CENTRAL UNIVERSITY OF ANDHRA PRADESH

ANANTHAPURAMU

Vidya Dadati Vinayam

(Education Gives Humility)

M.Sc. Mathematics

"Numbers have life; they're not just symbols on paper"

- Shakunthala Devi

Structure and Syllabus

(2021-22 Batch)

CONTENTS

Important Information to Students

I. Programme: M.Sc. Mathematics

II. Eligibility: Bachelor's degree with a minimum of 60% marks in the aggregate of optional subjects with Mathematics/ Statistics as one of the subjects; OR with at least 55% of marks for those students who have done B.A. / B.Sc. (Hons) course in Mathematics / Statistics.

III. The minimum duration for completion of the programme is four semesters (two academic years) and the maximum duration is eight semesters (four academic years) or as per amendments made by the regulatory bodies from time to time.

IV. A student should attend at least 75% of the classes, seminars, practicals in each course of study.

V. All theory courses in the programme carry a Continuous Internal Assessment (CIA) component to a maximum of 40 marks and End Semester Examination (ESE) for a maximum of 60 marks. The minimum pass marks for a course is 40%.

All lab components carry a Continuous Internal Assessment (CIA) component to a maximum of 60 marks and End Semester Practical Examination (ESE) for maximum of 40 marks. The minimum pass marks for a course in 40%

VI. A student should pass separately in both CIA and the ESE, i.e., a student should secure 16 (40% of 40) out of 40 marks for theory and 24 (40% of 60) out of 60 marks for lab components in the CIA. Therefore, a student should secure 24 (40% of 60) out of 60 marks for theory and 16 (40% of 40) out of 40 marks for lab components in the end semester examination.

VII. A student failing to secure the minimum pass marks in the CIA is not allowed to take the end semester examination of that course. S/he has to redo the course by attending special classes for that course and get the pass percentage in the internal tests to become eligible to take the end semester examination.

VIII. Students failing a course due to lack of attendance should redo the course.

IX. Re-evaluation is applicable only for theory papers and shall not be entertained for other components such as practicals/ thesis/dissertation/ internship, etc.

X. An on-campus elective course is offered only if a minimum of ten or 40% of the students registered, whichever is higher, exercise their option for that course.

Introduction to the Programme

M.Sc. Mathematics is one of the fine new postgraduate programmes being offered by CUAP in 2021-22 academic year. This programme provides the students with great opportunity in job seeking, higher education and research. While preparing the syllabus of the core courses and the basket of elective courses one has to take into account to provide the following points.

a) The core courses should help the students to write the competitive examinations (like CSIR-UGC net) to pursue mathematics at the later years.
b) The course Statistics and Probability should contain more of applied probabilities rather than concepts involving deeper analysis.
c) The course Number Theory can have topics like cryptography.
d) The elective courses should facilitate the student to seek for the jobs in case he/she does not want to continue mathematics.
e) The course also encourages the department to float elective courses that are inter-disciplinary.
f) The student-centric approach of the curriculum has been designed to equip learners with appropriate knowledge, skills and values of the discipline.

Objectives of the Programme:

Upon completion of the M.Sc. programme, the graduate will

- Have professional and ethical responsibility and able to adopt new skills and techniques.
- Be able to plan, organize, lead and work in team to carry out tasks to the success of the team.
- Understand the need for continuous learning and prepare himself / herself with relevant inter–personal skills as an individual, as a member or as a leader throughout the professional career.

- Be motivated to prepare himself/ herself to pursue higher studies and research to meet out academic demands of the country.
- Communicate mathematical ideas with clarity and able to identify, formulate and solve mathematical problems.
- Have knowledge in wide range of mathematical techniques and application of mathematical methods/tools in scientific and engineering domains.
- Have both analytical and computational skills in mathematical sciences.

Learning Outcomes of the Programme:

On successful completion of the programme students should be able to:

- Solve diverse mathematical problems and capable of analyzing the obtained results.
- Analyze and interpret the outcomes and develop new ideas based on the issues in broader social context.
- Apply the knowledge and design the methodology to the real world problems.
- Use the learned techniques, skills and modern mathematical tools suitable to the problem encountered.
- Acquire problem solving skills, analytical thinking, creativity and mathematical reasoning.
- Write effective reports and documents, prepare effective presentations and communicate the findings efficiently.
- Develop confidence to crack the competitive exams like NET, GATE, SET, etc.

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M.Sc. Mathematics : Semester and Course wise Credits

Semester	Discipline Core (DSC) (L+T+P)	Discipline Elective (DSE) / Elective (EL)	Project Work / Dissertation	Lab	Total Credits
I	DSC 1 (4) DSC 2 (4) DSC 3 (4) DSC 4 (4) DSC 5 (2)	EL-1 by MOOC (3)		DSC 5 (2)	23
II	DSC 6 (4) DSC 7 (4) DSC 8 (4) DSC 9 (4) DSC 10 (4)	EL-2 by MOOC (3)			23
III	DSC 11 (4) DSC 12 (4) DSC 13 (4)	EL-3 (2) EL-4 (3) EL-5 by MOOC (2)		EL-3 (1)	20
IV	DSC 14 (1)	EL-6 (3) EL-7 (3)	DSC 15 (6) Project Work/ Dissertation	DSC 14 (1)	14
Total	51	19	6	4	80
Percentage	63.75	23.75	7.50	5.00	-

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M.Sc. Mathematics : Programme Structure

S. No.	Course Code	Title of the Course	Number of Credits	Contact Hours		
				L	T/L	P/S
Semester – I						
1.	MAT101	Linear Algebra*	4	46	6	6
2.	MAT102	Algebra *	4	46	6	6
3.	MAT103	Real Analysis	4	46	6	6
4.	MAT104	Ordinary Differential Equations	4	46	6	6
5.	MAT105	Programming and Tools for Mathematics	2	30	-	-
		Lab: Programming and Tools for Mathematics	2	-	45	-
6.	MAT106	MOOCS-I/Online/Elective #	3	-	-	-
		Total	**23**	**214**	**69**	**24**

Note: # as per the choice of the student and the instructor
* Core/Generic Elective

S. No.	Course Code	Title of the Course	Number of Credits	Contact Hours		
				L	T/L	P/S
Semester – II						
1.	MAT201	Multivariable Calculus	4	46	6	6
2.	MAT202	Topology	4	46	6	6
3.	MAT203	Measure and Integration	4	46	6	6
4.	MAT204	Complex Analysis	4	46	6	6
5.	MAT205	Discrete Mathematics*	4	46	6	6
6.	MAT206	MOOCS-II/Online/ Elective #	3	-	-	-
7.	MAT207	Add on Course	-	22	4	4
		Total	**23**	**252**	**34**	**34**

Note: # as per the choice of the student and the instructor
* Core/Generic Elective

S. No.	Course Code	Title of the Course	Number of Credits	Contact Hours		
				L	T/L	P/S
Semester-III						
1.	MAT301	Partial Differential Equations	4	46	6	6
2.	MAT302	Functional Analysis	4	46	6	6
3.	MAT303	Probability and Statistics	4	46	6	6
	MAT304	MOOCS-III/Online/ Elective#	2	-	-	-
4.	**Elective-I (any *One* of the paper from below list)** @		**3#**	**35**	**5**	**5**
5.	**Elective-II (any *One* of the paper from below list)** @		**3#**	**35**	**5**	**5**
	MAT315	Numerical Analysis and Scientific Computing	2$	30	-	-
		Lab: Numerical Analysis and Scientific Computing	1	-	22	-
	MAT316	Linear Programming*				
	MAT317	Elements of Fourier Analysis				
	MAT318	Advanced Complex Analyses				
Total			**20**	**238**	**50**	**28**

@ The number of elective courses may increase

Note: According to students choice the elective-I and II contact hours per week may change for #Theory and **$** Lab

As per the choice of the student and the instructor * Discipline Elective /Generic Elective

S. No.	Course Code	Title of the Course	Number of Credits	Contact Hours		
				L	T/L	P/S
Semester-IV						
1.	MAT401	*e*-Resource	1	15	-	-
		Lab- *e*-Resource	1	-	22	-
2.	MAT402	Dissertation	6	75	5	10
3.	**Elective-I (any one of the paper from below list)@**		3	35	5	5
4.	**Elective-II (any one of the paper from below list)@**		3	35	5	5
	MAT415	Advanced Complex Analyses#				
	MAT416	Topics in Operator Theory				
	MAT417	Design and Analysis of Algorithms*				
	MAT418	Automata Theory and Formal Languages*				
Total			**14**	**160**	**37**	**20**

Note: @ The number of elective courses may increase

Students can be done additional MOOC courses, if they want to acquire additional credits

"MAT-318: Advanced Complex Analyses" course will be offered in Semester-IV also for the benifit of those students who missed it in Semester-III.

* Discipline Elective /Generic Elective

L: Lectures; S: Seminars; P: Presentations; L: Lab; T: Tutorials

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M. Sc. Mathematics : Credit Distribution

Semester	Total Credits	Cumulative Credit at the end of the Semester
Semester-I	23	23
Semester-II	23	46
Semester-III	20	66
Semester-IV	14	80

- **Assessment Pattern:** 40% of internal [formative evaluation -- two best out of three tests (for a maximum of 15 marks each = 30marks) -- and seminar/ assignments/ attendance (10 marks)] and 60% (summative evaluation -- end of semester examination).

End Semester Examination

Maximum Marks: 60 Time: 3 Hours

Dissertation

Dissertation/Project report : Evaluation - 60 marks
Viva-Voce - 40 marks

SEMESTER-WISE DETAILED SYLLABUS

SEMESTER-I

Course Code : **MAT101** Core/ Elective : **Core** No. of Credits : **4**	Course Title **Linear Algebra**

Course Objective:

- To prepare students to handle solving problems involving linear equations and determining the qualitative properties of the solution set.
- To obtain determinant of a matrix and describe its properties.

Learning Outcome:

On successful completion of this course the student should be able to:

- Understand the concepts of vector spaces, sub spaces, basis, dimension and their properties.
- Understand the concepts linear transformations and their properties.
- Obtain determinant of a matrix and describe its properties.
- Understand the properties of inner product space and determine orthogonality in inner product spaces.

Course Outline:

Unit-I:

System of Linear equations, Various types of matrices - Row-Reduced Echelon matrices Definition, various examples and basic properties of vector spaces over R and C.

Unit-II:

Subspaces, Direct sums and Quotient spaces. Bases and dimension.

Unit-III:

Linear transformations and their matrix representations, Dual vector Spaces.

Unit-IV:

Determinant of a matrix and its properties, Eigen values and Eigenvectors, Diagonalizations.

Unit-V:

Inner product spaces, Adjoints Unitary and Normal operators, orthogonal matrices, rotations, spectral theorem. Bilinear forms.

References:

Michael Artin, "*Algebra*". PHI, 2010.

K. Hoffman and R. Kunze, "*Linear Algebra*". PHI, 2014.

S. Kumaresan, "*Linear Algebra*". PHI, 2000.

M.T. Nair & A. Singh, "*Linear Algebra*". Springer, 2019.

Course Code : **MAT102** Core/ Elective : **Core** No. of Credits : **4**	Course Title **Algebra**

Course Objectives:

- To learn the group, matrix groups and permutation groups.
- To learn the concepts and basic ideas involved in homomorphism and quotient rings.
- To understand the fundamental concepts of ideal and unique factorization domains.

Learning Outcome:

On successful completion of this course the student should be able to:

- Acquire the basic knowledge and structure of groups, sub groups and cyclic groups.
- Get the behaviour of permutations and operations on them.
- Study the homomorphisms and isomorphisms with applications.
- Understand the applications of ring theory in various fields.
- Understand the ring theory concepts with the help of knowledge in group theory.

Course Outline:

Unit-I:

Groups: Groups, Various examples, Matrix groups, permutation groups.

Unit-II:

Group actions, Sylow theorems.

Unit-III:

Rings, ideals, homomorphisms, quotient rings.

Unit-IV:

Integral domains, Fields, Euclidean domains.

Unit-V:

Principal Ideal and Unique Factorization domains.

References:

D. A. R. Wallace, "*Groups, Rings and Fields*". Springer (SUMS), 1998.

M. Artin, "*Algebra*", PHI, 2010.

P. B. Bhattacharya, S. K. Jain and S. R. Nagpaul, "*Basic Abstract algebra*". Cambridge University Press, 2003.

Course Code **: MAT103** Core/ Elective **: Core** No. of Credits **: 4**	Course Title **Real Analysis**

Course Objectives:

- To develop fundamental concepts in Real Analysis and make the student acquainted with tools of analysis which is essential for the study and appreciation of many related branches of mathematics and applications.
- To implement the theorems taught in the course to work associated problems, including proving results of suitable accessibility.

Learning Outcomes:

After completion of the course student should be able to:

- Get a clear idea about real numbers and real valued functions.
- Know the countability and uncountability of the sets.
- Test the continuity and Riemann integration of a function.
- Obtain the skills of analyzing the concepts and applying appropriate methods for testing convergence of a sequence/series.
- Know the differences between open, closed and bounded sets.

Course Outline:

Unit-I:

Real line, Limits and continuity, Completeness property Countable and Uncountable sets, Cantor sets, monotone functions.

Unit-II:

Metric Spaces, examples, the relative metric, interior and limit points, open and closed sets, bounded sets, convergence in metric spaces, complete metric spaces. Continuous functions and homeomorphisms. Nested set theorem, Baire category theorem.

Unit-III:

Compactness, Totally bounded sets, Characterizations of compactness, Finite intersection property, Continuous functions on compact sets, Uniform continuity. Connectedness and its properties, Continuous functions.

Unit-IV:

Riemann integration: Fundamental theorem of calculus. Set of measure zero, Lebesgue's Criterion, Cantor set, Integrable functions.

Unit-V:

Convergence of sequence and series of functions: Point wise and uniform convergence of functions, Series of functions, Power series, Dini's theorem, Ascoli's theorem. Nowhere-differentiable Continuous functions, Weierstrass approximation theorem.

References:

Carothers, N. L. "*Real analysis"*. Cambridge University Press, Cambridge, xiv+401 pp, 2000.

Charles G. Denlinger, "*Elements* of *Real Analysis"*. Johns & Bartlett Learning, 2011.

Rudin, Walter*, "Principles of Mathematical Analysis"*. McGraw-Hill, New York, 1976.

Pugh, Charles C, "*Real Mathematical Analysis*. *Undergraduate Texts in Mathematics*". Springer, Cham, xi+478 pp, 2015.

Course Code : **MAT104** Core/ Elective : **Core** No. of Credits : **4**	Course Title **Ordinary Differential Equations**

Course Objectives:

- To introduce the theory and methods of ordinary differential equations.
- To implement the methods taught in the course to work associated problems, including proving results of suitable accessibility.
- To understand the Existence and Uniqueness Theorem and its applications.
- To prepare students to solve problems arising from many applications such as mathematical models of physical or engineering processes.

Learning Outcomes:

After completion of the course student should be able to:

- Generate linear ordinary differential equations using power series method.
- Understand Existence and Uniqueness of Initial Value Problems
- Solve the BVP's for second order equations using Green's function.
- Know asymptotic behavior and stability.

Course Outline:

Unit-I:

Review of solution methods for first order as well as second order equations, Power Series methods with properties of Bessel functions and Legendre polynomials.

Unit-II:

Existence and Uniqueness of Initial Value Problems: Picard‘s and Peano‘s Theorems, Gronwall‘s inequality, continuation of solutions and maximal interval of existence, continuous dependence.

Unit-III:

Higher Order Linear Equations and linear Systems: fundamental solutions, Wronskian, variation of constants, matrix exponential solution, behaviour of solutions. Two Dimensional Autonomous Systems and Phase Space Analysis: critical points, proper and improper nodes, spiral points and saddle points.

Unit-IV:

Asymptotic Behavior: stability (linearized stability and Lyapunov methods).

Unit-V:

Boundary Value Problems for Second Order Equations: Green's function, Sturm comparison theorems and oscillations, eigenvalue problems.

References:

G. F. Simmons, *"Differential Equations with Applications and Historical Notes"*. New York: McGrawHill, 1991.

M. Hirsch, S. Smale and R. Deveney, *"Differential Equations, Dynamical Systems and Introduction to Chaos"*. Academic Press, 2004L.

Perko, *"Differential Equations and Dynamical Systems, Texts in Applied Mathematics"*. Volume 7, 2nd Edition, Springer Verlag, New York, 1998.

Mohan C. Joshi, *"Ordinary Differential Equations: Modern Perspective"*. Narosa Publishing House, 2006.

A.. K.. Nandakumaran, P. S. Datti, Raju K. George, *"Ordinary Differential Equations : Principles and Applications"*. Cambridge IISc Series, Cambridge University Press, 2017.

V. Raghavendra, V. Lakshmikantam, S Deo, *"Text book of ordinary differential equations"*. Tata McGrawHill Education, 2008.

D. A. Sanchez, *"Ordinary Differential Equations and Stability Theory: An Introduction"*. Dover Publ. Inc., New York, 1968.

Course Code : **MAT105** Core/ Elective : **Core** No. of Credits : **4**	Course Title **Programming and Tools for Mathematics**

Course Objectives:

The main purpose of the course:

- To provide basic knowledge of Python.
- Along with computer programming language the students also learn Saga, LaTex, and other Scientific computing packages.

Learning Outcomes:

After completion of the course student should be able to:

- Problem solving and programming capability of Python.
- Acquire knowledge on LaTex and other scientific computing packages.

Course Outline:

Unit-I:

Basic Introduction to Python I: (a) Introduction to (object oriented) programming (b) Input/output, files, lists.

Unit-II:

Basic Introduction to Python II: (a) Exception handling (b) Libraries...

Unit-III:

Introduction to Sage.

Unit-IV:

Introduction to LaTeX.

Unit-V:

Scientific Computing packages.

Some sample outlines:

https:// www.cmi.ac.in / madhavan / courses / python2021 / (just the first module, second module will be covered in Algorithms course) **(Online Sources).**

https:// www.imsc.res.in / amri / sagecourse / **(Online Sources).**

Gratzer, Geroge, "*More Math into LaTex*". Spinger Publication, 2007.

Stefan Kottwitz, "*LaTex–Bigginner's Guide*". Packt Publiclations, 2011.

Gratzer and Geroge, "*Practicle LaTex*". Spinger Publication, 2014.

SEMESTER-II

Course Code : **MAT201** Core/ Elective : **Core** No. of Credits : **4**	Course Title **Multivariable Calculus**

Course Objectives:

- To provide students with a good understanding of the concepts and methods of multivariate calculus, described in detail in the syllabus.
- To help the students develop the ability to solve problems using multivariate calculus.
- To develop abstract and critical reasoning by studying proofs as applied to multivariate calculus.

Learning Outcomes:

After completion of the course student should be able to:

- Solve problems using chain rule and directional derivative of a curve.
- Knows about the inverse function and implicit function theorems.
- Apply the Lagrange multiplier method.
- Describe the properties of space curves.

Course Outline:

Unit-I:

Differentiability of functions from an open subset of R^n into R^m its basic properties, Chain rule, Partial and Directional derivatives.

Unit-II:

Continuously differentiable functions, Inverse function theorem, Implicit function theorem.

Unit-III:

Interchange of order of differentiation, Taylor's series, local Extrema of a function, Extremum problems with constraints, Lagrange multiplier method with applications.

Unit-IV:

An introduction of plane and space curves and their properties.

Unit-V:

An introduction of surfaces in R^3.

References:

Walter Rudin, "*Principles of Mathematical Analysis"*. Third Edition, McGraw-Hill, 1976.

Tom M. Apostol, "*Analysis"*. Narosa Publishing House, 1996.

Andrew Pressley, "*Elementary Differential Geometry* Springer". SUMS series, 2012.

†. It is advised to use the book by Pressley given above for these two sections.

Prerequisites: Linear algebra and Real analysis.

Course Code : **MAT202** Core/ Elective : **Core** No. of Credits : **4**	Course Title **Topology**

Course Objective:

- To prepare students to handle courses involving topology and geometry including complex analysis, functional analysis and several variable calculus.

Learning Outcome:

After completion of the course student should be able to:

- Understand the concepts such as open and closed sets, interior, closure and boundary.
- Create new topological spaces by using sub spaces, product and metric topologies.
- Know the connectedness, locally connected and path connected spaces.

Course Outline:

Unit-I:

Topological Spaces, Open and closed sets, interior, Closure and Boundary of sets, Basis for Topology.

Unit-II:

Product Topology, Subspace Topology, Metric Topology, Continuous functions, open maps, homeomorphisms.

Unit-III:

Connected spaces, Connected components, locally connected spaces, path-connected spaces.

Unit-IV:

Countability axioms, First countable spaces, Compact Spaces, Locally compact spaces

Unit-V:

Separation axioms, T1 spaces, Hausdorff, regular, normal spaces; Uryshon lemma, Tietze Extension Theorem.

References:

J. R. Munkres, *"Topology"*. PHI, 2013.

M. A. Armstrong, *"Basic Topology"*. Springer-Verlag, 1983.

K. Janich, *"Topology"*. Springer-Verlag, 1984.

Course Code : **MAT203** Core/ Elective : **Core** No. of Credits : **4**	Course Title **Measure and Integration**

Course Objectives:

- To gain understanding of the abstract measure theory, definition and main properties of the integral.
- To construct Lebesgue's measure on the real line and in n-dimensional Euclidean Space.
- To explain the basic advanced directions of the theory.

Learning Outcomes:

After completion of the course student should be able to:

- Understand the basic concepts underlying the definition of the general Lebesgue integral.
- Prove basic results of measure and integration theory.
- Demonstrate understanding of the statement and proof of the fundamental integral convergence theorems, and their applications.

Course Outline:

Unit-I:

Review of Riemann Integral Lebesgue Measure: Lebesgue outer measure; Lebesgue measurable sets; Existence of non-Lebesgue measurable set.

Measure on an arbitrary σ-algebra: Generated σ-algebra and Borel σ-algebra; Dirac delta measure, finite measure, probability measure and sigma-finite measure; Complete measure and completion.

Unit-II:

Measurable Functions: Pointwise convergence and almost everywhere convergence; Egoroffs theorem; Convergence in measure.

Unit-III:

Integral of measurable functions: Monotone convergence theorem; Fatou's lemma, Measures induced by positive measurable functions; Radon-Nykodym theorem for σ-finite measures. Integral of real and complex valued measurable functions: Dominated convergence theorem; HÖlders and Minkowski's inequalities; L^p-spaces and their completeness.

Unit-IV:

Indefinite Integral of Integrable Functions: Indefinite integral of integrable functions, Functions of bounded variation, absolutely continuous functions, Fundamental theorem for Lebesgue integration.

Unit-V:

Product measure space: Product σ-algebra and product measure; Fubini's theorem; Convolution of integrable functions.

References:

G. de Barra, *"Measure and Integration"*. Wiley Eastern, 1981.

M. Thamban Nair, *"Measure and Integration: A First Course"*. Taylor & Francis, CRC- Press, 2020.

H. L. Royden, *"Real Analysis"*. 3rd Edition, Prentice-Hall of India, (Chapter 3, Sections 1-5), 1995.

W. Rudin, "*Real and Complex Analysis"*. 3rd edition, McGraw-Hill, International Editions, (Chapters 1, 3), 1987.

E. Stein and R. Shakarchi, "*Real Analysis: Measure Theory, Integration, and Hilbert Spaces"*. Princeton University Press, Princeton and Oxford, (Chapters 1-3, 6), 2005.

Course Code : **MAT204** Core/ Elective : **Core** No. of Credits : **4**	Course Title **Complex Analysis**

Course Objectives:

- To lay the foundation for this subject, to develop clear thinking and analyzing capacity for further study.
- Cauchy's Theorem guaranteeing that certain integrals along closed paths are zero. This striking result leads to useful techniques for evaluating real integrals based on the 'calculus of residues'.
- Important results are the Mean Value Theorem, leading to the representation of some functions as power series (the Taylor series), and the Fundamental Theorem of Calculus which establishes the relationship between differentiation and integration.

Learning Outcomes:

After completion of the course student should be able to:

- Analyze limits and continuity for complex functions as well as consequences of continuity.
- Applying the concept and consequences of analyticity and the Cauchy-Riemann equations and of results on harmonic and entire functions including the fundamental theorem of algebra.
- Evaluating integrals along a path in the complex plane and understand the statement of Cauchy's Theorem
- Represent functions as Taylor, power and Laurent series, classify singularities and poles, find residues and evaluate complex integrals using the residue theorem.

Course Outline:

Unit-I:

Metric in complex plane. Stereographic projection. Fractional linear transformation.

Unit-II:

Analytic functions Cauchy-Riemann equations, harmonic functions Elementary functions: Exponential function, Hyperbolic and trigonometric functions, Logarithms, Branch and branch cuts.

Power series: Domain and Radius of convergence, Characterization of analyticity via power series.

Unit-III:

Integration: Curves in the complex plane, Integral along piecewise smooth curves, Contour integration, Cauchy's theorem, Cauchy's integral formulas.

Unit-IV:

Zeroes of analytic functions, Identity theorem, Maximum modulus theorem, Schwarz's lemma and some applications, Isolated singularities, Laurent series.

Unit-V:

Residues and Real Integrals: Residue theorem, Calculation of residues, Evaluation of improper integrals.

References:

Donald Sarason, *"Complex Function Theory"*. TRIM Series, 2010.

Conway, John B, *"Functions of one complex variable"*. 2nd Edition. Graduate Texts in Mathematics, 11. Springer-Verlag, New York- Berlin, xiii+317 pp, 1978.

Stein, Elias M., Shakarchi, Rami *"Complex analysis. Princeton Lectures in Analysis"*. Princeton University Press, Princeton, NJ, xviii+379 pp2, 2003.

Ahlfors, Lars V, *"Complex analysis: An introduction of the theory of analytic functions of one complex variable"*. 2nd Edition McGraw- Hill Book Co., New York-Toronto-London xiii+317 pp, 1966.

Course Code : **MAT205** Core/ Elective : **Core** No. of Credits : **4**	Course Title **Discrete Mathematics**

Course Objectives:

- To provide students with an overview of discrete mathematics.
- To learn about the topics such as logic and proofs, sets and functions, and the probability.
- To work with sets, relations for solving applied problems and investigate their properties.
- To introduce basic concepts of graphs, digraphs and trees.

Learning Outcomes:

After completion of the course student should be able to:

- Analyze logical propositions via truth tables.
- Prove mathematical theorems using mathematical induction.
- Understand the statistics as a science of decision making in the real life problems with the description of uncertainty.

Course Outline:

Unit-I:

Introduction to proposition and predicate Logic Sets, relations, functions Proof techniques, induction, Pigeonhole principle and applications.

Unit-II:

Ramsey Theory and applications Basic combinatorics, permutations, combinations, counting using recurrence relation. Principle of inclusion and exclusion and applications.

Unit-III:

Recurrences, generating functions, formal power series.

Unit-IV:

Graph Theory

- Paths, Cycles, Trees, Connectivity, Menger's Theorem
- Flows, Maximum Flow-Minimum Cut theorem
- Matching (Hall's theorem, Tutte's generalisation)
- Planarity

Unit-V:

Probabilistic method and applications.

References:

C. L. Liue, *"Elements of Discrete Mathematics"*. Tata McGraw-Hill Education Pvt. Ltd, 2008.

Peter Cameron, *"Combinatorics – Topics, Techniques, Algorithms"*. Cambridge University Press, 6 October, 1994.

J. Matousek and J. Nesetril, *"Invitation to Discrete Mathematics"*. Oxford University Press, 1998.

J. H. van Lint and R.M. Wilson, *"Combinatorics"*. Cambridge University Press; 2nd edition, 22 November, 2001.

M. Aigner and G.M. Ziegler, *"Proofs from the book"*. 5th edition, Springer, 2014.

SEMESTER-III

Course Code : **MAT301** Core/ Elective : **Core** No. of Credits : **4**	Course Title **Partial Differential Equations**

Course Objective:

- To develops the ability to solve partial differential equations of first and second order by standard methods.
- To prepare students to solve problems arising from many applications such as mathematical models of physical or engineering processes.

Learning Outcome:

After completion of the course student should be able to:

- Solve partial differential equations of first and second order.
- Model initial and boundary value problems.
- Understand the Heat and Wave equations and its properties.

Course Outline:

Unit-I:

Cauchy Problems for First Order Hyperbolic Equations: method of characteristics, Monge cone. Classification of Second Order Partial Differential Equations: normal forms and characteristics.

Unit-II:

Initial and Boundary Value Problems: Lagrange-Green's identity and uniqueness by energy methods. Stability theory, energy conservation and dispersion.

Unit-III:

The Heat Equation - The maximum and minimum principles, Uniqueness, Continuous dependence, Method of separation of variables, Time-independent boundary conditions, Time-dependent boundary conditions, Duhamel's principle.

Unit-IV:

The Wave Equation - Introduction, The infinite string problem, The D'Alembert solution of the wave equation, The semi-infinite string problem, The finite vibrating string problem, The method of separation variables, The inhomogeneous wave equation.

Unit-V:

Laplace Equation. Basic properties, The maximum and minimum principle, Green's identity and fundamental solution. The method of separation of variables The Dirichlet problem for rectangles, annuli and disk. The exterior Dirichlet problem. The Fourier transform methods for PDE's

References:

Ian N. Sneddon, *"Elements of Partial Differential Equations"*. Dover Publications, 2006.

F. John, *"Partial Differential Equations"*. 3rd Edition., Narosa Publications, New Delhi, 1979.

A. K. Nandakumaran, and P. S. Datti, *"Partial Differential Equations Classical Theory with a Modern Touch"*. Cambridge University Press, 2020.

E. Zauderer, *"Partial Differential Equations of Applied Mathematics"*. 2nd Edition, John Wiley and Sons, 1989.

L.C. Evans, *"Partial Differential Equations"*. Graduate Studies in Mathematics, Vol.19, AMS, Providence, 1998.

Course Code : **MAT302** Core/ Elective : **Core** No. of Credits : **4**	Course Title **Functional Analysis**

Course Objective:

- To prepare students to handle Functional Analysis, Fourier series and their convergence, Laplace and Fourier transforms Wavelets analysis and Continuous probability theory.

Learning Outcome:

After completion of the course student should be able to:

- Take courses in advanced functional analysis, partial differential equations etc.
- Study abstract measure theory and probability theory.

Course Outline:

Unit-I:

Normed linear space; Banach space and basic properties; Standard examples of sequence spaces (c_{00} with p-norm, c_0 and c with supnorm, ℓ^p) and functions spaces (C[a, b] with p-norm, L^p[a, b]); best approximation property; characterizations of finite-dimensional normed linear spaces.

Unit-II:

Hahn-Banach extension theorem; Bounded operators; Space of bounded operators; Uniform boundedness principle; Riesz representation theorem. Closed graph theorem and Open mapping theorem.

Unit-III:

Inner product space and Hilbert space; Projection theorem; Orthonormal basis; Bessel's inequality and Parseval's formula; Riesz- Fischer theorem.

Unit-IV:

Dual spaces of c_{00}, c_0, c, $\ell^p(1 \leq p < \infty)$, statements of duals of $L^p[a, b]$ and $C[a, b]$ with supremum norm; Separability, Reflexivity, weak and weak*-convergence.

Unit-V:

An introduction to spectral theory: Spectrum of bounded operators; Compact operators and their spectrum; Spectral theorem for compact self-adjoint operators.

References:

M. Thamban Nair, *"Functional Analysis: A First Course"*. Prentice Hall of India, 2002; PHI- Learning, 2nd Edition, 2020.

B.V. Limaye, *"Functional Analysis"*. 2nd Edition, New Age International, Second Edition, 1996.

G. Bachmann and L. Naricii, *"Functional Analysis"*. Academic Press, 1996.

B. Bollabas, *"Linear Analysis"*, Cambridge University Press (Indian edition).1999.

A.E. Taylor and D.C. Lay, *"Introduction to Functional Analysis"*. 2nd Edition., Wiley, New York, 1980.

J.B. Conway, *"A Course in Functional Analysis"*. 2nd Edition, Springer, 1997.

Simon, *"Barry Real analysis with a 68-page companion booklet. A Comprehensive Course in Analysis"*. Part 1. American Mathematical Society, Providence, RI, xx+789 pp, 2015.

Course Code : **MAT303** Core/ Elective : **Core** No. of Credits : **4**	Course Title **Probability and Statistics**

Course Objectives:

- To provide an understanding of the basic concepts in probability, conditional probability and independent events.
- To focus on the random variable, mathematical expectation, and different types of distributions, sampling theory and estimation theory.
- To acquaint students with various statistical methods and their applications in different fields.
- To design a statistical hypothesis about the real world problem and also it is inevitable to have the knowledge of hypothesis testing for any research work.

Learning Outcomes:

The Students will be able to but not limited to:

- Apply key concepts of probability, including discrete and continuous random variables, probability distributions, conditioning, independence, expectations, and variances.
- Define and explain the different statistical distributions (e.g., Normal, Binomial, Poisson) and the typical phenomena that each distribution often describes.
- Define and demonstrate the concepts of estimation and properties of estimators.
- Apply the concepts of interval estimation, confidence intervals, hypothesis testing and p-value.

Course Outline:

Unit-I:

Basic Combinatorics, Classical and Axiomatic definitions of probability. Properties of Probability function. Conditional probability, Bayes Rule. Independence of Events and multiplication rule.

Unit-II:

Random Variables, Cumulative distribution function and its properties. Probability mass and Probability density functios. Expectation, moments and moment generating function. Distribution of a function of a random variable. Marko and Chebyschev inequality. Special Distributions. Distribution of a function of a random variable. Markov and Chebyshevs inequality. Special distributions: Bernoulli, Binomial, Geometric, negative binomial hypergeometric, Poisson Exponential Gamma, and other distributions. Joint distributions, marginal and conditional distributions.

Unit-III:

Independence of random variables, covariance and correlation. Functions of random variables and their distributions. Multinomial distributions. Bivariate normal distributions and their properties. Weak Law of large numbers, Central limit theorem and their applications.

Unit-IV:

Descriptive statistics, Graphical representation of the dat, histogram and relative frequency histogram, measures of location, variability skewness and kurtosis. Population, sample parameters. Random sample, sampling distributions of a statistic. t, F and $\chi 2$ distributions and their interrelations.

Unit-V:

Point estimation method of moments maximum likelihood estimator, unbiasedness, consistency. Large sample and exact confidence intervals for mean, proportions. Testing of hypotheses. Neyman Pearson fundamental lemma. Likelihood ratio tests for one sample and two sample problems for normal populations. P value. Chi-square test of goodness of fit.

References:

Sheldon Ross, *"A first course in Probability"*. Pearson; 10th edition, 28 November, 2018.

George Casella and Roger L. Berger Duxbury, *"Statistical Inference"*. Thomson Learning, Wadsworth Group, 2002.

Course Code : **MAT315** Core/ Elective : **Elective** No. of Credits : **3**	Course Title **Numerical Analysis and Scientific Computing**

Course Objectives:

- To know about various types of Errors, Calculate the error correction and get actual root of the equation.
- To understand different methods of solution of the equations and compare them.
- To get the detailed knowledge about different numerical methods which are used in engineering field, with emphasis on how to prepare program for different methods.

Learning Outcome:

After completion of the course student should be able to:

- Use numerical methods in modern scientific computing.
- Be familiar with finite precision computing, numerical solutions of nonlinear equations in a single variable, numerical interpolation and approximation of functions, numerical integration and differentiation etc.
- Be familiar with programming with numerical packages like MATLAB.

Course Outline:

Unit-I:

Principle of Scientific Computing: Errors: Floating-point approximation of a number, Loss of significance and error propagation, Stability in numerical computation.

Unit-II:

Linear Systems: Gaussian elimination with pivoting strategy, LU factorization, Residual corrector method, Solution by iteration (Jacobi and Gauss -Seidal with convergence analysis), Matrix norms and error in approximate solution, Eigen value problem (Power method), Gershgorins theorem (without proof).

Unit-III:

Nonlinear Equations: Bisection method, Fixed-point iteration method, Secant method, Newton's method, Rate of convergences, Solution of a system of nonlinear equations, Unconstrained optimization. Interpolation by Polynomials: Lagrange interpolation, Newton interpolation and divided differences, Error of the interpolating polynomials, Piecewise linear and cubic spline interpolation, Trigonometric interpolation.

Unit-IV:

Data fitting and least-squares approximation problem. Differentiation and Integration: Difference formulae, Some basic rules of integration, Adaptive quadratures, Gaussian rules, Composite rules, Error formulas. Differential Equations: Euler method, Runge-Kutta methods, Multi -step methods, Predictor-Corrector methods Stability and convergence, Two point boundary value problems.

Unit-V:

Lab Component: Exposure to MATLAB and implementation of Algorithms discussed in this course.

References:

K. E. Atkinson, *"An Introduction to Numerical Analysis"*. 2nd Edition, Wiley-India, 1989.

S. D. Conte and C. de Boor, *"Elementary Numerical Analysis –An Algorithmic Approach"*. 3rd Edition, McGraw-Hill, 1981.

Steve C. Chapra, *"Applied Numerical Methods with MATLAB for Engineers and Scientists"*. McGraw-Hill Science Engineering, 2017.

R. L. Burden and J. D. Faires, *"Numerical Analysis"*. 7th Edition, Thomson, 2001.

R. S. Gupta, *"Elements of Numerical Analysis"*. Macmillan India Ltd. New Delhi, 2009.

Course Code **: MAT316** Core/ Elective **: Elective** No. of Credits **: 3**	Course Title **Linear Programming**

Course Objectives:

- To impart the knowledge of formulation of practical problems using the linear programming method and its extensions.
- To understand the theoretical basics of different computational algorithms used in solving linear programming and related problems.

Learning Outcomes:

After completion of the course student should be able to:

- Understand linear optimization theory and its applications.
- Understand the appropriate methods for the efficient computation of optimal solutions of a problem which is modeled by a linear objective function and a set of linear constraints.
- Model a problem as a linear programming problem and to apply the appropriate method in order to find an optimal solution.

Course Outline:

Unit-I:

Introduction, Optimization problems, Convexity, Convex opt, general overview. Two forms of LP (canonical and equational form), basic feasible solutions.

Unit-II:

Some Geometry behind LP (linear spaces, affine spaces, ...). Introduction to the simplex method, tableau. Getting initial feasible solutions, pivot rules, termination and cycling.

Unit-III:

Lower bound on worst case (Klee-Minty example), Kalai-Kleitman bound on diameter of polyhedra. Abstract LP-type problems.

Unit-IV:

Fundamental theorem of linear inequalities. `lence of Polyhedral cones and finitely generated cones (Farkas- Minkowski-Weyl).

Unit-V:

Fundamental Theorem of Polyhedra theory and (variants of) Farkas's Lemma. Duality in LP, Interior Point Algorithms.

References:

G. Hadley, *"Linear Programming"*. Narosa Publications, January, 2002.

A similar course (but is more CS oriented) https://www.imsc.res.in/vikram/lpco/lpco.html **(Online Source)**

Schrijver, *"Theory of Linear and Integer Programming"*. Wiley Series in Discrete, 1998.

Course Code **: MAT317** Core/ Elective **: Elective** No. of Credits **: 3**	Course Title **Elements of Fourier Analysis**

Course Objective:

- The learning objectives of the development of the discipline "Fourier analysis and its applications" are the formation of students' basic knowledge in the field of modern Fourier analysis and approximation theory.

Learning Outcomes:

After completion of the course student should be able to:

- Understand the basic ideas of Fourier analysis, theory of functional spaces etc.
- Understand and reproduce proofs of the key course theorems.
- Analysis of the spectral characteristics of signals using Fourier transforms.
- Applying the transform techniques to analyze the continuous – time and discrete – time.
- Fourier analysis is the commonly used mathematical tool and can be formed by a variety of commercially available software as math lab and statistica.

Course Outline:

Unit-I:

Fourier transform of the functions on T, the unit circle and on R. Fourier coefficients – Fourier series - Properties of Fourier transform.

Unit-II:

Rapidly decreasing functions of R and their Fourier transforms.

Unit-III:

Convolutions - The Banach algebra $L^1(R)$ and $L^1(Z)$ – Approximate identities. - The classical kernels on T. Fejer's, Poisson's and Dirichlet's summability kernels.

Unit-IV:

Summability Kernels on R. Maximal ideal spaces of the Banach algebra of $L^1(R)$, $L^1(T)$, Uniqueness of Fourier transforms - - Fourier inversion theorem.

Unit-V:

The Plancherel theorem on R - Translation Invariant subspaces of L^2 (R) and its applications.

References:

G. Folland, *"A course in abstract harmonic analysis"*. CRC Press, 1994.

H. Helson, *"Harmonic analysis"*. 2nd Edition., Trim Series, Hindustan Book Agency, 1995.

Y. Katznelson, *"Introduction to harmonic analysis"*. J. Wiley and Sons, 1968.

L.H. Loomis, *"An introduction to abstract harmonic analysis"*. Van Nostrand, New York, 1953.

E. Hewitt & K.A. Ross, *"Abstract harmonic analysis"*. vol. I, Springer -Verlag, 1963.

W. Rudin, *"Real and complex analysis"*. 2nd Edition, TMH Edition, 1962.

Course Code **: MAT318** Core/ Elective **: Elective** No. of Credits **: 3**	Course Title **Advanced Complex Analysis**

Course Objectives:

- To introduce advanced level course in Complex Analysis of one variable.
- To dwells deeper into the analytic properties of holomorphic and harmonic functions.
- To focus on topics those were dealt in an elementary complex analysis course from a deeper point of view.

Learning Outcomes:

After completion of the course student should be able to:

- Discuss the properties of holomorphic and harmonic functions.
- Prove the Maximum Modulus Principle and prove its corollaries.
- Get more acquainted with rational functions on single complex variables and, its zeroes and poles.
- Participate in scientific discussions and conduct researches on high international level in contemporary and classical complex analysis and its applications.

Course Outline:

Unit-I:

Singularities of a meromorphic function, Casorati-Weierstrass Theorem and its applications, automorphism group of the complex plane (Chapter VIII, [1]).

Unit-II:

Homotopy Version of Cauchy's Theorem, Runge's Approximation Theorem, Sharpened Form of Runge's Theorem (Chapter IX, [1]).

Unit-III:

Cauchy's Theorem for Simply Connected Domains, The Residue Theorem, Cauchy's Formula, applications to definite integrals (Chapter IX and X, [1]).

Unit-IV:

The Argument Principle, Rouche's Theorem, The Local Mapping Theorem and its consequences, The Riemann Mapping Theorem (Statement) and Riemann maps, Stieltjes-Osgood Theorem, Proof of the Riemann Mapping Theorem (Chapter XI, [1]).

Unit-V:

The Mittag-Leftler Theorem, Infinite Products, The Weierstrass Product Theorem (Chapter XIII, [2]).

References:

Donald Sarason, *"Complex Function Theory"*. TRIM Series, Hindustan Book Agency, 2010.

T. Gamelin, *"Complex Analysis"*. Springer-Verlag, New York, 2004.

Conway, John B, *"Functions of one complex variable"*. Second edition. Graduate Texts in Mathematics, 11. Springer-Verlag, New York- Berlin, xiii+317 pp, 1978.

C. Berenstein and R. Gay, "*Complex Variables. An Introduction"*. Springer- Verlag, New York, 1991.

Simon, Barry, *"Advanced complex analysis. A Comprehensive Course in Analysis"*. Part 2B. American Mathematical Society, Providence, RI, xvi+321, 2015.

SEMESTER-IV

Course Code **: MAT415** Core/ Elective **: Elective** No. of Credits **: 3**	Course Title **Advanced Complex Analysis**

Course Objectives:

- To introduce advanced level course in Complex Analysis of one variable.
- To dwells deeper into the analytic properties of holomorphic and harmonic functions.
- To focus on topics those were dealt in an elementary complex analysis course from a deeper point of view.

Learning Outcomes:

After completion of the course student should be able to:

- Discuss the properties of holomorphic and harmonic functions.
- Prove the Maximum Modulus Principle and prove its corollaries.
- Get more acquainted with rational functions on single complex variables and, its zeroes and poles.
- Participate in scientific discussions and conduct researches on high international level in contemporary and classical complex analysis and its applications.

Course Outline:

Unit-I:

Singularities of a meromorphic function, Casorati-Weierstrass Theorem and its applications, automorphism group of the complex plane (Chapter VIII, [1]).

Unit-II:

Homotopy Version of Cauchy's Theorem, Runge's Approximation Theorem, Sharpened Form of Runge's Theorem (Chapter IX, [1]).

Unit-III:

Cauchy's Theorem for Simply Connected Domains, The Residue Theorem, Cauchy's Formula, applications to definite integrals (Chapter IX and X, [1]).

Unit-IV:

The Argument Principle, Rouche's Theorem, The Local Mapping Theorem and its consequences, The Riemann Mapping Theorem (Statement) and Riemann maps, Stieltjes-Osgood Theorem, Proof of the Riemann Mapping Theorem (Chapter XI, [1]).

Unit-V:

The Mittag-Leftler Theorem, Infinite Products, The Weierstrass Product Theorem (Chapter XIII, [2]).

References:

Donald Sarason, *"Complex Function Theory"*. TRIM Series, Hindustan Book Agency, 2010.

T. Gamelin, *"Complex Analysis"*. Springer-Verlag, New York, 2004.

Conway, John B, *"Functions of one complex variable"*. Second edition. Graduate Texts in Mathematics, 11. Springer-Verlag, New York- Berlin, xiii+317 pp, 1978.

C. Berenstein and R. Gay, "*Complex Variables. An Introduction"*. Springer- Verlag, New York, 1991.

Simon, Barry, *"Advanced complex analysis. A Comprehensive Course in Analysis"*. Part 2B. American Mathematical Society, Providence, RI, xvi+321, 2015.

Course Code **: MAT416** Core/ Elective **: Elective** No. of Credits **: 3**	Course Title **Topics in Operator Theory**

Course Objectives:

- To introduce fundamental topics in operator theory.
- It is a field that has great importance for other areas of mathematics and physics, such as algebraic topology, differential geometry, and quantum mechanics.
- To assume a basic knowledge in functional analysis but no prior acquaintance with operator theory is required.

Learning Outcomes:

After completion of the course student should be able to:

- Find the essential spectra of linear operators.
- Find the maximal spectra of concrete commutative Banach algebras.
- Describe the functional calculi and the spectral decompositions of concrete self-adjoint operators.

Course Outline:

Unit-I:

Review of Results on Operators

Basic definitions and results on bounded operators on a Banach space, Dual space, Adjoint of bounded operators on a Hilbert space, Statements of Hahn-Banach theorem, closed graph theorem, and uniform boundedness principle.

Unit-II:

Banach Algebras and Spectral Theory for Operators on A Banach Space

Properties and examples of Banach algebras, ideals and quotients, Spectrum and Riesz functional calculus on Banach algebras, Spectrum of bounded operators on a Banach space, Spectral theory of compact operators.

Unit-III:

C*-Algebras: Properties and examples, Abelian C^*-algebras and functional calculus, Positive elements in C^*-algebra.

Unit-IV:

Spectral theory for Hilbert space Operators

Spectral measures and representations of abelian C^*-algebras, Spectral theorem for normal operators, some applications of the spectral theorem, Topologies on the space of bounded operators, Commuting operators.

Unit-V:

Unbounded Operators on A Hilbert Space and Spectral Theory

Closed and closable operators, adjoint and their properties, Symmetric and self adjoint operators, Cayley transform, Spectral theorem for unbounded normal operators.

References:

J.B. Conway, *"A Course in Functional Analysis"*. 2nd Edition, Springer, (Relevant topics from Chapters VII - X), 1997.

G. Bachmann and L. Naricii, *"Functional Analysis"*. Academic Press, 1966.

B.V. Limaye, *"Functional Analysis"*. 2nd Edition, New Age International, 1996.

M. Thamban Nair, (2001/2020). *"Functional Analysis: A First Course"*. Prentice Hall of India, PHI-Learning, 2nd Edition, 2020.

Course Code : **MAT417** Core/ Elective : **Elective** No. of Credits : **3**	Course Title **Design and Analysis of Algorithms**

Course Objectives:

- To introduce some models of computation and techniques for analyzing algorithms.
- To study specific algorithm design methods such as the greedy method, divide and conquer, dynamic programming.
- The ability to classify a problem as belonging to a class with a particular algorithmic approach (such as greedy, divide and conquer, dynamic programming)
- To study the concept of NP-Completeness and to introduce the notion of approximation algorithm for NP-Hard Problems.

Learning Outcomes:

After completion of the course student should be able to:

- Understand fundamentals of algorithms.
- Understand various design methods for graphs and trees.
- Learning different concepts of dynamic programming, graph coloring, all pairs shortest path etc.

Course Outline:

Unit-I:

Quantifying Efficiency, Asymptotics, Divide and Conquer and Recurrences Sorting, Searching, Integer Multiplication, Matrix multiplication, fast Fourier Transform.

Unit-II:

Graph Algorithms, BFS, DFS applications, Minimum Spanning Trees, Single Source Shortest Path.

Unit-III:

Dynamic Programming, Matrix Chain Multiplication, Longest Common Subsequence, All Pairs Shortest Paths, Graph Coloring, TSP.

Unit-IV:

Number Theoretic Algorithms (can be omitted if the Number theory course covers these) GCD, quadratic residues, chinese remainder theorem, primality and factoring.

Unit-V:

Computational Geometry, NP-completeness and beyond.

References:

Cormen, Lieserson, Rivest and Stein, *"Introduction to Algorithms"*. 3rd edition, the MIT Press. Latest edition, 2001.

Kleinberg and Tardos, *"Algorithm Design"*. Person, Latest edition, 2005.

Papadimitriou, Vazirani, Dasgupta, *"Algorithms"*. McGraw-Hill Education; 1st edition, September 13, 2005.

Course Code : **MAT418** Core/ Elective : **Elective** No. of Credits : **3**	Course Title **Automata Theory and Formal Languages**

Course Objectives:

- To focuses on the basic theory of Computer Science and formal methods of computation like automata theory, formal languages, grammars and Turing Machines.
- To explore the theoretical foundations of computer science from the perspective of formal languages and classify machines by their power to recognize languages.

Learning Outcomes:

After completion of the course student should be able to:

- Understand the basic properties of formal languages and grammars.
- Differentiate regular, context-free and recursively enumerable languages.
- Make grammars to produce strings from a specific language.

Course Outline:

Unit-I:

Finite State Automata Alphabets, strings and languages. Deterministic and non-deterministic finite automata. The language accepted. The equivalence of DFA and NDFA.

Unit-II:

Regular Languages. Regular expressions and regular languages. Pumping lemma for regular languages. Closure properties for regular languages. Decision properties of regular languages.

Unit-III:

Context free languages Context free grammars. Derivation tree. Ambiguity in CFG. Pumping lemma for Context free languages.

Unit-IV:

Pushdown Automata Equivalence of PDA and CFG.

Unit-V:

Turing Machines Language of a Turing machine. Some basic decidability and undecidability results.

References:

Hopcroft J. E, Motwani.R, Ullman J.D *"Introduction to Automata Theory, Languages and Computations"*. Pearson Education, 3rd Edition, 2008.

Harry R. Lewis, Christos H Papdimitriou, *"Elements of the Theory of Computation"*. Prentice Hall of India. 2nd Edition, 2003.

Peter Linz, *"An introduction to Formal Language and Automata"*. Narosa Publishers, 3rd Edition, 2002.

Mishra K. L. P. Chandrasekaran N, *"Theory of Computer Science Automata, Languages and Computation"*. Prentice Hall of India, 3rd Edition, 2004.