MAHISHADAL RAJ COLLEGE

Mahishadal, Purbamedinipur

West Bengal-721628

Under Graduate Syllabus in Mathematics

Under the Choice Based Credit System (CBCS)

[With effect from 2017-18]

with

Program outcomes, Course outcomes, and Program specific outcomes

Department of Mathematics(UG), Mahishadal Raj College

Under Graduate Syllabus in Mathematics(Honours)

Under the Choice Based Credit System (CBCS)
[With effect from 2017-18]

Semester	Course Type	Course code	Course title	Credit	L-T-P	Marks		
						CA	ESE	TOTAL
I	Core-1	C1T	Calculus, Geometry, and Differential calculus.	6	5-1-0	15	60	75
	Core-2	C2T	Algebra	6	5-1-0	15	60	75
	GE-1		To be choice from other department	6	4/5 2/1	15	60	75
	AECC-1		English	2	1-1-0	10	40	50
Semester-1: Total				**20**				**275**

Semester	Course Type	Course code	Course title	Credit	L-T-P	Marks		
						CA	ESE	TOTAL
II	Core-3	C3T	Real Analysis.	6	5-1-0	15	60	75
	Core-4	C4T	Differential equation and vector calculus	6	5-1-0	15	60	75
	GE-2		To be choice from other department	6	4/5 2/1	15	60	75
	AECC-2		ENVS	4	1-1-0	10	40	100
Semester-II: Total				**22**				**325**

Semester	Course Type	Course code	Course title	Credit	L-T-P	Marks		
						CA	ESE	TOTAL
III	Core-5	C5T	Theory of real functions and introduction to metric space.	6	5-1-0	15	60	75
	Core-6	C6T	Group Theory-I	6	5-1-0	15	60	75
	Core-7	C7T	Numerical methods	6	4-0-0	10	40	50
		CP7	Lab		0-0-4	05	20	25
	GE-3		To be choice from other department	6	4/5	15	60	75
	SEC-1		Logic & Sets **or** OOP in C++	2	1-1-0	10	40	50
Semester-III: Total				**26**				**350**

UG syllabus with Program outcomes, Course outcomes, and Program specific outcomes

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Semester	Course Type	Course code	Course title	Credit	L-T-P	Marks		
						CA	ESE	TOTAL
IV	Core-8	C8T	Riemann integration and series of function.	6	5-1-0	15	60	75
	Core-9	C9T	Multivariate calculus	6	5-1-0	15	60	75
	Core-10	C10T	Ring theory and linear algebra	6	5-1-0	15	60	75
	GE-4		To be choice from other department	6	4/5	15	60	75
	SEC-2		Graph theory	2	1-1-0	10	40	50
Semester-IV: Total				**26**				**350**

Semester	Course Type	Course code	Course title	Credit	L-T-P	Marks		
						CA	ESE	TOTAL
V	Core-11	C11T	Partial differential equations and applications.	6	5-1-0	15	60	75
	Core-12	C12T	Group Theory-II	6	5-1-0	15	60	75
	DSE-1		Linear Programming **or** Theory of equations	6	5-1-0	15	60	75
	DSE-2		Probability & Statistics or Boolean algebra and Automata theory	6	5-1-0	15	60	75
Semester-V: Total				**24**				**300**

Semester	Course Type	Course code	Course title	Credit	L-T-P	Marks		
						CA	ESE	TOTAL
VI	Core-13	C11T	Metric Spaces & Complex Analysis.	6	5-1-0	15	60	75
	Core-14	C12T	Ring Theory & Linear Algebra-II	6	5-1-0	15	60	75
	DSE-3		Mechanics **OR** Number theory	6	5-1-0	15	60	75
	DSE-4		Mathematical Modeling **OR** Bio Mathematics	6	5-1-0	15	60	75
Semester-VI: Total				**24**				**300**
Program total, i.e., total in all semester				**142**				**1900**

CC = Core Course, **AECC** = Ability Enhancement Compulsory Course , **GE** = Generic Elective , **SEC** = Skill Enhancement Course , **DSE** = Discipline Specific Elective , **CA**= Continuous Assessment , **ESE**= End Semester Examination , **CT** = Core Theory, **CP**=Core Practical , **L** = Lecture, **T** = Tutorial ,**P** = Practical , **ENV**S = Environmental Studies

UG syllabus with Program outcomes, Course outcomes, and Program specific outcomes

Program Specific Outcomes of the B.Sc. Mathematics(Honours) 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 – CC1 & Generic course GE-1
Course Title: Calculus, Geometry & Differential Equation
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Group-A: Calculus **Marks: 60**

Total No. of Lectures: 60 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 parametric curves, area under a curve, area and volume of surface of revolution, techniques of sketching conics. [12H]

Unit 3

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]

Unit 4

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. [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) N-th 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 – CC2
Course Title: Algebra
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Algebra	**Marks:60** **Total No. of Lectures: 60 Hours**
Unit 1	
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]	
Unit 2	
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]	
Unit 3	
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]	
Unit 4	
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

Course details of Semester-II

Course Code: MTMH – CC3
Course Title: Real Analysis
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Real Analysis	**Marks-60** **Total No. of Lectures: 60 Hours**
Unit 1	
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]	
Unit 2	

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]

Unit 3

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]

Graphical Demonstration (Teaching aid)

1. Plotting of recursive sequences.
2. Study the convergence of sequences through plotting.
3. Verify Bolzano-Weierstrass theorem through plotting of sequences and hence identify convergent subsequences from the plot.
4. Study the convergence/divergence of in finite series by plotting their sequences of partial sum.
5. Cauchy's root test by plotting nth roots.
6. Ratio test by plotting the ratio of nth and (n+1)th term.

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 Rea 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

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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.

Course Code: MTMH – CC4
Course Title: Differential Equations & Vector Calculus
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Group A: Differential Equations **Marks-40** **Total No. of Lectures: 40 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. [18H]
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. [7H]
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. [10H]
Unit 4
Triple product, introduction to vector functions, operations with vector-valued function, limits and continuity of vector functions, differentiation and integration of vector functions. [20H]

Graphical demonstration (Teaching aid)
a) Plotting of family of curves which are solutions of second order differential equation. b) Plotting of family of curves which are solutions of third order differential equation.
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 ➢ Marsden, J., and Tromba, Vector Calculus, McGraw Hill. ➢ 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

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) Know about the vector triple product, differentiation and integration of a vector function.

(e) Find the vector equation of plane, straight line and application in mechanics

Generic Course (GE-2)

Course Code: MTM GE 2
Course Title: Algebra
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Classical Algebra	**Marks:60** **Total No. of Lectures: 60 Hours**
Unit 1	
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]	
Unit 2	
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]	
Unit 3	
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]	
Unit 4	
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, 3rdEd., 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

Course details of Semester-III

Course Code: MTMH – CC5
Course Title: Theory of Real Functions& Introduction to Metric Space
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Theory of Real Functions& Introduction to Metric Space **Marks-60** **Total No. of Lectures: 60 Hours**
Unit 1
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]
Unit 2

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]

Unit 3

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]

Unit 4

Metric spaces: 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. [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.S. Kumaresan, Topology of Metric Spaces, 2nd Ed., Narosa Publishing House,2011 G.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 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.

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c) Basic topology of metric space and their properties.

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

Course Code: MTMH – C6
Course Title: Group Theory 1
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Group Theory 1 **Marks-60** **Total No. of Lectures: 60 Hours**
Unit 1
Symmetries of a square, dihedral groups, definition and examples of groups including permutation groups and quaternion groups (through matrices), elementary properties of groups. [10H]
Unit 2
Subgroups and examples of subgroups, centralizer, normalizer, center of a group, product of two subgroups. [15H]
Unit 3
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. [15H]
Unit 4
External direct product of a finite number of groups, normal subgroups, factor groups, Cauchy's theorem for finite abelian groups. [10H]
Unit 5
Group homomorphisms, properties of homomorphisms, Cayley's theorem, properties of isomorphisms. First, Second and Third isomorphism theorems. [10H]
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. ➢ 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.
- D.S. Malik, John M. Mordeson and M.K. Sen, Fundamentals of abstract algebra

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) Analyse the consequences of Lagrange's theorem.
e) Learn about the structure preserving maps between groups and their consequences.
f) Able to solve the problems of direct product of finite number of groups, factor groups.
g) Learn about the finite abelian groups and related theorems and problems.
h) Learn group homomorphism and its properties, fundamental isomorphism theorems and able to solve related problems of homomorphism and isomorphism.

Course Code: MTMH – CC7
Course Title: Numerical Methods and Numerical LAB
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Numerical Methods	**Marks-40** **Total No. of Lectures: 40 Hours**
Unit 1	
Algorithms. Convergence. Errors: relative, absolute. 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.	[8H]
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. [6H]

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. Approximation: Least square polynomial approximation. [10H]

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. [8H]

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 ascending order.
3. Solution of transcendental and algebraic equations by
   i) Bisection method
   ii) Newton Raphson method.

iii) Secant method.
iv) Regula Falsi method.

4. Solution of system of linear equations
   i) LU decomposition method
   ii) Gaussian elimination method
   iii) Gauss-Jacobi method
   iv) Gauss-Seidel method
5. Interpolation
   i) Lagrange Interpolation
   ii) Newton Interpolation
6. Numerical Integration
   i) Trapezoidal Rule
   ii) Simpson's one third rule
   iii) Weddle's Rule
   iv) Gauss Quadrature
7. Method of finding Eigenvalue by Power method
8. Fitting a Polynomial Function
9. Solution of ordinary differential equations
   i) Euler method
   ii) Modified Euler method
   iii) Runge Kutta method

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: MTM SEC-1
Course Title: Object oriented programming in C++
Credit: 02
No of Lectures: 40 hours
Full Marks: 50

C-Programming/ Object Oriented Programming in C++ **Marks-40** **Total No. of Lectures: 40 Hours**
Unit 1
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. [15H]
Unit 2
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. [20H]
Unit 3
Template class in C++, copy constructor, subscript and function call operator, concept of namespace and exception handling. [5H]
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.
d) Use mathematical libraries for computational objectives.
e) Use of objects, classes, and their properties helps to learn about object oriented programming.
f) They can learn how to hide data from malicious corruption, inheritance, and polymorphism proterties.

OR

Course Code: MTMH SEC-1
Course Title: Logic and Sets
Credit: 06
No of Lectures: 40 hours
Full Marks: 50

Logic and Sets **Marks-40** **Total No. of Lectures: 40 Hours**
Unit 1
Introduction, propositions, truth table, negation, conjunction and disjunction. Implications, bi-conditional propositions, converse, contra positive and inverse propositions and precedence of logical operators. Propositional equivalence: Logical equivalences. Predicates and quantifiers: Introduction, quantifiers, binding variables and negations. [15H]
Unit 2
Sets, subsets, set operations and the laws of set theory and Venn diagrams. Examples of finite and infinite sets. Finite sets and counting principle. Empty set, properties of empty set. Standard set operations. classes of sets. Power set of a set. [10H]
Unit 3
Difference and Symmetric difference of two sets. Set identities, generalized union and intersections. Relation: Product set. Composition of relations, types of relations, partitions, equivalence Relations with example of congruence modulo relation. Partial ordering relations, n-ary relations.

[15H]
Reference Books
➢ R.P. Grimaldi, Discrete Mathematics and Combinatorial Mathematics, Pearson Education, 1998. ➢ P.R. Halmos, Naive Set Theory, Springer, 1974. ➢ E. Kamke, Theory of Sets, Dover Publishers, 1950

Learning Outcomes of the course

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

a) Basic knowledge on sets, set operations, and different properties.

b) Familiarize with relations, equivalence relations, partitions and basic properties of numbers.

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

d) Basic knowledge on classical logic, Proportional logic, and predicate calculus.

Generic Course (GE-3)

Course Code: MTM GE 3
Course Title: Differential Equations and Vector calculus
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Group-A: Differential Equation **Marks-40** **Total No. of Lectures: 40 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. [15H]
Unit 2
Systems of linear differential equations, types of linear systems, differential operators, an operator method for linear systems with constant coefficients. [8H] Basic Theory of linear systems in normal form, homogeneous linear systems with constant

coefficients: Two Equations in two unknown functions. [7H]

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. [10H]

Group-B: Vector calculus **Marks-20**

Total No. of Lectures: 20 Hours

Unit 1

Triple product, introduction to vector functions, operations with vector-valued functions, limits and continuity of vector functions, differentiation and integration of vector functions. [20H]

Graphical demonstration (Teaching aid)

1. Plotting of family of curves which are solutions of second order differential equation.
2. Plotting of family of curves which are solutions of third order differential equation.

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.
- Marsden, J., and Tromba, Vector Calculus, McGraw Hill.
- 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

Learning Outcomes of the course

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

1) Students are able to solve homogeneous and non-homogeneous differential equations with constant coefficient and variable coefficients.
2) Determine the equilibrium points of linear system of differential equations and analyze the stability of differential equations.
3) They can solve the power series solution of differential equation at ordinary points, singular points.
4) Learn the definition of differentiability of function of single variable and study the related theorem on differentiability.
5) Know about the vector triple product, differentiation and integration of a vector function.
6) Find the vector equation of plane, straight line and application in mechanics

Course details of Semester-IV

Course Code: MTMH – CC8
Course Title: Riemann Integration and Series of Functions
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Riemann Integration and series of functions	**Marks-60** **Total No. of Lectures: 60 Hours**
Unit 1	
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]	
Unit 2	
Improper integrals. Convergence of Beta and Gamma functions. [2H]	
Unit 3	
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]	
Unit 4	

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]
Unit 5
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

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

Course Code: MTMH – CC9 and GE-4
Course Title: Multivariate Calculus
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Multivariate Calculus	**Marks-60** **Total No. of Lectures: 60 Hours**
Unit 1	
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. [20 H]
Unit 2
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. [20H]
Unit 3
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]
Unit 4
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]
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) Pvt. Ltd. (Pearson Education), Delhi, 2007. ➢ E. 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 ➢ 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 ➢ Marsden, J., and Tromba, Vector Calculus, McGraw Hill. ➢ Maity, K.C. and Ghosh, R.K. Vector Analysis, New Central Book Agency (P) Ltd. Kolkata (India). ➢ Terence Tao, Analysis II, Hindustan Book Agency, 2006 ➢ M.R. Speigel, Schaum's outline of Vector Analysis.

Learning Outcomes of the course

a) Develop concepts on limit and continuity of functions of two or more variables, their partial derivatives, total derivative and differentiability.

b) Chain rule for one and two independent parameters, directional derivatives, the gradient, maximal and normal property of the gradient, tangent planes.

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

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

e) Basic definition and propertise of Curl, divergence.

Course Code: MTMH – CC10

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

Ring Theory-I	**Marks-60** **Total No. of Lectures: 60 Hours**
Unit 1	
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. [15H]	
Unit 2	
Ring homomorphisms, properties of ring homomorphisms. Isomorphism theorems I, II and III, field of quotients. [15H]	
Unit 3	
Vector spaces, subspaces, algebra of subspaces, quotient spaces, linear combination of vectors, linear span, linear independence, basis and dimension, dimension of subspaces. [15H]	
Unit 4	
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. [15H]	
Reference Books	
➢ John B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002. ➢ M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011. ➢ Stephen H. Friedberg, Arnold J. Insel, Lawrence E. Spence, Linear Algebra, 4th Ed., Prentice- Hall of India Pvt. Ltd., New Delhi, 2004.	

- Joseph A. Gallian, Contemporary Abstract Algebra, 4th Ed., Narosa Publishing House, New Delhi, 1999.
- S. Lang, Introduction to Linear Algebra, 2nd Ed., Springer, 2005.
- Gilbert Strang, Linear Algebra and its Applications, Thomson, 2007.
- S. Kumaresan, Linear Algebra- A Geometric Approach, Prentice Hall of India, 1999.
- Kenneth 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.
- D.S. Malik, John M. Mordeson and M.K. Sen, Fundamentals of abstract algebra.

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 theorems.
c) Learn in detail about homomorphism, isomorphism, and related theories.
d) Learn in detail about the field of quotient.
e) Know the vector spaces, subspaces, quotient spaces and dimension and able to solve problems of dimension, linear dependence and independence.
f) Understand the linear transformation, algebra of linear transformation and isomorphism theorem.
g) Compute linear transformations, kernel and range, and inverse linear transformations, and find matrices of general linear transformations.

Skill Enhancement Course (SEC-2)

Course Code: MTMH SEC 2
Course Title: Graph Theory
Credit: 02
No of Lectures: 40 hours
Full Marks: 50

Graph Theory	**Marks-50** **Total No. of Lectures: 40 Hours**
Unit 1	
Definition, examples and basic properties of graphs, pseudo graphs, complete graphs, bipartite graphs isomorphism of graphs. [14H]	
Unit 2	
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]
Unit 3
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.

Course details of Semester-V

Course Code: MTMH – CC11

Course Title: Partial Differential Equations & Application
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Partial Differential Equations & Applications	**Marks-60** **Total No. of Lectures: 60 Hours**
Unit 1	
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]
Unit 2
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]
Unit 3
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]
Unit 4
Central force. Constrained motion, varying mass, tangent and normal components of acceleration, modelling ballistics and planetary motion, Kepler's second law. [18H]
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. ➢ 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) 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) Know the application of differential equation in particle dynamics, like, central force, planetary motion, etc.

Course Code: MTMH – CC12
Course Title: Group Theory II
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Group Theory-II **Marks-60** **Total No. of Lectures: 60 Hours**
Unit 1
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. [15H]
Unit 2
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. [15H]
Unit 3
Group actions, stabilizers and kernels, permutation representation associated with a given group action. Applications of group actions. Generalized Cayley's theorem. Index theorem. [15H]
Unit 4
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. [15H]
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, 1999. ➢ 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 ➢ D.S. Malik, John M. Mordeson and M.K. Sen, Fundamentals of abstract algebra. ➢ I.N. Herstein, Topics in Algebra, Wiley Eastern Limited, India, 1975

Learning outcomes of the course

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

a) Understand group homomorphism and its properties, fundamental isomorphism theorems and able to solve related problems of homomorphism and isomorphism.
b) Solve the problems of direct product of finite number of groups, factor groups.
c) Apply the Internal Direct Product Theorem in simple cases
d) Express a given finite cyclic group as the direct product of cyclic groups of prime power order and, given two direct products of cyclic groups, determine whether or not they are isomorphic.
e) Understand fundamental theorem of finite abelian groups.
f) Be familiar with group actions and conjugacy in S_n.
g) Understand Sylow's theorems and their applications.
h) Apply Group actions and Sylow theorems to check non-simplicity of a group.

Discipline Specific Elective (DSE-1)

Course Code: MTMH DSE1
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**
Unit 1
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]
Unit 2
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]
Unit 3

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

Course Code: MTMH DSE2
Course Title: Probability & Statistics
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Probability & Statistics **Marks-60** **Total No. of Lectures: 60 Hours**
Unit 1
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]
Unit 2
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]
Unit 3
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]
Unit 4
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) Analysed the data on the basis of hypothesis.

Course details of Semester-VI

Course Code: MTMH – CC13
Course Title: Metric Spaces and Complex Analysis
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Group A: Metric Spaces **Marks-30** **Total No. of Lectures: 30 Hours**
Unit 1
Sequences in metric spaces, Cauchy sequences. Complete metric spaces, Cantor's theorem. [13H]
Unit 2
Continuous mappings, sequential criterion and other characterizations of continuity. Uniform continuity. Connectedness, connected subsets of R. 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. [17H]
Unit 3
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]
Unit 4
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]
Unit 5
Liouville's theorem and the fundamental theorem of algebra. Convergence of sequences and series, Taylor series and its examples. [5H]
Unit 6
Laurent series and its examples, absolute and uniform convergence of power series. [5H]
Reference Books
➢ SatishShirali and Harikishan L. Vasudeva, Metric Spaces, Springer Verlag, London, 2006.

- S. Kumaresan, Topology of Metric Spaces, 2nd Ed., Narosa Publishing House, 2011.
- G.F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, 2004.
- 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.

Learning Outcomes of the course

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

a) Basic topology of metric space and their properties.

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

c) Visualize complex numbers as points of $\mathbb{R}$ and stereographic projection of complex plane on the Riemann sphere.

d) Understand the significance of differentiability and analyticity of complex functions leading to the Cauchy-Riemann equations.

e) Learn the role of Cauchy-Goursat theorem and Cauchy integral formula in evaluation of contour integrals.

f) Apply Lowville's theorem in fundamental theorem of algebra.

g) Understand the convergence, term by term integration and differentiation of a power series of complex numbers**.**

h) Learn Taylor and Laurent series expansions of analytic functions

Course Code: MTMH – CC14
Course Title: Ring Theory and Linear Algebra II
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Ring Theory-I	**Marks-60** **Total No. of Lectures: 60 Hours**
Unit 1	
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]	

Unit 2
Dual spaces, dual basis, double dual, transpose of a linear transformation and its matrix in the dual basis, annihilators. Eigen spaces of a linear operator, diagonalizability, invariant subspaces and Cayley-Hamilton theorem, the minimal polynomial for a linear operator, canonical forms. [15H]
Unit 3
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. [20H]
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, 1999. ➢ Stephen H. Friedberg, Arnold J. Insel, Lawrence E. Spence, Linear Algebra, 4th Ed., Prentice- Hall of India Pvt. Ltd., New Delhi, 2004. ➢ S. Lang, Introduction to Linear Algebra, 2nd Ed., Springer, 2005. ➢ Gilbert Strang, Linear Algebra and its Applications, Thomson, 2007. ➢ S. Kumaresan, Linear Algebra- A Geometric Approach, Prentice Hall of India, 1999. ➢ Kenneth Hoffman, Ray Alden Kunze, Linear Algebra, 2nd Ed., Prentice-Hall of India Pvt. Ltd., 1971. ➢ S.H. Friedberg, A.L. Insel and L.E. Spence, Linear Algebra, Prentice Hall of India Pvt. Ltd., 2004

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. 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.
a) Recognize consistent and inconsistent systems of linear equations by the row echelon form of the augmented matrix, using rank.
b) Find eigenvalues and corresponding eigenvectors for a square matrix
c) Learn in detail about polynomial rings, factorization of polynomial, divisibility of integral Domains.
d) Define inner product space and its basic properties and related theorems.
e) Study of eigen space of linear operator and its related mathematical problems.

f) Obtain various variants of diagonalisation of linear transformations and Realise importance of adjoint of a linear transformation and its canonical form.

g) Discuss orthogonal and orthonormal bases.

h) Explain the Gram-Schmidt orthogonalization process.

i) Compute the orthogonal projection of a vector onto a subspace, given a basis for the subspace

j) Discuss general inner product spaces and symmetric matrices, and associated norms

k) Explain how orthogonal projections relate to least square approximations

Course Code: MTMH DSE3
Course Title: Mechanics
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Mechanics **Marks-60** **Total No. of Lectures: 60 Hours**
Unit 1
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]
Unit 2
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]
Unit 3
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.
c) 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.

OR

Course Code: MTMH DSE3
Course Title: Number Theory
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Number Theory	**Marks-60**
	Total No. of Lectures: 60 Hours
Unit 1	
Linear diophantine equation, prime counting function, statement of prime number theorem, Goldbach conjecture, linear congruences, complete set of residues. Chinese remainder theorem, Fermat's little theorem, Wilson's theorem. [16H]	

Unit 2
Number theoretic functions, sum and number of divisors, totally multiplicative functions, definition and properties of the Dirichlet product, the Mobius Inversion formula, the greatest integer function, Euler's phi- function, Euler's theorem, reduced set of residues, some properties of Euler's phi-function. [22H]
Unit 3
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.

Course Code: MTMH DSE2
Course Title: Mathematical Modeling
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Mathematical Modeling	**Marks-60**

Total No. of Lectures: 60 Hours
Unit 1
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]
Unit 2
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: Bio Mathematics
Credit: 06
No of Lectures: 60 hours
Full Marks: 75

Bio Mathematics **Marks-60** **Total No. of Lectures: 60 Hours**
Unit 1
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]
Unit 2
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]
Unit 3
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.