. Anderson, Hyperbolic geometry, second edition, Springer Undergraduate Mathematics Series, Springer-Verlag London, Ltd., London, 2005.<br>2. L. Keen and N. Lakic, Hyperbolic geometry from a local view point, London Mathematical Society Student Texts, Cambridge University Press, Cambridge, 2007. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 |
| **CO2** | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 |
| **CO3** | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 |
| **CO4** | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 |
| **CO5** | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 |

**Course Code: MAT21E** **Credit: 4**

## Discrete Dynamical Systems

**Course Outcome (CO)**

On completion of the course, the student will be able to

| | Course Outcome | Level |
|---|---|---|
| **CO 1** | appreciate the basics of topological dynamics with the help of illustrous examples. Understand that not only period three maps or chaotic, there are lot more. Using Sarkoviskii's theorem. | Remember & Understand |
| **CO 2** | discuss on the concept of attracting and repelling periodic points. Understand the theory of bifurication and understand and apply them. | Apply |
| **CO 3** | be well versed in Symbolic dynamics. Get an expertise in topological conjugacy. | Analyze |
| **CO 4** | thoroughly understand Newton's method in the perview of DDS. | Evaluate |
| **CO 5** | appreciate complex dynamics. Self similarity and Mendolbortt sets will be there favourite topics to discuss. | Create |

**Syllabus**

| Units | Content | Hrs. |
|---|---|---|
| **I** | Orbits - Phase portraits - Periodic points and stable sets. Sarkovskii's theorem. | 12 |
| **II** | Attracting and repelling periodic points - Differentiability and its implications - Parametrized family of functions and bifurcations - The logistic map. | 12 |
| **III** | Symbolic dynamics - Devaney's definition of Chaos - Topological Conjugacy. | 12 |
| **IV** | Newton's method-Numerical solutions of differential equations. | 12 |
| **V** | The dynamics of Complex functions - The quadratic family and the Mandelbrot set. | 12 |
| | **References**<br>1. Richard A. Holmgren, A First Course in Discrete Dynamical Systems, Springer Verlag (1994).<br>2. Robert L. Devaney, A First Course in Chaotic Dynamical Systems, Addison-Wesley Publishing Company, Inc. 1992. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 |
| **CO2** | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 |
| **CO3** | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 |
| **CO4** | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 |
| **CO5** | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 |

**Generic Electives**

**Course Code: MAT01G** **Credit: 4**

**Python for Sciences**

**Course Outcome (CO)**

On completion of the course, the student will be able to

| | Course Outcome | Level |
|---|---|---|
| **CO 1** | comfortably use Linux command line, VI editor and necessary basic commands of Linux. Python basics. | Remember & Understand |
| **CO 2** | use various data types in Python for storing list of items. | Apply |
| **CO 3** | write basic Python programs and functions using conditionals and loop structures. | Analyze |
| **CO 4** | write Python programs for various numerical algorithms. | Evaluate |
| **CO 5** | work with the Numpy and Scipy libraries. | Create |

**Syllabus**

| Units | Content | Hrs. |
|---|---|---|
| **I** | Introduction to linux commands and VI Editor. Overview of installing and running Python. Python interpreter and IDLE, one more text editor GEANY. Simple commands to use Python as a calculator. Python 2.x vs Python 3.x. Variables, Statements, Getting input from the user, Functions, Modules, Running Python scripts from a Command Prompt. Strings, Concatenating strings, String representation; repr and str; input vs raw input. String Conversions; Methods S ¸find, join, lower, replace, split, strip, translate. | 12 |
| **II** | Lists, Tuples and Dictionaries; Lists S ¸Indexing, Slicing, Adding Sequences, Multiplication, Membership, Length, Minimum and Maximum. List operations and methods. Tuple operations. Creating and using Dictionaries; Dictionary operations, String formatting with Dictionaries, Dictionary methods. | 12 |
| **III** | Conditionals and Loops, Importing libraries, Assignment, Blocks, if statement, else and elif clauses, Nesting Blocks. While loops, for loops, Iteration, Breaking, else clauses in Loops. Printing and Output formatting. Format specifiers like align, sign, width, precision, type etc.,. File operations. Python shell error handling. Python exceptions: Try and Except function. | 12 |
| **IV** | Various programs related to basic mathematics followed by Bisection Method, Newton Raphson Method, Regula Falsi Method, Trapezoidal Rule for integration, Simpsons 1/3rd rule, Euler's method for ODE, RK method of ODE etc., | 12 |
| **V** | Numpy and Scipy. Obtaining Numpy and Scipy libraries. Using Ipython. Numpy basics, Array creation, Printing Arrays, Basic operations, Universal functions, Indexing, Slicing and iterating. Changing shapes, stacking and splitting of arrays. Matplotlib and plotting. Scipy: scipy.special, scipy.integrate, | 12 |

| | | |
|---|---|---|
| | scipy.optimize, scipy.interpolate, scipy.fftpack, scipy.linalg, scipy.stats. | |
| | **References:**<br>1. M. Dawson, Python programming for the absolute beginner, 3rd Edition,Course Technology, 2010.<br>2. K.V. Namboothiri, Python for Mathematics Students, Version 2.1, March2013.<br>3. (https://drive.google.com/openid=0B27RbnD0q6rgZk43akQ0MmRXNG8).<br>4. Numpy tutorial - https://www.numpy.org/devdocs/user/quickstart.html<br>5. Beginner's Guide to matplotlib - https://matplotlib.org/users/beginner.html<br>6. Scipy tutorial - https://docs.scipy.org/doc/scipy/reference/tutorial/index.html | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 |
| **CO2** | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 |
| **CO3** | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 |
| **CO4** | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 |
| **CO5** | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 |

**Course Code: MAT02G** **Credit: 4**

## Game Theory

**Course Outcome (CO)**

On completion of the course, the student will be able to

| | Course Outcome | Level |
|---|---|---|
| **CO 1** | To study Real vector spaces and linear transformations on these spaces. | Remember & Understand |
| **CO 2** | To apply Linear programming and the theory of duality for the linear programs. | Apply |
| **CO 3** | To analyze the Simplex method, its working principle and using the algorithm to find the optimal of both primal and dual problems. | Analyze |
| **CO 4** | To understand Two person zero-sum matrix games, existence Nash equilibrium/optimal strategies for such games. | Evaluate |
| **CO 5** | To apply Iterated Elimination of Dominated Strategies(IEDS) procedure on a matrix game. To formulate the problem of finding Nash equilibrium as a linear program and compute the optimal strategies using simplex method. | Create |

**Syllabus**

| Units | Content | Hrs. |
|---|---|---|
| **I** | Linear algebra: vectors, scalar product, matrices, linear inequalities, solution of linear equations, real vector spaces of finite dimensions, linear transformations. | 12 |
| **II** | Convex sets and polytopes, convex cones, extreme vectors and extreme solutions for linear inequalities. | 12 |
| **III** | Linear programming: Example problems, formulation of linear programming problem, primal and dual problem; simplex method and its variations for solving linear programming problems, duality theorem. | 12 |
| **IV** | Two-person games: Examples, definitions and elementary theory; solutions of games, pure and mixed strategies, value of the game and optimal strategies; saddle point and minimax theorem; symmetric games; proof of fundamental theorem of games. | 12 |
| **V** | Solutions to matrix games: Relation between matrix games and linear programming; solving games by the simplex method; optimal strategies and solutions. | 12 |
| | **References:** 1. D. Gale, The Theory of Linear Economic Models, Mc Graw-Hill Book Company, London, 1990. 2. V. Chvatal, Linear Programming, W. H. Freeman and Company, 1983. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| **CO2** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO3** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO4** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO5** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Subject Code: MAT03G** **Credits: 3**

## History of Mathematics

**Course Outcome (CO)**

On completion of the course the students will be able to

| | Course Outcome | Level |
|---|---|---|
| **CO 1** | Know the of contributions to mathematics by different ancient and modern civilizations | Remember Understand |
| **CO 2** | To know about the development of Euclidean and non-Euclidean Geometry | Apply |
| **CO 3** | To appreciate the contribution of Indians in the fields of Mathematics | Analyze |
| **CO 4** | To develop gender sensitiveness by learning about the contributions of woman mathematicians | Evaluate |
| **CO 5** | To appreciate the traditional knowledge of Astronomy by Indian | Create |

**Syllabus**

| Units | Content | Hrs. |
|---|---|---|
| **I** | Development of Euclidean Geometry and Non-Euclidean Geometries | 12 |
| **II** | The Stories of ¼, *e* and *i* . | 12 |
| **III** | Mathematics in Different Cultures (with special emphasize on Indian Astronomy). | 12 |
| **IV** | Study of Kanakkathikaram and Lilavathi . | 12 |
| **V** | Development of Modern Mathematics. | 12 |
| | **References.**<br>1. G.G. Joseph, Crest of the peacock, Third Edition, Princeton University Press, Princeton, 2011. | |

**Mapping of Program Specific Outcomes with Course Outcomes**

| CO /PSO | PSO1 | PSO2 | PSO3 | PSO4 | PSO5 | PSO6 | PSO7 | PSO8 |
|---|---|---|---|---|---|---|---|---|
| **CO1** | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| **CO2** | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| **CO3** | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| **CO4** | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| **CO5** | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |