RAJA NARENDRA LAL KHAN WOMEN'S COLLEGE
(AUTONOMOUS)

Under Graduate Syllabus in Mathematics

Under the Choice Based Credit System (CBCS)

[w.e.f 2019-20]

Raja N.L Khan Women's College (Autonomous)

Gope Palace, Midnapore 721 102 West Bengal

Semester – I

Course Type	Course Code	Course Details		L-T-P	Credit	Marks Distribution				No of Lectures (Hours)	Total Lectures (Hours)
						IA	CA	ESE	Total		
Core-1	**MTMH-C101**	**Group-A**	Calculus	5-1-0	6	10	5	60	75	24	60
		Group-B	Geometry							27	
		Group-C	History of Mathematics							9	
Core-2	**MTMH - C102**	**Group-A**	Classical Algebra	5-1-0	6	10	5	60	75	23	60
		Group-B	Abstract Algebra-I							14	
		Group-C	Linear Algebra-I							23	
General Elective -1	**MTM GE 101**	Group-A	Numerical Methods	5-1-0	6	10	5	60	75	34	60
		Group-B	Differential Calculus-I							26	
AECC -1	**COMM English**	Communicative English		1-1-0	2						

L=Lecture, T=Tutorial, P=Practical

AECC – Ability Enhancement Compulsory Course; COMM English-Communicative English

GE-General Elective; IA-Internal Assessment; CA-Class Attendance; ESE-End Semester Examination

Semester – II

Course Type	Course Code	Course Details		L-T-P	Credit	Marks Distribution				No of Lectures(Hours)	Total Lectures (Hours
						IA	CA	ESE	Total		
Core-3	**MTMH -C201**	**Group-A**	Group Theory-I	5-1-0	6	10	5	60	75	37	60
		Group-B	Vector Analysis-I							23	
Core-4	**MTMH -C202**		Real Analysis-I	5-1-0	6	10	5	60	75	60	60
General Elective -2	**MTM-GE201**	Group-A	Differential Equation	5-1-0	6	10	5	60	75	28	60
		Group-B	Differential Calculus-II							32	
AECC -2	**ENVS**	Environmental Studies		1-1-0	4						

Semester – III

Course Type	Course Code	Course Details		L-T-P	Credit	Marks Distribution				No of Lectures (Hours)	Total Lectures (Hours)
						IA	CA	ESE	Total		
Core-5	**MTMH-C301**	**Group-A**	Ordinary Differential Equations	5-1-0	6	10	5	60	75	36	60
		Group-B	Applications of Dynamics							24	
Core-6	**MTMH - C302**	**Group-A**	Group Theory-II	5-1-0	6	10	5	60	75	24	60
		Group-B	Linear Algebra-II							36	
Core-7	**MTMH - C303**		Real Analysis-II	5-1-0	6	10	5	60	75	60	60
General Elective -3	**MTM GE 301**	Group-A	Analytical Geometry	5-1-0	6	10	5	60	75	21	60
		Group-B	Algebra							30	
		Group-C	Vector Algebra							09	
SEC-1	MTMH SEC301	C-Programming/ Object Oriented Programming in C++		1-1-0	2	5	5	40	50	40	40

SEC- Skill Enhancement Course

Semester – IV

Course Type	Course Code	Course Details		L-T-P	Credit	Marks Distribution				No of Lectures (Hours)	Total Lectures (Hours)
						IA	CA	ESE	Total		
Core-8	**MTMH-C401**	**Group-A**	Numerical Methods	4-0-0	4	10	5	40	75	40	60
		Group-B	Numerical LAB	0-0-4	2			20		20	
Core-9	**MTMH - C402**		**Ring Theory-I**	5-1-0	6	10	5	60	75	60	60
Core-10	**MTMH - C403**	Group-A	Vector Analysis-II	5-1-0	6	10	5	60	75	37	60
		Group-B	Metric Space-I							23	
General Elective -4	**MTM GE 401**	Group-A	Differential Calculus-III	5-1-0	6	10	5	60	75	20	60
		Group-B	Integral Calculus							09	
		Group-C	Differential Equations							12	
		Group-D	Probability &Statistics							19	
SEC-2	MTMH SEC401	Graph Theory		1-1-0	2	5	5	40	50	40	40

Semester – V

Course Type	Course Code	Course Details		L-T-P	Credit	Marks Distribution				No of Lectures (Hours)	Total Lectures (Hours)
						IA	CA	ESE	Total		
Core-11	**MTMH-C501**		Real Analysis-III	5-1-0	6	10	5	60	75	60	60
Core-12	**MTMH - C502**	**Group-A**	Partial Differential Equations	5-1-0	6	10	5	60	75	42	60
		Group-B	Metric Space-II							18	
DSE-1	**MTMH - DSE 501**		Linear Programming Problem Or Point Set Topology Or Theory of Equations	5-1-0	6	10	5	60	75	60	60
DSE-2	**MTMH - DSE 502**		Probability and Statistics Or Boolean Algebra and Automata Theory Or Portfolio Optimization	5-1-0	6	10	5	60	75	60	60

DSE- Discipline Specific Elective

Semester – VI

Course Type	Course Code	Course Details		L-T-P	Credit	Marks Distribution				No of Lectures (Hours)	Total Lectures (Hours)
						IA	CA	ESE	Total		
Core-13	MTMH-C601		Group Theory-III	5-1-0	6	10	5	60	75	60	60
Core-14	MTMH - C602	Group-A	Linear Algebra-III	5-1-0	6	10	5	60	75	30	60
		Group-B	Complex Analysis							30	
DSE-3	MTMH - DSE 601		Mechanics Or Number Theory Or Industrial Mathematics	5-1-0	6	10	5	60	75	60	60
DSE-4	MTMH - DSE 602		Mathematical Modeling Or Differential Geometry Or Bio Mathematics	5-1-0	6	10	5	60	75	60	60

Program Learning Outcomes of the B.Sc. Mathematics Course

The expected outcomes of under graduate mathematics courses are summarization of disciplinary knowledge, communicative skills, critical thinking and analytical reasoning, capacity of problem solving, research related skills, digital efficiency, enhance ethical values , lifelong acquire knowledge etc.

(a) This program demonstrates fundamental systematic knowledge of mathematics .It should also enhance the subject specific knowledge and help the students in searching jobs in Government and Non-Government sectors.

(b) Bachelor’s degree in mathematics is the culmination of in-depth knowledge of algebra, differential calculus, geometry, ordinary differential equations, partial differential numerical analysis and several other branches of mathematics. This also leads to study of related areas like computer science and statistics. Thus, this programme helps learners in building a solid foundation for higher studies in mathematics.

(c) The skills and knowledge gained has intrinsic beauty, which also leads to proficiency in analytical reasoning. This can be utilised in mathematical modelling and solving real life problems.

(d) Students undergoing this programme learn to logically question assertions, to recognise patterns and to distinguish between essential and irrelevant aspects of problems. They also share ideas and insights while seeking and benefitting from knowledge and insight of others. This helps them to learn behave responsibly in a rapidly changing interdependent society.

(e) Students completing this programme will be able to present mathematics clearly and precisely, make vague ideas precise by formulating them in the language of mathematics, describe mathematical ideas from multiple perspectives and explain fundamental concepts of mathematics to non-mathematicians.

(f) Completion of this programme will also enable the learners to join teaching profession in primary and secondary schools.

(g) This programme will also help students to enhance their employability for government jobs like WBCS, IAS etc , jobs in banking, insurance and investment sectors, data analyst jobs and jobs in various disciplines.

(h) This course is the gate way of entering into the premier institutes through admission test like JAM, MAT, CAT etc.

(i) One most significant outcome of the programme is the inculcation of higher values of life among the learners that enable them to face any hazard of the future life.

(j) Apply knowledge, understanding and skills to identify the difficult/unsolved problems in mathematics and to collect the required information in possible range of sources and try to analyse and evaluate these problems using appropriate methodologies.

(k) Capability to use appropriate software to solve system of equations and differential equations, basic programmes using the concept of C, C++ languages.

Course Details of Semester-I

Course Code: MTMH – C101
Course Title: Calculus, Geometry & History of Mathematics
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Group-A: Calculus	**Marks: 24** **Total No. of Lectures: 24 Hours**
Hyperbolic functions, higher order derivatives, Leibnitz rule and its applications to problems of type$e^{ax+b}\sin x$,$e^{ax+b}\cos x$, $(ax+b)^n\sin x$,$(ax+b)^n\cos x$, concavity and inflection points, envelopes, asymptotes, curve tracing in cartesian coordinates, tracing in polar coordinates of standard curves, L'Hospital's rule, applications in business, economics and life sciences. [12H] Reduction formulae, derivations and illustrations of reduction formulae of the type $\int(\sin nx)dx$,$\int(\cos nx)dx$,$\int(\tan nx)dx$, $\int(\sec nx)dx$, $\int(\log x)^n dx$, $\int(\sin x)^n(\cos x)^m dx$, parametric equations, parameterizing a curve, arc length of a curve, arc length of parametric curves, area under a curve, area and volume of surface of revolution, techniques of sketching conics. [12H]	
Group-B: Geometry	**Marks: 27** **Total No. of Lectures: 27 Hours**
Reflection properties of conics, rotation of axes and second degree equations, classification of conics using the discriminant, polar equations of conics. [10H] Spheres. Cylindrical surfaces. Central conicoid, paraboloids, plane sections of conicoid, generating lines, classification of quadrics, illustrations of graphing standard quadric surfaces like cone, ellipsoid. [17H]	
Group C: History of Mathematics	**Marks: 09** **Total No. of Lectures: 09 Hours**
Pre historic mathematics, the historical period down to 1000 BC: Contribution of India, Babylon and Egypt. The period from 1000 B.C to 300 B.C: origin of Green mathematics, from Pythagoras to Plato, influence of Plato and Aristotal. The period from 300 B.C to 500 A.M: the school of Alexandria, Euclid, Eratosthenes and Archimedis. The period from 500 AM to 1000 A.M: Contribution of India and China. The orient from 1000 to 1500: India and China. The sixteenth century, the seventh century, Contribution of India, Copernicus, Galileo, Descartes, Pascal, Marquis De, L'Hopitals, Napier, Newton, Wallis, Leibnitz, Keplar, Bernoulli's, The eighteenth century and after: Taylor, Maclurin, Sir William, De-Moivre, Rowan Hamilton, D'Alembert, Lagrange, Laplace, Legendre, Gauss, Jacobi, Weistrass, Dedikind, Cantor, Euler. [09H]	

Graphical Demonstration (Teaching Aid)

1. Plotting of graphs of functione^{ax+b}, $\log(ax+b)$l, $1/(ax+b)$,$\sin(ax+b)$, $\cos(ax+b)$, $|ax+b|$ and to illustrate the effect of a and b on thegraph.
2. Plotting the graphs of polynomial of degree 4 and 5, the derivative graph, the second derivative graph and comparingthem.
3. Sketching parametric curves (E.g. trochoid, cycloid, epicycloids,hypocycloid).
4. Obtaining surface of revolution ofcurves.
5. Tracing of conics in cartesian coordinates/ polarcoordinates.
6. Sketching ellipsoid, hyperboloid of one and two sheets, elliptic cone, elliptic, paraboloid, and hyperbolic paraboloid using Cartesian coordinates.

Reference Books

- G.B. Thomas and R.L. Finney, Calculus, 9th Ed., Pearson Education, Delhi,2005.
- M.J. Strauss, G.L. Bradley and K. J. Smith, Calculus, 3rd Ed., Dorling Kindersley (India) P. Ltd. (Pearson Education), Delhi,2007.
- H. Anton, I. Bivens and S. Davis, Calculus, 7th Ed., John Wiley and Sons (Asia) P. Ltd., Singapore, 2002.
- R. Courant and F. John, Introduction to Calculus and Analysis (Volumes I & II), Springer- Verlag, New York, Inc., 1989.
- S.L. Ross, Differential Equations, 3rd Ed., John Wiley and Sons, India, 2004.
- Murray, D., Introductory Course in Differential Equations, Longmans Green and Co.
- G.F. Simmons, Differential Equations, Tata Mcgraw Hill.
- T. Apostol, Calculus, Volumes I and II.
- S. Goldberg, Calculus and mathematical analysis.

Learning Outcomes of the course

After completion of the course, the student will learn the following

(a) Tracing of curves in Cartesian and polar coordinates

(b) nth order differentiation of hyperbolic function, trigonometric function, algebraic function and product of two functions using Leibnitz rule.

(c) Techniques to find the area under curve, area and volume of surface of revolution, length of curve

(d) Explain the properties and equation of three dimension shapes like sphere, cone, cylinder, ellipsoid, hyperboloid of one and two sheet, elliptic paraboloid etc

(e) Know about the Legendary Mathematicians in India, Babylon and Egypt and their contributions in mathematics in different period.

Course Code: MTMH – C102
Course Title: Algebra
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Group-A: Classical Algebra **Marks:23** **Total No. of Lectures: 23 Hours**
Polar representation of complex numbers, nth roots of unity, De Moivre's theorem for rational indices and its applications. [5H] Theory of equations: Relation between roots and coefficients, transformation of equation, Descartes rule of signs, cubic and biquadratic equation, Ferrari's method, Cardon's method. [14H] Inequality: The inequality involving AM≥ GM≥ HM, Cauchy-Schwartz inequality.[4H]
Group-B: Abstract Algebra-I **Marks: 14** **Total No. of Lectures: 14 Hours**
Equivalence relations. Functions, composition of functions, Invertible functions, one to one correspondence and cardinality of a set. Well-ordering property of positive integers, division algorithm, divisibility and Euclidean algorithm. Congruence relation between integers. Principles of Mathematical induction, statement of Fundamental Theorem of Arithmetic. [14H]
Group-C: Linear Algebra-I **Marks: 23** **Total No. of Lectures: 23 Hours**
Systems of linear equations, row reduction and echelon forms, vector equations, the matrix equation Ax=b, solution sets of linear systems, applications of linear systems, linear independence. [9H] Introduction to linear transformations, matrix of a linear transformation, inverse of a matrix, characterizations of invertible matrices. Subspaces of R^n, dimension of subspaces of R^n, rank of a matrix, Eigen values, eigen vectors and characteristic equation of a matrix. Cayley-Hamilton theorem and its use in finding the inverse of a matrix. [14H]
Reference Books
➢ Titu Andreescu and Dorin Andrica, Complex Numbers from A to Z, Birkhauser,2006. ➢ Edgar G. Goodire and Michael M. Parmenter, Discrete Mathematics with Graph Theory, 3rd Ed.,Pearson Education (Singapore) P. Ltd., Indian Reprint, 2005.

- David C. Lay, Linear Algebra and its Applications, 3rd Ed., Pearson Education Asia, Indian Reprint, 2007.
- K.B. Dutta, Matrix and linear algebra.
- K. Hoffman, R. Kunze, Linear algebra.
- W.S. Burnstine and A.W. Panton, Theory of equations.

Learning Outcomes of the course

After completion of the course, the student will learn the following

(a) Understand the importance of roots of real and complex polynomials and learn various methods of obtaining roots
(b) Familiarize with relations, equivalence relations, partitions and basic properties of numbers.
(c) Apply De Moivre's theorem to solve numerical Problems and determine the roots of polynomial equation.
(d) Recognize consistent and inconsistent systems of linear equations by the row echelon form of the augmented matrix, using rank
(e) Find eigenvalues and corresponding eigenvectors for a square matrix

Generic Course (GE-1)

Course Code: MTM GE 101
Course Title: Numerical Methods and Differential Calculus-I
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Group-A: Numerical Methods	**Marks-34** **Total No. of Lectures: 34 Hours**
Unit 1	
Algorithms, convergence, relative errors, absolute errors, round off, truncation.	[2H]
Unit 2	
Transcendental and polynomial equations: Bisection method, Newton's method, secant method, Regula-falsi method, fixed point iteration, Newton-Raphson method. Rate of convergence of these methods.	[7H]
Unit 3	
System of linear algebraic equations: Gaussian elimination and Gauss Jordan methods.	

Gauss Jacobi method, Gauss Seidel method and their convergence analysis. LU decomposition. [6H]

Unit 4

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

Numerical differentiation: Methods based on interpolations, methods based on finite differences. [8H]

Unit 5

Numerical Integration: Newton Cotes formula, Trapezoidal rule, Simpson's $1/3^{rd}$ rule, Simpsons 3/8th rule, Weddle's rule, Boole's Rule. Midpoint rule, Composite trapezoidal rule, composite Simpson's $1/3^{rd}$ rule, Gauss quadrature formula.

The algebraic eigen value problem: Power method. [5H]

Approximation: Least square polynomial approximation. [1H]

Unit 6

Ordinary differential equations: The method of successive approximations, Euler's method, the modified Euler method, Runge-Kutta methods of orders two and four. [3H]

Group-B: Differential Calculus-I **Marks-26**

Total No. of Lectures: 26 Hours

Unit-1

Hyperbolic functions, higher order derivatives, Leibnitz rule and its applications to problems of type $e^{ax+b}\sin x$, $e^{ax+b}\cos x$, $(ax+b)^n\sin x$, $(ax+b)^n\cos x$, concavity and inflection points, envelopes, asymptotes, curve tracing in cartesian coordinates, tracing in polar coordinates of standard curves, L'Hospital's rule, applications in business, economics and life sciences. [12H]

Unit-2

Reduction formulae, derivations and illustrations of reduction formulae of the type $\int(\sin nx)dx$,$\int(\cos nx)dx$,$\int(\tan nx)dx$,$\int(\sec nx)dx$, $\int(\log x)^n dx$, $\int(\sin x)^n(\cos x)^m dx$, parametric equations, parameterizing a curve, arc length of a curve, arc length of parametriccurves, area under a curve, area and volume of surface of revolution, techniques of sketching conics. [14H]

Reference Books

Brian Bradie, A Friendly Introduction to Numerical Analysis, Pearson Education, India,2007.

C.F. Gerald and P.O. Wheatley, Applied Numerical Analysis, Pearson

Education, India,2008.
G.B. Thomas and R.L. Finney, Calculus, 9th Ed., Pearson Education, Delhi,2005.
H. Anton, I. Bivens and S. Davis, Calculus, 7th Ed., John Wiley and Sons (Asia) P. Ltd., Singapore, 2002.
John H. Mathews and Kurtis D. Fink, Numerical Methods using Matlab, 4th Ed., PHI Learning Private Limited,2012.

- M.J. Strauss, G.L. Bradley and K. J. Smith, Calculus, 3rd Ed., Dorling Kindersley (India) P. Ltd. (Pearson Education), Delhi,2007
M.K. Jain, S.R.K. Iyengar and R.K. Jain, Numerical Methods for Scientific and Engineering
Computation, 6th Ed., New age International Publisher, India, 2007.
- R. Courant and F. John, Introduction to Calculus and Analysis (Volumes I & II), Springer- Verlag, New York, Inc., 1989.
- S. Goldberg, Calculus and mathematical analysis.
- S.L. Ross, Differential Equations, 3rd Ed., John Wiley and Sons, India,2004.
- Scarborough, James B., Numerical Mathematical Analysis, Oxford and IBH publishingco.
- T. Apostol, Calculus, Volumes I andII.
Uri M. Ascher and Chen Greif, A First Course in Numerical Methods, 7th Ed., PHI Learning Private Limited,2013.

Learning Outcomes of the course

After completion of the course, the student will learn the following

(a) Calculate the qualitative and quantitative measurement and to minimize the error in different scale.

(b) Obtain numerical solutions of algebraic and transcendental equations by different methods and compare the obtained results.

(c) Find numerical solutions of system of linear equations and check the accuracy of the solutions.
(d) Learn about various interpolating and their applications.
(e) Solve initial and boundary value problems in differential equations using numerical methods.
(f) Tracing of curves in Cartesian and polar coordinates
(g) nth order differentiation of hyperbolic function, trigonometric function, algebraic function and product of two functions using Leibnitz rule.
(h) Techniques to find the area under curve, area and volume of surface of revolution, length of curve
(i)Techniques to find the integration of form $\int (\sin nx)dx$,$\int (\cos nx)dx$,$\int (\tan nx)dx$,$\int (\sec nx)dx$, $\int (\log x)^n dx$, $\int (\sin x)^n (\cos x)^m$dx

Course Details of Semester-II

Course Code: MTMH – C201
Course Title: Group Theory-I & Vector Analysis-I
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Group A: Group Theory-I **Marks-37** **Total No. of Lectures: 37 Hours**
Symmetries of a square, dihedral groups, definition and examples of groups including permutation groups and quaternion groups (through matrices), elementary properties of groups. [10H] Subgroups and examples of subgroups, centralizer, normalizer, center of a group, product of two subgroups. [13H] Properties of cyclic group, classification of subgroups of cyclic groups. Cyclic notation for permutations, properties of permutations, even and odd permutations, alternating group, properties of cosets, Lagrange's theorem and consequences including Fermat's Little theorem. [14H]
Group-B: Vector Analysis-I **Marks-23** **Total No. of Lectures: 23 Hours**
Triple product, introduction to vector functions, operations with vector-valued function, limits and continuity of vector functions, differentiation and integration of vector functions. Vector equation of straight line and plane, Solution of vector equation, Application of vector in mechanics, Lamis's theorem. [23H]
Reference Books:
➢ John B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002. ➢ M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011. ➢ Joseph A. Gallian, Contemporary Abstract Algebra, 4th Ed., Narosa Publishing House, New Delhi, 1999. ➢ D.S. Malik, John M. Mordeson and M.K. Sen, Fundamentals of abstract algebra. ➢ Joseph J. Rotman, An Introduction to the Theory of Groups, 4th Ed., Springer

Verlag, 1995.

- I.N. Herstein, Topics in Algebra, Wiley Eastern Limited, India, 1975.
- Maity, K.C. and Ghosh, R.K. Vector Analysis, New Central Book Agency (P) Ltd. Kolkata (India).
- M.R. Speigel, Schaum's outline of Vector Analysis.
- Marsden, J., and Tromba, Vector Calculus, McGraw Hill.

Learning Outcomes of the course

After completion of the course, the student will learn the following

(a) Know about the mathematical structure and define the groups.
(b) Link the fundamental concepts of groups and symmetries of geometrical objects.
(c) Explain the significance of the notions of cosets, normal subgroups and factor groups.
(d) Analyze consequences of Lagrange's theorem.
(e) Learn about structure preserving maps between groups and their consequences.
(f) Know about the vector triple product, differentiation and integration of a vector function.
(g) Find the vector equation of plane, straight line and application in mechanics

Course Code: MTMH – C202
Course Title: Real Analysis-I
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Real Analysis-I	**Marks-60** **Total No. of Lectures: 60 Hours**
Review of algebraic and order properties of R, ε-neighborhood of a point in R. Idea of countable sets, uncountable sets and uncountability of R. Bounded above sets, bounded below sets, bounded sets, unbounded sets. Suprema and infima. Completeness property of R and its equivalent properties. The Archimedean property, density of rational (and Irrational) numbers in R, intervals. Limit points of a set, isolated points, open set, closed set, derived set, Illustrations of Bolzano-Weierstrass theorem for sets, compact sets in R, Heine-Borel Theorem. [15H] Sequences, bounded sequence, convergent sequence, limit of a sequence, liminf, limsup. Limit theorems. Monotone sequences, monotone convergence theorem. Subsequences, divergence criteria. Monotone subsequence theorem (statement only), Bolzano Weierstrass theorem for sequences. Cauchy sequence, Cauchy's convergence criterion. [23H] Infinite series, convergence and divergence of infinite series, Cauchy criterion, tests for	

convergence: comparison test, limit comparison test, D'Alembert,s ratio test, Raabes test, Cauchy's nth root test, integral test. Logarithmic test, Cauchy's condensation test, Gauss's test, Alternating series, Leibniz test, Abel's test, Dirichlet's test. Absolute and conditional convergence. [22H]
Reference Books
➢ R. Bartle and D.R. Sherbert, Introduction to Real Analysis, John Wiley and Sons, 2003. ➢ Brian S. Thomson, Andrew. M. Bruckner and Judith B. Bruckner, Elementary Real Analysis, Prentice Hall, 2001. ➢ K.A. Ross, Elementary Analysis: The Theory of Calculus, Springer, 2004. ➢ Mattuck, Introduction to Analysis, Prentice Hall, 1999. ➢ S.R. Ghorpade and B.V. Limaye, a Course in Calculus and Real Analysis, Springer, 2006. ➢ T. Apostol, Mathematical Analysis, Narosa Publishing House ➢ Courant and John, Introduction to Calculus and Analysis, Vol II, Springer ➢ W. Rudin, Principles of Mathematical Analysis, Tata McGraw-Hill ➢ Terence Tao, Analysis II, Hindustan Book Agency, 2006. ➢ S. Goldberg, Calculus and mathematical analysis. ➢ Gerald G. Bilodeau , Paul R. Thie, G.E. Keough, An Introduction to Analysis, 2nd Ed., Jones& Bartlett, 2010. ➢ Introduction to Real Analysis, S.K. Mapa

Learning Outcomes of the course

After completion of the course, the student will learn the following

(a) Understand basic structure and properties real number set and its extension
(b) Basic knowledge of topology of a real number set and theorems.
(c) Understanding of bounded, convergent, divergent, Cauchy and monotonic sequences and their properties.
(d) Different types series and its convergence and divergence using D'Alembert ratio test, Cauchy's root test, Rabees test etc.

Generic Course (GE-2)

Course Code: MTM GE 201
Course Title: Differential Equations and Differential Calculus-II
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Group-A: Differential Equation	**Marks-28**

Total No. of Lectures: 28 Hours

Unit 1

Lipschitz condition and Picard's Theorem (Statement only). General solution of homogeneous equation of second order, Principle of super position for homogeneous equation, Wronskian: its properties and applications, Linear homogeneous and non-homogeneous equations of higher order with constant coefficients, Euler's equation, method of undetermined coefficients, method of variation of parameters. [14H]

Unit 2

Systems of linear differential equations, types of linear systems, differential operators, an operator method for linear systems with constant coefficients. [5H]

Basic Theory of linear systems in normal form, homogeneous linear systems with constant coefficients: Two Equations in two unknown functions. [5H]

Unit 3

Equilibrium points, Interpretation of the phase plane, Power series solution of a differential equation about an ordinary point, solution about a regular singular point. [4H]

Group-B: Differential Calculus-II **Marks-32**

Total No. of Lectures: 32 Hours

Unit 1

Differentiability of a function at a point and in an interval, algebra of differentiable functions. Relative extrema, interior extremum theorem. Rolle's theorem. Mean value theorem, intermediate value property of derivatives, Darboux's theorem. [11H]

Cauchy's mean value theorem. Taylor's theorem with Lagrange's form of remainder, Taylor's theorem with Cauchy's form of remainder, application of Taylor's theorem to convex functions, relative extrema. Taylor's series and Maclaurin's series expansions of exponential and trigonometric functions, ln (1 + x), Sinx, Cosx, e^x and $(x+1)^n$. [10H]

Unit 2

Functions of several variables, limit and continuity of functions of two or more variables. Partial differentiation, total differentiability and differentiability, sufficient condition for differentiability. Chain rule for one and two independent parameters, directional derivatives, the gradient, maximal and normal property of the gradient, tangent planes.

[12H]

Reference Books

- Belinda Barnes and Glenn R. Fulford, Mathematical Modeling with Case Studies, A Differential Equation Approach using Maple and Matlab, 2nd Ed., Taylor and Francis group, London and New York, 2009.

- C.H. Edwards and D.E. Penny, Differential Equations and Boundary Value problems Computing and Modeling, Pearson Education India, 2005.
- S.L. Ross, Differential Equations, 3rd Ed., John Wiley and Sons, India, 2004.
- Martha L Abell, James P Braselton, Differential Equations with MATHEMATICA, 3rd Ed., Elsevier Academic Press, 2004.
- Murray, D., Introductory Course in Differential Equations, Longmans Green and Co.
- Boyce and Diprima, Elementary Differential Equations and Boundary Value Problems, Wiley.
- G.F. Simmons, Differential Equations, Tata McGraw-Hill
- G.B. Thomas and R.L. Finney, Calculus, 9th Ed., Pearson Education, Delhi, 2005.
- M.J. Strauss, G.L. Bradley and K. J. Smith, Calculus, 3rd Ed., Dorling Kindersley (India) P. Ltd. (Pearson Education), Delhi,2007.
- H. Anton, I. Bivens and S. Davis, Calculus, 7th Ed., John Wiley and Sons (Asia) P. Ltd., Singapore, 2002.
- R. Courant and F. John, Introduction to Calculus and Analysis (Volumes I & II), Springer- Verlag, New York, Inc., 1989.
- T. Apostol, Calculus, Volumes I and II.
- S. Goldberg, Calculus and mathematical analysis.

Learning Outcomes of the course

After completion of the course, the student will learn the following

(a) Students are able to solve homogeneous and non-homogeneous differential equations with constant coefficient and variable coefficients

(b) Determine the equilibrium points of linear system of differential equations and the analyze the stability of differential equation

(c) They can solve the power series solution of differential equation at ordinary points, singular points

(d) Learn the definition of differentiability of function of single variable and study the related theorem on differentiability.

(e) Expand the trigonometric function, logarithmic function, algebraic function in term of series using Taylor's theorem and Maclurin's theorem

(f) Learn the continuity and differentiability of function two variable, chain rule for one and two independent parameters, directional derivatives,

Course Details of Semester-III

Course Code: MTMH – C301
Course Title: Ordinary Differential Equations and Applications to Dynamics
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Group A: Ordinary Differential Equations	**Marks-36** **Total No. of Lectures: 36 Hours**
Differential equations and mathematical models. General, particular, explicit, implicit and singular solutions of a differential equation. Exact differential equations and integrating factors, separable equations and equations reducible to this form, linear equation and Bernoulli equations, special integrating factors and transformations. [11H] Lipschitz condition and Picard's Theorem (Statement only). General solution of homogeneous equation of second order, principle of super position for homogeneous equation, Wronskian: its properties and applications, Linear homogeneous and nonhomogeneous equations of higher order with constant coefficients, Euler's equation, method of undetermined coefficients, method of variation of parameters. [10H] Systems of linear differential equations, types of linear systems, differential operators, an operator method for linear systems with constant coefficients, Basic Theory of linear systems in normal form, homogeneous linear systems with constant coefficients: Two Equations in two unknown functions. [10H] Equilibrium points, Interpretation of the phase plane [2H] Power series solution of a differential equation about an ordinary point, solution about a regular singular point. [3H]	
Group B: Applications to Dynamics	**Marks-24** **Total No. of Lectures: 24 Hours**
Dynamics of Particle: Motion in Plane (Radial and cross radial, tangential and normal components), Central force. Constrained motion, Varying mass, Planetary motion. [24H]	
Reference Books	
➢ S.L. Ross, Differential Equations, 3rd Ed., John Wiley and Sons, India, 2004. ➢ Murray, D., Introductory Course in Differential Equations, Longmans Green and Co. ➢ Boyce and Diprima, Elementary Differential Equations and Boundary Value Problems, Wiley. ➢ G.F. Simmons, Differential Equations, Tata Mc Graw Hill.	

- Belinda Barnes and Glenn R. Fulford, Mathematical Modeling with Case Studies, A Differential Equation Approach using Maple and Matlab, 2nd Ed.,Taylor and Francis group, London and New York, 2009.
- C.H. Edwards and D.E. Penny, Differential Equations and Boundary Value problems Computing and Modeling, Pearson Education India, 2005.
- Martha L Abell, James P Braselton, Differential Equations with MATHEMATICA, 3rd Ed., Elsevier Academic Press, 2004.
- Loney, S. L., An Elementary Treatise on the Dynamics of particle and of Rigid Bodies, Loney Press.

Learning Outcomes of the course

After completion of the course, the student will learn the following

(a) Learn the exact differential equation and solve it by integrating factors, method of separation of variable etc.

(b) Know the principle of super position for homogeneous equation, Wronskian: its properties and applications,

(c) Learn solution methodology of linear homogeneous and nonhomogeneous equations of higher order with constant coefficients, Euler's equation, method of undetermined coefficients and method of variation of parameters

(d) Know the power series solution of ordinary differential equation.

(e) Determine the equilibrium points of system of linear equations and its stability.

(f) Know the application of differential equation in particle dynamics like central force, planetary motion etc.

Course Code: MTMH – C302
Course Title: Group Theory-II & Linear Algebra-II
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Group Theory-II	**Marks-24** **Total No. of Lectures: 24 Hours**
External direct product of a finite number of groups, normal subgroups, factor groups, Cauchy's theorem for finite abelian groups.	[8H]
Group homomorphisms, properties of homomorphisms, Cayley's theorem, properties of isomorphisms. First, Second and Third isomorphism theorems.	[8H]
Automorphism, inner automorphism, automorphism groups, automorphism groups of finite and infinite cyclic groups, applications of factor groups to automorphism groups,	

Characteristic subgroups, Commutator subgroup and its properties. [8H]

Linear Algebra-II **Marks-36**

Total No. of Lectures: 36 Hours

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

[19H]

Linear transformations, null space, range, rank and nullity of a linear transformation, matrix representation of a linear transformation, algebra of linear transformations. Isomorphisms. Isomorphism theorems, invertibility and isomorphisms, change of coordinate matrix. [17H]

Reference Books

- Stephen H. Friedberg, Arnold J. Insel, Lawrence E. Spence, Linear Algebra, 4th Edition., Prentice- Hall of India Pvt. Ltd., New Delhi, 2004.
- John B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.
- M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.
- Joseph A. Gallian, Contemporary Abstract Algebra, 4th Ed., Narosa Publishing House, New Delhi, 1999.
- D.S. Malik, John M. Mordeson and M.K. Sen, Fundamentals of abstract algebra.
- Kennath Hoffman, Ray Alden Kunze, Linear Algebra, 2nd Ed., Prentice- Hall of India Pvt. Ltd., 1971.
- D.A.R Wallace, Groups, Rings and Fields, Springer Verlag London Ltd., 1998.
- S. Kumaresan, Linear Algebra- A Geometric Approach, Prentice Hall of India, 1999.
- S. Lang, Introduction to Linear Algebra, 2nd Ed., Springer, 2007.
- Gilbert Strange, Linear Algebra and Its Applications, Thomson, 2007.

Learning Outcomes of the course

After completion of the course, the student will learn the following
(a) Able to solve the problems of direct product of finite number of groups, factor groups.
(b) Learn the finite abelian groups and related theorems and problems
© Learn group homomorphism and its properties, fundamental isomorphism theorems and able to solve related problems of homomorphism and isomorphism.
(d) Know the vector spaces, subspaces, quotient spaces and dimension and able to solve problems of dimension, linear dependence and independence
(e) Understand the linear transformation, algebra of linear transformation and isomorphism theorem
(f) Compute linear transformations, kernel and range, and inverse linear transformations, and find matrices of general linear transformations.

Course Code: MTMH – C303
Course Title: Real Analysis-II
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Real Analysis-II	**Marks-60** **Total No. of Lectures: 60 Hours**
Limits of functions (ε - δ approach), sequential criterion for limits, divergence criteria. Limit theorems, one sided limits. Infinite limits and limits at infinity. Continuous functions, sequential criterion for continuity and discontinuity. Algebra of continuous functions. Continuous functions on an interval, intermediate value theorem, location of roots theorem, preservation of intervals theorem. Uniform continuity, non-uniform continuity criteria, uniform continuity theorem. [15H] Differentiability of a function at a point and in an interval, Caratheodory's theorem, algebra of differentiable functions. Relative extrema, interior extremum theorem. Rolle's theorem. Mean value theorem, intermediate value property of derivatives, Darboux's theorem. Applications of mean value theorem to inequalities and approximation of polynomials. [15H] Cauchy's mean value theorem. Taylor's theorem with Lagrange's form of remainder, Taylor's theorem with Cauchy's form of remainder, application of Taylor's theorem to convex functions, relative extrema. Taylor's series and Maclaurin's series expansions of exponential and trigonometric functions, ln (1 + x), 1/(ax + b) and(x+1)n . Application of Taylor's theorem to inequalities. [15H] Functions of several variables, limit and continuity of functions of two or more variables Partial differentiation, total differentiability and differentiability, sufficient condition for differentiability. Chain rule for one and two independent parameters, directional derivatives, the gradient, maximal and normal property of the gradient, tangent planes, Extrema of functions of two variables, method of Lagrange multipliers, constrained optimization problems. [15H]	
Reference Books	
➢ R. Bartle and D.R. Sherbert, Introduction to Real Analysis, John Wiley and Sons, 2003. ➢ Brian S. Thomson, Andrew. M. Bruckner and Judith B. Bruckner, Elementary Real Analysis, Prentice Hall, 2001. ➢ K.A. Ross, Elementary Analysis: The Theory of Calculus, Springer, 2004. ➢ A Mattuck, Introduction to Analysis, Prentice Hall, 1999. ➢ S.R. Ghorpade and B.V. Limaye, a Course in Calculus and Real Analysis, Springer, 2006. ➢ T. Apostol, Mathematical Analysis, Narosa Publishing House ➢ Courant and John, Introduction to Calculus and Analysis, Vol II, Springer ➢ W. Rudin, Principles of Mathematical Analysis, Tata McGraw-Hill	

- Terence Tao, Analysis II, Hindustan Book Agency, 2006.
- S. Goldberg, Calculus and mathematical analysis.
- erald G. Bilodeau , Paul R. Thie, G.E. Keough, An Introduction to Analysis, 2nd Ed., Jones& Bartlett, 2010.
- . Marsden, A.J. Tromba and A. Weinstein, Basic Multivariable Calculus, Springer (SIE), Indian reprint, 2005.
- James Stewart, Multivariable Calculus, Concepts and Contexts, 2nd Ed., Brooks /Cole, Thomson Learning, USA, 2001
- G.B. Thomas and R.L. Finney, Calculus, 9th Ed., Pearson Education, Delhi, 2005.

Learning Outcomes of the course

After completion of the course, the student will learn the following
(a) Understand the concept of real-valued functions, limit, continuity, uniform continuity and differentiability in detail and related theorems

(b) Student can find expansions of real functions in series forms.

(c) Develop concepts on limit and continuity of functions of two or more variables, their partial derivatives, total derivative and differentiability, Chain rule for one and two independent parameters, directional derivatives, the gradient, maximal and normal property of the gradient, tangent planes

(d) Find Extrema of functions of two variables & understand the use of the method of Lagrange multipliers & solve constrained optimization problem

Skill Enhancement Course (SEC)

Course Code: MTMH- SEC301
Course Title: C-Programming/ Object Oriented Programming in C++
Credit: 02
No of Lectures: 40 hours
Full Marks: 50

C-Programming/ Object Oriented Programming in C++ **Marks-50** **Total No. of Lectures: 40 Hours**
Character set in. Key words: if, while, do, for, int, char, float, etc. Data type: character, integer, floating point, etc. Variables, Operators: =, == ,!, < > , etc. (arithmetic, assignment,

relational, logical, increment, etc.). Expressions: arithmetic and logical expressions. Standard input/output. Use of while, if-else, for, do - while, switch, continue, etc. Arrays, strings, user defined function. Header File. [16H]

Programming paradigms, characteristics of object oriented programming languages, brief history of C++, structure of C++ program, differences between C and C++, basic C++ operators, Comments, working with variables, enumeration, arrays and pointer. [12H]

Objects, classes, constructor and destructors, friend function, inline function, encapsulation, data abstraction, inheritance, polymorphism, dynamic binding, operator overloading, method overloading, overloading arithmetic operator and comparison operators. [12H]

Reference Books

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

Learning Outcomes of the course

After completion of the course, the student will learn the following

(a) Learn about the keywords, arithmetic operators, logical operators, intrinsic function in C language
(b) Understand the control statements like while statement, do while statement, if else statement, go to statement etc which are used to solve mathematical as well as numerical problems.
(C) Understand and apply the programming concepts of C++ which is important for mathematical investigation and problem solving.
(b) Use mathematical libraries for computational objectives.

Generic Course (GE-3)

Course Code: MTM GE301
Course Title: Analytical Geometry, Algebra & Vector Algebra
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Group-A: Analytical Geometry	**Marks-21** **Total No. of Lectures: 21 Hours**
Two dimensions: Polar equations of straight lines and circles, Polar equation of a conic referred to a focus as pole, equations of chord; tangent and normal. Transformations of rectangular axes: Translation, rotation and their combinations. General equation of second degree in two variables and its reduction to canonical (normal) forms. Classification of conics and their equations in canonical forms. Pairs of straight-lines: Condition that the general equation of second degree may represent two straight lines. Point of intersection of two intersecting straight lines, angle and angle bisectors between two lines given by $ax2 + 2hxy + by2 = 0$. Equations of two straight lines joining the origin to the points in which line meets a conic. [21H]	
Group-B: Algebra	**Marks-30** **Total No. of Lectures: 30 Hours**
Complex Number: Algebra of complex number, Modulus and Amplitude of complex number, De Moivre's theorem and its applications. [3H] Determinants: Properties, co-factors and minors, reduction of determinants, product of two determinants, ad joint and inverse of a determinant, symmetric and skew symmetric determinants. [5H] Matrices of real numbers: Equality of matrices, addition of matrices, multiplication of a matrix by a scalar. Multiplication of matrices-distributive, associative properties. Transpose of matrix-its properties. Square matrices. Symmetric, skew symmetric matrices, scalar matrices, identity matrix, inverse of a non-singular scalar matrix. Orthogonal matrix, rank of a matrix, determination of rank, solution of a system of linear equations with not more than three variables by matrix method (not involving ranks). [9H] Theory of Set: Algebra of sets, Universal set, Empty set, Subsets, Union and Intersection of sets, Partition, Finite Set, Complements, Venn Diagram, Cartesian product of two sets, Mappings, One-to-one and onto mappings, Composition of Mappings. [5H] Group: Definition and examples taken from various branches (examples from number system roots of unity, 2 x 2 real matrices, non-singular real matrices of a fixed order). Elementary properties using the definition of group. Definition and examples of sub groups. [5H] Ring and Field: Definition and examples of ring sub-ring. Integral Domain, Division of zero, every field is an integral domain. Field, sub-field [3H]	
Group-C: Vector Algebra	**Marks-09** **Total No. of Lectures: 09 Hours**
Vector Algebra: Collinear and coplanar vectors, scalar and vector product of two vectors, scalar triple product of three vectors and its geometrical interpretation, simple application to geometry. [09H]	

Reference Books
➢ Maity, K.C. and Ghosh, R.K. Vector Analysis, New Central Book Agency (P) Ltd. Kolkata (India). ➢ M.R. Speigel, Schaum's outline of Vector Analysis. ➢ Marsden, J., and Tromba, Vector Calculus, McGraw Hill. ➢ Titu Andreescu and Dorin Andrica, Complex Numbers from A to Z, Birkhauser, 2006. ➢ David C. Lay, Linear Algebra and its Applications, 3rd Ed., Pearson Education Asia, Indian Reprint, 2007. ➢ K.B. Dutta, Matrix and linear algebra. ➢ K. Hoffman, R. Kunze, Linear algebra. ➢ W.S. Burnstine and A.W. Panton, Theory of equations.

Learning Outcomes of the course

After completion of the course, the student will learn the following

(a). Fundamental concepts of mathematical structure, groups and symmetric of geometrical objects and their properties.

(b) Basic knowledge about Cartesian and polar coordinates systems and General equation of second degree equation and discussion on derivation of its canonical forms.

(c) Basic knowledge on different types of product operation (dot, cross, triple and box product) on vectors.

(e). Knowledge on Abstract algebra is largely useful for students who intend to major in mathematics and do further work in a mathematics-intensive area such as physics, computer science. Knowledge on Group theory is useful to Robotics, Computer Vision and Computer Graphics.

(f). Studying geometry provides many foundational skills and that helps to build the thinking skills of logic, deductive reasoning and problem-solving.

(g). Knowledge on vector is helpful to solve many real life applications, including situations involving force or velocity

Course Details of Semester-IV

Course Code: MTMH – C401
Course Title: Numerical Methods and Numerical LAB
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Group A: Numerical Methods **Marks-40**
Total No. of Lectures: 40 Hours

Algorithms. Convergence. Errors: relative, absolute. Round off. Truncation. [2H]

Transcendental and polynomial equations: Bisection method, Newton's method, secant method, Regula-falsi method, fixed point iteration, Newton-Raphson method. Rate of convergence of these methods. [10H]

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

Interpolation: Lagrange and Newton's methods. Error bounds. Finite difference operators. Gregory forward and backward difference interpolation. Numerical differentiation: Methods based on interpolations, methods based on finite differences. [9H]

Numerical Integration: Newton Cotes formula, Trapezoidal rule, Simpson's $1/3^{rd}$ rule, Simpsons 3/8th rule, Weddle's rule, Boole's Rule. midpoint rule, Composite trapezoidal rule, composite Simpson's $1/3^{rd}$rule, Gauss quadrature formula. The algebraic eigen value problem: Power method. Approximation: Least square polynomial approximation. [10H]

Ordinary differential equations: The method of successive approximations, Euler's method, the modified Euler method, Runge-Kutta methods of orders two and four. [9H]

Reference Books

- Brian Bradie, A Friendly Introduction to Numerical Analysis, Pearson Education, India,2007.
- M.K. Jain, S.R.K. Iyengar and R.K. Jain, Numerical Methods for Scientific and Engineering
- Computation, 6th Ed., New age International Publisher, India, 2007.
- C.F. Gerald and P.O. Wheatley, Applied Numerical Analysis, Pearson Education, India,2008.
- Uri M. Ascher and Chen Greif, A First Course in Numerical Methods, 7th Ed., PHI Learning Private Limited,2013.
- John H. Mathews and Kurtis D. Fink, Numerical Methods using Matlab, 4th Ed., PHI Learning Private Limited,2012.
- Scarborough, James B., Numerical Mathematical Analysis, Oxford and IBH publishing co.
- Atkinson, K. E., An Introduction to Numerical Analysis, John Wiley and Sons,1978.
- Yashavant Kanetkar, Let Us C , BPB Publications.

Group B: Numerical LAB **Marks-20** **Credits-02**
Total No. of Lectures: 20 Hours

List of practical (using any software)

1. Calculate the sum 1/1 + 1/2 + 1/3 +1/4 + ---------- + 1/N.
2. Enter 100 integers into an array and sort them in an ascendingorder.
3. Solution of transcendental and algebraic equationsby
   i) Bisectionmethod
   ii) Newton Raphsonmethod.
   iii) Secantmethod.
   iv) RegulaFalsi method.
4. Solution of system of linearequations
   i) LU decompositionmethod
   ii) Gaussian eliminationmethod
   iii) Gauss-Jacobimethod
   iv) Gauss-Seidelmethod
5. Interpolation
   i) Lagrange Interpolation
   ii) NewtonInterpolation
6. NumericalIntegration
   i) TrapezoidalRule
   ii) Simpson's one thirdrule
   iii) Weddle'sRule
   iv) GaussQuadrature
7. Method of finding Eigenvalue by Powermethod
8. Fitting a PolynomialFunction
9. Solution of ordinary differentialequations
   i) Eulermethod
   ii) Modified Eulermethod
   iii) RungeKuttamethod

Note: For any of the CAS (Computer aided software) Data types-simple data types, floating data types, character data types, arithmetic operators and operator precedence, variables and constant declarations, expressions, input/output, relational operators, logical operators and logical expressions, control statements and loop statements, Arrays should be introduced to the students.

Learning Outcomes of the course

After completion of the course, the student will learn the following

(a) Overcome the limitations of analytical methods using numerical approach

(b) How to remove different types of errors occurs during solving different types of problems.

(c) How to solve not only polynomials equations but also transcendental equations of any degree.
(d) How to integrate the functions which can't be integrated using any analytical methods.
(e) How to solve a system of linear equations and how to solve a first order differential equation using some numerical methods.
(f) Using least square method students can predict the situations of upcoming days in different pandemic situations.
(g) All these numerical methods are very helpful in research field as well as most of the complex problems.

Course Code: MTMH – C402

Course Title: Ring Theory-I
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Ring Theory-I	**Marks-60** **Total No. of Lectures: 60 Hours**
Definition and examples of rings, properties of rings, subrings, integral domains and fields, characteristic of a ring. Ideal, ideal generated by a subset of a ring, factor rings, operations on ideals, prime and maximal ideals. [20H] Ring homomorphisms, properties of ring homomorphisms. Isomorphism theorems I, II and III, field of quotients. [15H] Polynomial rings over commutative rings, division algorithm and consequences, principal ideal domains, factorization of polynomials, reducibility tests, irreducibility tests, Eisenstein criterion, and unique factorization in Z [x]. Divisibility in integral domains, irreducible, primes, unique factorization domains, Euclidean domains. [25H]	
Reference Books	
➢ Stephen H. Friedberg, Arnold J. Insel, Lawrence E. Spence, Linear Algebra, 4^{th} Edition., Prentice- Hall of India Pvt. Ltd., New Delhi, 2004. ➢ John B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson,2002. ➢ M. Artin, Abstract Algebra, 2nd Ed., Pearson,2011. ➢ Joseph A. Gallian, Contemporary Abstract Algebra, 4th Ed., Narosa Publishing House, New Delhi, 1999. ➢ D.S. Malik, John M. Mordeson and M.K. Sen, Fundamentals of abstract algebra. ➢ Kennath Hoffman, Ray Alden Kunze, Linear Algebra, 2^{nd} Ed., Prentice- Hall of India Pvt. Ltd., 1971.	

- D.A.R Wallace, Groups, Rings and Fields, Springer Verlag London Ltd., 1998.
- S. Kumaresan, Linear Algebra- A Geometric Approach, Prentice Hall of India, 1999.
- S. Lang, Introduction to Linear Algebra, 2nd Ed., Springer, 2007.
- Gilbert Strange, Linear Algebra and Its Applications, Thomson, 2007.

Learning Outcomes of the course

After completion of the course, the student will learn the following
(a) Develop a concept on Ring Theory of Abstract Algebra in details
(b) Know the fundamental concepts in ring theory such as the concepts of ideals, quotient rings, integral domains and fields, Isomorphism of rings and fundamental theorem
(c) Learn in detail about polynomial rings, factorization of polynomial, divisibility of integral domains

Course Code: MTMH – C403
Course Title: Vector Analysis-II & Metric Space –I
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Group A: Vector Analysis-II	**Marks-37** **Total No. of Lectures: 37 Hours**
Double integration over rectangular region, double integration over non-rectangular region, Double integrals in polar co-ordinates, Triple integrals, triple integral over a parallelepiped and solid regions. Volume by triple integrals, cylindrical and spherical co-ordinates. Change of variables in double integrals and triple integrals. [15H] Definition of vector field, divergence and curl. Line integrals, applications of line integrals: mass and work. Fundamental theorem for line integrals, conservative vector fields, independence of path. [10H] Green's theorem, surface integrals, integrals over parametrically defined surfaces. Stoke's theorem, The Divergence theorem. [12H]	
Group B: Metric Space – I	**Marks-23** **Total No. of Lectures: 23 Hours**
Definition and examples. Open and closed balls, neighbourhood, open set, interior of a set. Limit point of a set, closed set, diameter of a set, subspaces, dense sets, separable spaces. [10H] Sequences in metric spaces, Cauchy sequences. Complete metric spaces, Cantor's theorem. [13H]	

Reference Books
Arsden, J., and Tromba, Vector Calculus, McGraw Hill. ➢ .R. Speigel, Schaum's outline of Vector Analysis. ➢ . Kumaresan, Topology of Metric Spaces, 2nd Ed., Narosa PublishingHouse,2011. ➢ aity,K.C. and Ghosh, R.K. Vector Analysis, New Central Book Agency (P)Ltd. Kolkata (India). F. Simmons, Introduction to Topology and Modern Analysis, McGrawHill,2004. SatishShirali and Harikishan L. Vasudeva, Metric Spaces, Springer Verlag,London, 2006.

Learning Outcomes of the course

After completion of the course, the student will learn the following

a) Basic knowledge of vector integration of vector valued function in R, R^2 and R^3.

b) Basic definition and propertise of Curl, divergence.

c) Basic topology of metric space and their properties.

d) Basic knowledge of definition and properties of sequence in metric space.

Skill Enhancement Course (SEC-2)

Course Code: MTMH SEC 401
Course Title: Graph Theory
Credit: 02
No of Lectures: 40 hours
Full Marks: 50

Graph Theory **Marks-50** **Total No. of Lectures: 40 Hours**
Definition, examples and basic properties of graphs, pseudo graphs, complete graphs, bipartite graphs isomorphism of graphs. [14H]
Eulerian circuits, Eulerian graph, semi-Eulerian graph, theorems, Hamiltonian cycles, theorems Representation of a graph by matrix, the adjacency matrix, incidence matrix, weighted graph, [16H]
Tree and their properties, shortest path, Dijkstra's algorithm, Travelling salesman's problem,

spanning tree, Warshall algorithm.	[10H]
Reference Books	

- B.A. Davey and H.A. Priestley, Introduction to Lattices and Order, CambridgeUniversityPress, Cambridge, 1990.
- Edgar G. Goodaire and Michael M. Parmenter, Discrete Mathematics withGraph Theory, 2nd Edition, Pearson Education (Singapore) P. Ltd., Indian Reprint 2003.
- Rudolf Lidl and Gunter Pilz, Applied Abstract Algebra, 2nd Ed.,Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.

Learning Outcomes of the course

After completion of the course, the student will learn the following

(a) Appreciate the definition and basics of graphs along with different types with examples.
(b) Understand the definition of a tree and their properties. Represent the graphs by matrix.
(c) Know the applications of graph theory to find shortest path using Dijkstra's algorithm.
(d) Relate the graph theory to the real-world problems.

Generic Course (GE-4)

Course Code: MTM GE401
Course Title: Differential Calculus III, Integral Calculus, Differential Equations and Probability and Statistics
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Group-A: Differential Calculus -III	**Marks-20** **Total No. of Lectures: 20 Hours**
Algebra of limits and continuity (no proof), Definition and acquaintance (no proof required) with the properties of continuous function on closed intervals, Derivatives- its geometric and physical interpretation, rule of differentiation (a revision of previous knowledge only), Differential and its geometrical interpretation.	[8H]
Successive derivatives, Leibnitz theorem: increasing and decreasing function, sign of the derivatives, statement of Rolle's theorem and its geometrical interpretation, Lagrange's Mean value theorems and its geometrical interpretation, Cauchy's mean value theorem. Intermediate forms, L'Hospital's rule, maxima and minima (Differentiations and acquaintance with rules of finding extreme, emphasis on solving problems only).	[12H]
Group-B: Integral Calculus	**Marks-09**

Total No. of Lectures: 9 Hours

Indefinite integration: Standard form, Methods by substitution and integration by parts (Revision of previous knowledge), Integration of rational function and trigonometric function, Definite integral as the limit sum, Geometrical interpretation of definite integrals of bounded continuous functions, Fundamental theorem of integral calculus, Properties of definite integral and their applications. [9H]

Group-C: Differential Equations **Marks-12**
Total No. of Lectures: 10 Hours

First order linear and non-linear differential equations, Applications in simple geometrical problems, Second order linear differential equations with constant coefficients. [10H]

Group-D:Probability and Statistics **Marks-19**
Total No. of Lectures: 21 Hours

Unit 1

Random experiments, Statistical regularity and idea of probability as long run mutually exclusive and exhaustive events, union, intersection and complement, classical definition of probability, axiomatic approach of probability theory (detailed treatment not required), theorems on union of a number of events, conditional probability, theorem of total probability and Bayes' theorem, independent event and independent trails, random variable and its probability distribution (Binomial, Poisson, Normal, Uniform, Exponential Distribution), expectation and variance. [13H]

Unit 2

Qualitative and quantitative characters, Discrete variable and continuous variable, frequency distribution and its graphical representation, measure of central tendency (mean, median and mode), measures of dispersion (range, mean, deviation and standard deviation), correlation and regression. [8H]

Reference Books

- T. Apostol, Calculus, Volumes I and II.
- S. Goldberg, Calculus and mathematical analysis.
- G.B. Thomas and R.L. Finney, Calculus, 9th Ed., Pearson Education, Delhi,2005.
- Gupta, Ground work of Mathematical Probability and Statistics, Academicpublishers.
- Robert V. Hogg, Joseph W. McKean and Allen T. Craig, Introduction toMathematical Statistics, Pearson Education, Asia, 2007.
- Irwin Miller and Marylees Miller, John E. Freund, Mathematical Statisticswith

Applications, 7th Ed., Pearson Education, Asia, 2006.

- Sheldon Ross, Introduction to Probability Models, 9th Ed., Academic Press,Indian Reprint, 2007.
- Alexander M. Mood, Franklin A. Graybill and Duane C. Boes, Introduction tothe Theory of Statistics, 3rd Ed., Tata McGraw- Hill, Reprint 2007.
- S.L. Ross, Differential Equations, 3rd Ed., John Wiley and Sons, India, 2004.
- Murray, D., Introductory Course in Differential Equations, Longmans Greenand Co.
- Boyce and Diprima, Elementary Differential Equations and Boundary ValueProblems, Wiley.

Learning Outcomes of the course

After completion of the course, the student will learn the following

(a) Basic knowledge about tracing of curves in Cartesian and polar coordinates

(b) Discussion on nth order differentiation of hyperbolic function, trigonometric function, algebraic function and product of two functions using Leibnitz rule and problems and applications

(c) Basic knowledge on different techniques to find the area under curve, area and volume of surface of revolution, length of curve.

(d) Students are able to solve homogeneous and non-homogeneous differential equations With constant coefficients and variable coefficients.

(d) Sudents are able to expand the trigonometric function, logarithmic function, algebraic function in term of series using Taylor's theorem and Maclaurin's theorem.

(e) Basic knowledge on the continuity and differentiability of function two variables.

(f). Basic knowledge on definition of probability, random experiments, binomial and poisons distribution and their properties and applications.

(h) Discussion on properties and application on Mean ,Median, Mode of different distribution.

Course Details of Semester-V

Course Code: MTMH – C501
Course Title: Real Analysis – III
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Real Analysis – III	**Marks-60** **Total No. of Lectures: 60 Hours**

Riemann integration: inequalities of upper and lower sums, Darbaux integration, Darbaux theorem, Riemann conditions of integrability, Riemann sum and definition of Riemann integral through Riemann sums, equivalence of two definitions. Riemann integrability of monotone and continuous functions, properties of the Riemann integral; definition and integrability of piecewise continuous and monotone functions. Intermediate Value theorem for Integrals; Fundamental theorem of Integral Calculus. [20H] Improper integrals. Convergence of Beta and Gamma functions. [2H] Point wise and uniform convergence of sequence of functions. Theorems on continuity, derivability and integrability of the limit function of a sequence of functions. Series of functions; Theorems on the continuity and derivability of the sum function of a series of functions; Cauchy criterion for uniform convergence and Weierstrass M-Test. [15H] Fourier series: Definition of Fourier coefficients and series, Riemann Lebesgue lemma, Bessel's inequality, Parseval's identity, Dirichlet's condition. Examples of Fourier expansions and summation results for series. [13H] Power series, radius of convergence, Cauchy Hadamard theorem. Differentiation and integration of power series; Abel's theorem; Weierstrass approximation theorem. [10H]
Reference Books
➢ K.A. Ross, Elementary Analysis, The Theory of Calculus, Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004. ➢ R.G. Bartle D.R. Sherbert, Introduction to Real Analysis, 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002. ➢ Charles G. Denlinger, Elements of Real Analysis, Jones & Bartlett (Student Edition), 2011. ➢ S. Goldberg, Calculus and mathematical analysis. ➢ Santi Narayan, Integral calculus.

Learning Outcomes of the course

After completion of the course, the student will learn the following

a) Basic knowledge of definition, existence of Riemann integration of a function, example of Riemann integrable function and their theorems.

b) Discussion on existence and related theory on first, second Mean value Theorem.

c) Basic knowledge of Convergence of Improper integral

(e) Discussion on point wise and uniform convergence of sequence and series of function, different theorems on Power series and Fourier series

Course Code: MTMH – C502

Course Title: Partial Differential Equations & Metric Space – II
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Group A: Partial Differential Equation **Marks-42**
Total No. of Lectures: 42 Hours

Partial differential equations – Basic concepts and definitions. Mathematical problems. First-order equations: classification, construction and geometrical interpretation. Method of characteristics for obtaining general solution of quasi linear equations. Canonical forms of first-order linear equations. Method of separation of variables for solving first order partial differential equations. [10H]

Derivation of heat equation, wave equation and Laplace equation. Classification of second order linear equations as hyperbolic, parabolic or elliptic. Reduction of second order linear equations to canonical forms. [16H]

The Cauchy problem, Cauchy-Kowalewskaya theorem, Cauchy problem of an infinite string. Initial boundary value problems. Semi-infinite string with a fixed end, semi-infinite string with a free end. Equations with non-homogeneous boundary conditions. Non- homogeneous wave equation. Method of separation of variables, solving the vibrating string problem. Solving the heat conduction problem. [14H]

Group B: Metric Space – II **Marks-18**
Total No. of Lectures: 18 Hours

Continuous mappings, sequential criterion and other characterizations of continuity. Uniform continuity. Connectedness, connected subsets of R, Continuous functions on Connected sets.

[6H]

Compactness: Sequential compactness, Heine-Borel property, totally bounded spaces, finite intersection property, and continuous functions on compact sets. Homeomorphism. Contraction mappings. Banach fixed point theorem and its application to ordinary differential equation. [12H]

Reference Books

- Tyn Myint-U and Lokenath Debnath, Linear Partial Differential Equations for Scientists and Engineers, 4th edition, Springer, Indian reprint, 2006.
- S.L. Ross, Differential equations, 3rd Ed., John Wiley and Sons, India, 2004.
- Martha L Abell, James P Braselton, Differential equations with MATHEMATICA, 3rd Ed., Elsevier Academic Press, 2004.
- Sneddon, I. N., Elements of Partial Differential Equations, McGraw Hill.
- Miller, F. H., Partial Differential Equations, John Wiley and Sons.

. Kumaresan, Topology of Metric Spaces, 2nd Ed., Narosa Publishing House,2011. ➢ .F. Simmons, Introduction to Topology and Modern Analysis, McGraw Hill, 2004. ➢ Satish Shirali and Harikishan L. Vasudeva, Metric Spaces, Springer Verlag, London, 2006.

Learning Outcomes of the course

After completion of the course, the student will learn the following

(a) Understand the genesis of partial differential equations and its geometrical interpretation
(b) Learn various techniques of getting exact solutions of first order partial differential equations and linear differential equations of second order.
(c) Derive the heat equation, wave equation and Laplace equation.
(d) Classify the second order linear equations as hyperbolic, parabolic or elliptic .Learn the technique to reduce the second order linear equations to canonical forms.
(e) Understand several standard concepts of metric spaces and their properties like openness, closedness, completeness, compactness and connectedness.
(f) Identify the continuity of a function defined on metric spaces and homeomorphisms

Discipline Specific Elective (DSE-1)

Course Code: MTMH DSE501
Course Title: Linear Programming Problem
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Linear Programming Problem **Marks-60** **Total No. of Lectures: 60 Hours**
Introduction to linear programming problem. Theory of simplex method, graphical solution, convex sets, optimality and unboundedness, the simplex algorithm, simplex method in tableau format, introduction to artificial variables, two-phase method. Big-M method and their comparison. [22H] Duality, formulation of the dual problem, primal-dual relationships, economic interpretation of the dual. Transportation problem and its mathematical formulation, northwest-corner method, least cost method and Vogel approximation method for determination of starting basic solution, algorithm for solving transportation problem, assignment problem and its

mathematical formulation, Hungarian method for solving assignment problem. Travelling salesmen problem. [24H] Game theory: formulation of two persons zero sum games, solving two person zero sum games, games with mixed strategies, graphical solution procedure, linear programming solution of games. [14H]
Reference Books
➢ Mokhtar S. Bazaraa, John J. Jarvis and Hanif D. Sherali, Linear Programming and Network Flows, 2nd Ed., John Wiley and Sons, India, 2004. ➢ F.S. Hillier and G.J. Lieberman, Introduction to Operations Research, 9th Ed., Tata McGraw Hill, Singapore, 2009. ➢ Hamdy A. Taha, Operations Research, An Introduction, 8th Ed., Prentice-Hall India, 2006. ➢ G. Hadley, Linear Programming, Narosa Publishing House, New Delhi, 2002.

Learning Outcomes of the course

After completion of the course, the student will learn the following

(a) Analyze the real world problems and make it in the form of linear programming problem (LPP).
(b) Provide graphical solutions of linear programming problems with two variables and illustrate the concept of convex set and extreme points, basic feasible solution, unboundedness of LPP etc.
(c) Understand the theory of the simplex method and simplex algorithm
(d) Know about the relationships between the primal and dual problems.
(e) Learn about the applications to transportation, assignment and two-person zero-sum game problems
(f) Solution technique of transportation problem, assignment problem and game theory

Or

Course Code: MTMH DSE501
Course Title: Point Set Topology
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Point Set Topology	**Marks-60** **Total No. of Lectures: 60 Hours**
Countable and Uncountable Sets, Schroeder-Bernstein Theorem, Cantor's Theorem. Cardinal numbers and cardinal arithmetic. Continuum Hypothesis, Zorns Lemma, Axiom of Choice.	

Well-ordered sets, Hausdorff's maximal principle. Ordinal numbers. [20H] Topological spaces, basis and Subbasis for a topology, subspace topology, interior points, limit points, derived set, boundary of a set, closed sets, closure and interior of a set. Continuous functions, open maps, closed maps and homeomorphisms. Product topology, quotient topology, metric topology, Baire category theorem. [20H] Connected and path connected spaces, connected sets in R, components and path components, local connectedness. Compact spaces, compact sets in R. Compactness in metric spaces. Totally bounded spaces, Ascoli-Arzela theorem, the Lebesgue number lemma. Local compactness. [20H]
Reference Books
➢ Munkres, J.R., Topology, A First Course, Prentice Hall of India Pvt. Ltd., New Delhi, 2000. ➢ Dugundji, J., Topology, Allyn and Bacon, 1966. ➢ Simmons, G.F., Introduction to Topology and Modern Analysis, McGraw Hill, 1963. ➢ Kelley, J.L., General Topology, Van Nostrand Reinhold Co., New York,1995. ➢ Hocking, J., Young, G., Topology, Addison-Wesley Reading, 1961. ➢ Steen, L., Seebach, J., Counter Examples in Topology, Holt, Reinhart and Winston, New York, 1970. ➢ Abhijit Dasgupta, Set Theory, Birkhäuser.

Learning Outcomes of the course

After completion of the course, the student will learn the following

(a) The students would gain knowledge about how the topology on a space is determined by the collection of open sets, by the collection of closed sets, or by a basis of neighborhoods at each point and different topologies as subspace topology, order topology, product topology, metric topology and quotient topology, compactness and connectedness

(b) The students would be able to determine how a function to be continuous, can characterize metrizable spaces and present a systematic introduction of the fundamentals course on topology

Understand several standard concepts of metric spaces and their properties like

Or

Course Code: MTMH DSE501

Course Title: Theory of Equations

Credit: 06

No of Lectures: 60 hours

Full Marks: 75

Theory of Equations	Marks-60 Total No. of Lectures: 60 Hours
General properties of polynomials, Graphical representation of a polynomial, maximum and minimum values of a polynomials, General properties of equations, Descarte's rule of signs positive and negative rule, Relation between the roots and the coefficients of equations. [18H] Symmetric functions. Applications of symmetric function of the roots. Transformation of equations. Solutions of reciprocal and binomial equations. Algebraic solutions of the cubic and biquadratic. Properties of the derived functions. [18H] Symmetric functions of the roots, Newton's theorem on the sums of powers of roots, homogeneous products, limits of the roots of equations. [10H] Separation of the roots of equations, Strums theorem. Applications of Strum's theorem, conditions for reality of the roots of an equation. Solution of numerical equations. [14H]	
Reference Books	
➢ W.S. Burnside and A.W. Panton, The Theory of Equations, Dublin University Press, 1954. ➢ C. C. MacDuffee, Theory of Equations, John Wiley & Sons Inc., 1954.	

Learning Outcomes of the course

After completion of the course, the student will learn the following

(a) Concept of polynomial and its properties .

(b) Understanding the general properties of equations and to find the nature of roots of the equation using Descartes rule of sign.

(c) Discussion of symmetric function and find the roots of symmetric function.

(d) Know the solution of cubic , biquadratic equation and reciprocal equation.

(e) Separation of real roots by strum's theorem.

Course Code: MTMH DSE502
Course Title: Probability & Statistics
Credit: 06

No of Lectures: 60 hours
Full Marks: 75

Probability & Statistics	**Marks-60** **Total No. of Lectures: 60 Hours**
Sample space, probability axioms, real random variables (discrete and continuous), cumulative distribution function, probability mass/density functions, mathematical expectation, moments, moment generating function, characteristic function, discrete distributions: uniform, binomial, Poisson, geometric, negative binomial, continuous distributions: uniform, normal, exponential. [20H] Joint cumulative distribution function and its properties, joint probability density functions, marginal and conditional distributions, expectation of function of two random variables, conditional expectations, independent random variables, bivariate normal distribution, correlation coefficient, joint moment generating function (jmgf) and calculation of covariance (from jmgf), linear regression for two variables. [20H] Chebyshev's inequality, statement and interpretation of (weak) law of large numbers and strong law of large numbers. Central limit theorem for independent and identically distributed random variables with finite variance, Markov chains, Chapman-Kolmogorov equations, classification of states. [12H] Random Samples, Sampling Distributions, Estimation of parameters, Testing of hypothesis. [8H]	
Reference Books	
➢ Gupta, Ground work of Mathematical Probability and Statistics, Academic publishers. ➢ Robert V. Hogg, Joseph W. McKean and Allen T. Craig, Introduction to Mathematical Statistics, Pearson Education, Asia, 2007. ➢ Irwin Miller and Marylees Miller, John E. Freund, Mathematical Statistics with Applications, 7th Ed., Pearson Education, Asia, 2006. ➢ Sheldon Ross, Introduction to Probability Models, 9th Ed., Academic Press, Indian Reprint, 2007. ➢ Alexander M. Mood, Franklin A. Graybill and Duane C. Boes, Introduction to the Theory of Statistics, 3rd Ed., Tata McGraw- Hill, Reprint 2007.	

Learning Outcomes of the course

After completion of the course, the student will learn the following

(a) Understand the genesis of probability theory and define the probability theory in mathematical form
(b) Appreciate the importance of probability distribution of random variables and to know the notion of central tendency.
(c) Establish the joint distribution of two random variables in terms their correlation and regression.
(d) Understand central limit theorem which shows that the empirical frequencies of so many natural populations exhibit normal distribution.
(e) Learn about the sampling distribution of a statistic and know the characteristic of sample.
(f) Analyze the data on the basis of hypothesis.

Or

Course Code: MTMH DSE502
Course Title: Boolean Algebra and Automata Theory
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Boolean Algebra and Automata Theory **Marks-60** **Total No. of Lectures: 60 Hours**
Definition, examples and basic properties of ordered sets, maps between ordered sets, duality principle, lattices as ordered sets, lattices as algebraic structures, sublattices, products and homomorphisms. [08H]
Definition, examples and properties of modular and distributive lattices, Boolean algebras, Boolean polynomials, minimal and maximal forms of Boolean polynomials, Quinn-McCluskey method, Karnaugh diagrams, Logic gates, switching circuits and applications of switching circuits. [12H]
Introduction: Alphabets, strings, and languages. Finite automata and regular languages: deterministic and non-deterministic finite automata, regular expressions, regular languages and their relationship with finite automata, pumping lemma and closure properties of regular languages. [12H]
Context free grammars and pushdown automata: Context free grammars (CFG), parse trees, ambiguities in grammars and languages, pushdown automaton (PDA) and the language accepted by PDA, deterministic PDA, Non- deterministic PDA, properties of context free languages; normal forms, pumping lemma, closure properties, decision properties. [12H]
Turing Machines: Turing machine as a model of computation, programming with a Turing machine, variants of Turing machine and their equivalence.

[06H] Undecidability: Recursively enumerable and recursive languages, undecidable problems about Turing machines: halting problem. Post correspondence problem, and undecidability problems about CFGs. [08H]
Reference Books
➢ B A. Davey and H. A. Priestley, Introduction to Lattices and Order, Cambridge University Press, Cambridge, 1990. ➢ Edgar G. Goodaire and Michael M. Parmenter, Discrete Mathematics with Graph Theory, ➢ (2nd Ed.), Pearson Education (Singapore) P.Ltd., Indian Reprint 2003. ➢ Rudolf Lidl and Günter Pilz, Applied Abstract Algebra, 2nd Ed., Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004. ➢ J. E. Hopcroft, R. Motwani and J. D. Ullman, Introduction to Automata Theory, Languages, and Computation, 2nd Ed., Addison-Wesley, 2001. ➢ H.R. Lewis, C.H. Papadimitriou, C. Papadimitriou, Elements of the Theory of Computation, 2nd Ed., Prentice-Hall, NJ, 1997. ➢ J.A. Anderson, Automata Theory with Modern Applications, Cambridge University Press, 2006.

Learning Outcomes of the course

After completion of the course, the student will learn the following

a) Basic knowledge on Ordered set and Lattice and their classification and properties.

b) Discussion on Boolean algebra and is properties

c) Basic knowledge on simplification of Boolean expression, Proportional logic

d) Discussion on different types of machine, Language, Grammar and undecidability and their properties

Or

Course Code: MTMH DSE502
Course Title: Portfolio Optimization
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Portfolio Optimization	**Marks-60**

Total No. of Lectures: 60 Hours
Financial markets. Investment objectives. Measures of return and risk. Types of risks. Risk free assets. Mutual funds. Portfolio of assets. Expected risk and return of portfolio. Diversification. [20H]
Mean-variance portfolio optimization- the Markowitz model and the two-fund theorem, risk-free assets and one fund theorem, efficient frontier. Portfolios with short sales. Capital market theory. [20H]
Capital assets pricing model- the capital market line, beta of an asset, beta of a portfolio, security market line. Index tracking optimization models. Portfolio performance evaluation measures. [20H]
Reference Books
➢ F. K. Reilly, Keith C. Brown, Investment Analysis and Portfolio Management, 10th Ed., South-Western Publishers, 2011. ➢ H.M. Markowitz, Mean-Variance Analysis in Portfolio Choice and Capital Markets, Blackwell, New York, 1987. ➢ M.J. Best, Portfolio Optimization, Chapman and Hall, CRC Press, 2010. ➢ D.G. Luenberger, Investment Science, 2nd Ed., Oxford University Press, 2013.

Learning Outcomes of the course

After completion of the course, the student will learn the following

a) Discussion on basic objectives of financial investment and knowledge on risk management and estimation of return.
b) Basic knowledge on development of different financial management model and their analysis with some market theory.
c) Discussion on different parameters of portfolio optimization and their importance on portfolio management and expectations.

Course Details of Semester-VI

Course Code: MTMH C601
Course Title: Group Theory-III
Credit: 06
No of Lectures: 60 hours

Full Marks: 75

Group Theory-III	**Marks-60** **Total No. of Lectures: 60 Hours**
Properties of external direct products, the group of units modulo n as an external direct product, internal direct products, Fundamental theorem of finite abelian groups. [18H]	
Group actions, stabilizers and kernels, permutation representation associated with a given group action. Applications of group actions. Generalized Cayley's theorem. Index theorem. [21H]	
Groups acting on themselves by conjugation, class equation and consequences, conjugacy in Sn, p-groups, Sylow's theorems and consequences, Cauchy's theorem, Simplicity of An for n ≥ 5, non-simplicity tests. [21H]	

Reference Books

- John B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.
- M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.
- Joseph A. Gallian, Contemporary Abstract Algebra, 4th Ed., Narosa Publishing House, New Delhi, 1999.
- D.S. Malik, John M. Mordeson and M.K. Sen, Fundamentals of abstract algebra.
- Joseph J. Rotman, An Introduction to the Theory of Groups, 4th Ed., Springer Verlag, 1995.
- I.N. Herstein, Topics in Algebra, Wiley Eastern Limited, India, 1975.
- David S. Dummit and Richard M. Foote, Abstract Algebra, 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2004.
- J.R. Durbin, Modern Algebra, John Wiley & Sons, New York Inc., 2000.
- D. A. R. Wallace, Groups, Rings and Fields, Springer Verlag London Ltd., 1998.

Learning Outcomes of the course

After completion of the course, the student will learn the following
(a) Understand the basic concepts of group actions and their applications.
(b) Recognize and use the Sylow theorems to characterize certain finite groups.

(c) Understanding how one may piece together groups to make larger groups and then decompose it into a product of smaller groups.
(d) In Physics to understand symmetries and conservation lows and in engineering to design error-correcting codes
(e) Students can solve the famous Sicherman dice problem (1978) easily with the help of unique factorization property.

Course Code: MTMH C602
Course Title: Linear Algebra-III & Complex Analysis
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Group A: Linear Algebra-III **Marks-30** **Total No. of Lectures: 30 Hours**
Eigen spaces of a linear operator, diagonalizability, invariant subspaces and Cayley-Hamilton theorem, the minimal polynomial for a linear operator, canonical forms. [12H] Inner product spaces and norms, Gram-Schmidt orthogonalisation process, orthogonal complements, Bessel's inequality, the adjoint of a linear operator. Least squares approximation, minimal solutions to systems of linear equations. Normal and self-adjoint operators. Orthogonal projections and Spectral theorem. [18H]
Group B: Complex Analysis **Marks-30** **Total No. of Lectures: 30 Hours**
Limits, limits involving the point at infinity, continuity. Properties of complex numbers, regions in the complex plane, functions of complex variable, mappings. Derivatives, differentiation formulas, Cauchy-Riemann equations, sufficient conditions for differentiability. [10H] Analytic functions, examples of analytic functions, exponential function, logarithmic function, trigonometric function, derivatives of functions, and definite integrals of functions. Contours, Contour integrals and its examples, upper bounds for moduli of contour integrals. Cauchy- Goursat theorem, Cauchy integral formula. [10H] Liouville's theorem and the fundamental theorem of algebra. Convergence of sequences and

series, Taylor series and its examples.

[05H]

Laurent series and its examples, absolute and uniform convergence of power series

[05H]

Reference Books

- James Ward Brown and Ruel V. Churchill, Complex Variables and Applications, 8th Ed., McGraw – Hill International Edition, 2009.
- Joseph Bak and Donald J. Newman, Complex Analysis, 2nd Ed., Undergraduate Texts in Mathematics, Springer-Verlag New York, Inc., NewYork, 1997.
- S. Ponnusamy, Foundations of complex analysis.
- E.M.Stein and R. Shakrachi, Complex Analysis, Princeton University Press.
- Stephen H. Friedberg, Arnold J. Insel, Lawrence E. Spence, Linear Algebra, 4^{th} Edition., Prentice- Hall of India Pvt. Ltd., New Delhi, 2004.
- Kennath Hoffman, Ray Alden Kunze, Linear Algebra, 2^{nd} Ed., Prentice- Hall of India Pvt. Ltd., 1971.
- S. Kumaresan, Linear Algebra- A Geometric Approach, Prentice Hall of India, 1999.
- S. Lang, Introduction to Linear Algebra, 2^{nd} Ed., Springer, 2007.
- Gilbert Strange, Linear Algebra and Its Applications, Thomson, 2007.

Learning Outcomes of the course

After completion of the course, the student will learn the following

(a) Visualize complex numbers as points of $\mathbb{R}$ and stereographic projection of complex plane on the Riemann sphere.
(b) Understand the significance of differentiability and analyticity of complex functions leading to the Cauchy-Riemann equations.
(c) Learn the role of Cauchy-Goursat theorem and Cauchy integral formula in evaluation of contour integrals.
(d) Apply Lowville's theorem in fundamental theorem of algebra.
(e) Understand the convergence, term by term integration and differentiation of a power Series of complex numbers
(f) Learn Taylor and Laurent series expansions of analytic functions.
(g) Define inner product space and its basic properties and related theorems.
(h) Study of eigen space of linear operator and its related mathematical ptoblems.

Discipline Specific Elective (DSE-2)

Course Code: MTMH DSE601
Course Title: Mechanics
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Mechanics **Marks-60** **Total No. of Lectures: 60 Hours**
Co-planar forces, Astatic equilibrium, Centre of gravity for different bodies, Friction: Equilibrium of a particle on a rough curve, Virtual work, Forces in three dimensions, Stable and unstable equilibrium. [16H]
Equations of motion referred to a set of rotating axes, Motion of a projectile in a resisting medium. Stability of nearly circular orbits. Motion under the inverse square law. Slightly disturbed orbits. Motion of artificial satellites. Motion of a particle in three dimensions. Motion on a smooth sphere, cone, and on any surface of revolution. [22H]
Degrees of freedom. Moments and products of inertia. Momental Ellipsoid. Principal axes. D'Alembert's Principle, Motion about a fixed axis, Compound pendulum. Motion of a rigid body in two dimensions under finite and impulsive forces (Finite and varying mass). Conservation of momentum and energy [22H]
Reference Books
➢ I.H. Shames and G. Krishna Mohan Rao, Engineering Mechanics: Statics and Dynamics, (4th Ed.), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2009. ➢ R.C. Hibbeler and Ashok Gupta, Engineering Mechanics: Statics and Dynamics, 11th Ed., Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi. ➢ Chorlton, F., Textbook of Dynamics. ➢ Loney, S. L., An Elementary Treatise on the Dynamics of particle and of Rigid Bodies, Loney Press. ➢ Loney, S. L., Elements of Static sand Dynamics I and II. ➢ Ghosh, M. C, Analytical Statics. ➢ Verma, R. S., A Textbook on Statics, Pothishala, 1962. ➢ Matiur Rahman, Md., Statics. ➢ Ramsey, A. S., Dynamics (Part I).

Learning Outcomes of the course

After completion of the course, the student will learn the following

(a) Understand the reduction of force system in three dimensions to a resultant force acting at a point and a resultant couple.
(b) Learn about system of coplanar forces and students will learn how can we use these concepts in our real life.
iii) Know the inertia for a rigid body and the equation of momental ellipsoid together with the idea of principal axes and principal moments of inertia and to derive Euler's equations of motion of a rigid body, moving about a point which is kept fixed.
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Or

Course Code: MTMH DSE601
Course Title: Number Theory
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Number Theory **Marks-60**   **Total No. of Lectures: 60 Hours**
Linear diophantine equation, prime counting function, statement of prime number theorem, Goldbach conjecture, linear congruences, complete set of residues. Chinese remainder theorem, Fermat's little theorem, Wilson's theorem.   [16H]
Number theoretic functions, sum and number of divisors, totally multiplicative functions, definition and properties of the Dirichlet product, the Mobius Inversion formula, the greatest integer function, Euler's phi-function, Euler's theorem, reduced set of residues, some properties of Euler's phi-function.   [22H]
Order of an integer modulo n, primitive roots for primes, composite numbers having primitive roots, Euler's criterion, the Legendre symbol and its properties, quadratic reciprocity, quadratic congruences with composite moduli. Public key encryption, RSA encryption and decryption, the equation x2 + y2= z2, Fermat's Last theorem.   [22H]
Reference Books
➢ David M. Burton, Elementary Number Theory, 6th Ed., Tata McGraw-Hill, Indian reprint, 2007.

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

Learning Outcomes of the course

After completion of the course, the student will learn the following

(a) Learn about some important results in the theory of numbers including the prime number theorem, Chinese remainder theorem, Wilson's theorem, Fermat's little theorem and their consequences.
(b) Learn about number theoretic functions, modular arithmetic, definition and properties of the Dirichlet product, the Mobius Inversion formula, the greatest integer function, Euler's phi-function, Euler's theorem and their applications.
(c) Familiarise with modular arithmetic and find primitive roots of prime and composite numbers having primitive roots, Euler's criterion, the Legendre symbol and its properties.
(d) Apply public crypto systems, in particular, RSA.

Or

Course Code: MTMH DSE601
Course Title: Industrial Mathematics
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Industrial Mathematics	**Marks-60** **Total No. of Lectures: 60 Hours**
Medical Imaging and Inverse Problems. The content is based on Mathematics of X-ray and CT scan based on the knowledge of calculus, elementary differential equations, complex numbers and matrices. [15H] Introduction to Inverse problems: Why should we teach Inverse Problems? Illustration of Inverse problems through problems taught in Pre-Calculus, Calculus, Matrices and differential equations. Geological anomalies in Earth's interior from measurements at its surface (Inverse problems for Natural disaster) and Tomography. [16H] X-ray: Introduction, X-ray behavior and Beers Law (The fundamental question of image construction) Lines in the place. [06H] Radon Transform: Definition and Examples, Linearity, Phantom (Shepp - Logan Phantom-Mathematical phantoms).	

[06H]

Back Projection: Definition, properties and examples.

[02H]

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

[15H]

Reference Books

- Timothy G. Feeman, The Mathematics of Medical Imaging, A Beginners Guide, Springer Under graduate Text in Mathematics and Technology, Springer, 2010.
- C.W. Groetsch, Inverse Problems, Activities for Undergraduates, The Mathematical Association of America, 1999.
- Andreas Kirsch, An Introduction to the Mathematical Theory of Inverse Problems, 2nd Ed., Springer, 2011.

Learning Outcomes of the course

After completion of the course, the student will learn the following:
(a) Application of mathematics in the field of Medical Science especially in the field of X-ray behavior and Beers Law, Revision of properties of Fourier and inverse Fourier transforms and applications of their properties in image reconstruction
(b) Algorithms of CT scan machine. Algebraic reconstruction techniques abbreviated as ART with application to CT scan

Course Code: MTMH DSE602
Course Title: Mathematical Modeling
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Mathematical Modeling **Marks-60**

Total No. of Lectures: 60 Hours

Power series solution of Bessel's equation and Legendre's equation, Laplace transform and inverse transform, application to initial value problem up to second order.

[26H]

Monte Carlo simulation modeling: simulating deterministic behavior (area under a curve,

volume under a surface), generating random numbers: middle square method, linear congruence, queuing models: harbor system, morning rush hour, Overview of optimization modeling. Linear programming model: geometric solution algebraic solution, simplex method, sensitivity analysis. [34H]
Reference Books
➢ TynMyint-U and Lokenath Debnath, Linear Partial Differential Equation for Scientists and Engineers, Springer, Indian reprint, 2006. ➢ Frank R. Giordano, Maurice D. Weir and William P. Fox, A First Course in Mathematical Modeling, Thomson Learning, London and New York, 2003.
Graphical demonstration as Teaching aid using any software
1. Plotting of Legendre polynomial for n = 1 to 5 in the interval [0,1]. Verifying graphically that all the roots of Pn(x) lie in the interval [0,1]. **2.** Automatic computation of coefficients in the series solution near ordinary points. **3.** Plotting of the Bessel's function of first kind of order 0 to 3. **4.** Automating the Frobenius Series Method. **5.** Random number generation and then use it for one of the following (a) Simulate area under a curve (b) Simulate volume under a surface. **6.** Programming of either one of the queuing model (a) Single server queue (e.g. Harbor system) (b) Multiple server queue (e.g. Rush hour). **7.** Programming of the Simplex method for 2/3 variables.

Learning Outcomes of the course

After completion of the course, the student will learn the following:

a) They will understand the techniques of the Power series solution of Bessel's equation and Legendre's equation, Laplace transform and inverse transform.

b) Applications of Laplace transformation to solve the ODE and PDE.

c) Learn the simulation process and how to apply in queuing models: harbor system, morning rush hour etc.

Or

Course Code: MTMH DSE602
Course Title: Differential Geometry
Credit: 06
No of Lectures: 60 hours

Full Marks: 75

Differential Geometry	**Marks-60** **Total No. of Lectures: 60 Hours**

Theory of space curves: Space curves. Planer curves, curvature, torsion and Serret-Frenet formula. osculating circles, osculating circles and spheres. Existence of space curves. Evolutes and involutes of curves.

[20H]

Theory of surfaces: Parametric curves on surfaces. Direction coefficients. First and second Fundamental forms. Principal and Gaussian curvatures. Lines of curvature, Euler's theorem. Rodrigue's formula. Conjugate and asymptotic lines.

[20H]

Developables: Developable associated with space curves and curves on surfaces. Minimal surfaces.
Geodesics: Canonical geodesic equations. Nature of geodesics on a surface of revolution. Clairaut's theorem. Normal property of geodesics. Torsion of a geodesic. Geodesic curvature. Gauss-Bonnet theorem.

[20H]

Reference Books

- T.J. Willmore, An Introduction to Differential Geometry, Dover Publications, 2012.
- B. O'Neill, Elementary Differential Geometry, 2nd Ed., Academic Press, 2006.
- C.E. Weatherburn, Differential Geometry of Three Dimensions, Cambridge University Press2003.
- D.J. Struik, Lectures on Classical Differential Geometry, Dover Publications, 1988.
- S. Lang, Fundamentals of Differential Geometry, Springer, 1999.
- B. Spain, Tensor Calculus: A Concise Course, Dover Publications, 2003

Learning Outcomes of the course

After completion of the course, the student will learn the following

a) Basic knowledge of space curve and its properties

b) Understanding of space on a surface and their properties and associated theories

c) Basic knowledge on Geodesic and its development and properties.

Or

Course Code: MTMH DSE602
Course Title: Bio Mathematics
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Bio Mathematics	**Marks-60** **Total No. of Lectures: 60 Hours**
Mathematical biology and the modeling process: an overview. Continuous models: Malthus model, logistic growth, Allee effect, Gompertz growth, Michaelis-Menten Kinetics, Holling type growth, bacterial growth in a chemostat, harvesting a single natural population, Prey predator systems and LotkaVolterra equations, populations in competitions, epidemic models (SI, SIR, SIRS, SIC) [20H] Activator-inhibitor system, insect outbreak model: Spruce Budworm. Numerical solution of the models and its graphical representation. Qualitative analysis of continuous models: Steady state solutions, stability and linearization, multiple species communities and Routh-Hurwitz Criteria. Phase plane methods and qualitative solutions, bifurcations and limit cycles with examples in the context of biological scenario. Spatial models: One species model with diffusion. Two species model with diffusion, conditions for diffusive instability, spreading colonies of microorganisms, Blood flow in circulatory system, travelling wave solutions, spread of genes in a population. [22H] Discrete models: Overview of difference equations, steady state solution and linear stability analysis. Introduction to discrete models, linear models, growth models, decay models, drug delivery problem, discrete prey-predator models, density dependent growth models with harvesting, host-parasitoid systems (Nicholson-Bailey model), numerical solution of the models and its graphical representation. case studies. Optimal exploitation models, models in genetics, stage structure models, age structure models. [18H]	
Reference Books	
➢ L.E. Keshet, Mathematical Models in Biology, SIAM, 1988. ➢ J. D. Murray, Mathematical Biology, Springer, 1993. ➢ Y.C. Fung, Biomechanics, Springer-Verlag, 1990. ➢ F. Brauer, P.V.D. Driessche and J. Wu, Mathematical Epidemiology, Springer, 2008. ➢ M. Kot, Elements of Mathematical Ecology, Cambridge University Press, 2001.	

Graphical demonstration as Teaching aid using any software
1. Growth model (exponential case only). 2. Decay model (exponential case only). 3. Lake pollution model (with constant/seasonal flow and pollution concentration). 4. Case of single cold pill and a course of cold pills. 5. Limited growth of population (with and without harvesting). 6. Predator-prey model (basic volterra model, with density dependence, effect of DDT, two prey one predator). 7. Epidemic model of influenza (basic epidemic model, contagious for life, disease with carriers). 8. Battle model (basic battle model, jungle warfare, long range weapons).

Learning Outcomes of the course

After completion of the course, the student will learn the following
a) Basic knowledge of formulation, solution and long term behaviors of continuous time single, two and multi species population model.

b) Basic knowledge on stability, limit cycle and bifurcation of nonlinear differential equation

c) Basic knowledge of formulation, solution and long term behaviors of continuous time single, two and multi species population model.

d) Discussion on different types of established models as Host-parasite, Nicholsion- Baily SI, SIS and SIR epidemic model.