Ramakrishna Mission Residential College

(Autonomous)

Narendrapur, Kolkata – 700103

Department of Mathematics

Syllabus for three-year B.Sc.

In

Mathematics Honours

Under **CBCS**

2018

Name of the Programme	Programme Code
B. Sc. Mathematics Honours	BSHMAT

Program Objective

Honours – Mathematics, though not a science per se, is often referred to as the mother of all sciences. Its importance for a student willing to pursue basic science can never be underestimated. The principal objective of our syllabus is to empower the young learners, who aspire to make a career in teaching and/or research in Mathematics or any other related science subjects in future, so that their transition to the next higher step in mathematics learning may be as smooth as possible, through helping them to master a solid foundational knowledge of the basic theories from various branches of modern mathematics.

Generic Elective – This program is designed for the students who take Mathematics as an elective subject along with their chosen honours subject. Some of these honours subjects like Physics / Chemistry / Statistics / Computer Science / Economics specifically require some mathematical knowledge back-up, which is far from the rudimentary knowledge of mathematics that is provided at the plus two levels in general. Hence this course is designed to cater to this specific need by chalking out a common minimum requirement of the above mentioned disciplines, as far as practicable.

Course Structure: Semester-wise distribution of Courses

Honours

Semester	Course Name	Course Code	Credits
1	Classical Algebra , Abstract Algebra - I	HMAT1CC01N	6
	Analytical Geometry – 2D , Ordinary Differential Equations	HMAT1CC02N	6
2	Real Analysis-I	HMAT2CC03N	6
	Abstract Algebra – II, Linear Algebra – I	HMAT2CC04N	6
3	Analytical Geometry – 3D, Vector Analysis	HMAT3CC05N	6
	Linear Algebra – II, Application of Calculus	HMAT3CC06N	6
	Real Analysis – II	HMAT3CC07N	6
4	Analytical Dynamics of a Particle	HMAT4CC08N	6
	Linear Algebra – III	HMAT4CC09N	6
	Real Analysis – III, Multivariate Calculus	HMAT4CC10N	6
5	Partial Differential Equations and Complex Analysis	HMAT5CC11N	6
	Metric Space, Analytical Statics	HMAT5CC12N	6
	See DSE	HMAT5DS11L HMAT5DS12N	6
	See DSE	HMAT5DS21N HMAT5DS22N	6
6	Probability and Statistics	HMAT6CC13N	6
	Numerical Methods, Numerical Methods Lab	HMAT6CC14L	6
	See DSE	HMAT6DS31N HMAT6DS32N	6
	See DSE	HMAT6DS41N HMAT6DS42N	6
	Grand Total		108

*These courses are to be taken by the students of other discipline.

Discipline Specific Electives (DSE)*

DSE 1 (for Semester 5)	DSE 2 (for Semester 5)	DSE 3 (for Semester 6)	DSE 4 (for Semester 6)
1. Computer Programming with C & Mathematica 2. Boolean Algebra & Automata Theory	1. Advanced Algebra 2. Bio Mathematics	1. L.P.P. & Game Theory 2. Advanced Mechanics	1. Rigid Dynamics 2. Point Set Topology

*A student has to opt for any one of the courses available/given by the department in a specific year under each category.

Course Structure	DSE

Semester-wise detailed syllabus

SEMESTER – 1		
Name of the Course : Classical Algebra, Abstract Algebra – I		
Course Code : HMAT1CC01N		
Full Marks : 100		Credit: 6
Theory	Credits : 5 Full Marks : 65+20*	
Tutorial	Credits : 1 Full Marks : 15	
Number of classes required : 100		
*15 Marks are reserved for Internal Assessment (to be taken from the mid-semester exam) & 5 marks for Attendance		

Course Outcomes: At the end of studying this course a student

- will acquire knowledge on complex numbers, theory of equations and certain important inequalities and will be able to solve problems related to those topics.
- will acquire knowledge on rudimentary theory of numbers along with some cutting edge applications like RSA cryptosystem and digital signature.
- will acquire knowledge on basic Group theory and skill to solve the related problems that will make a foundation for the second part of this course to be given in Semester – 2.

Syllabus

Group – A [40 Marks]
(Classical Algebra)

1. **Integers**: Well–ordering property of positive integers, Second Principle of Mathematical Induction. Division Algorithm $(a = bq + r,\ b \neq 0,\ 0 \leq r < |b|)$. The greatest common divisor (a, b) of two integers a and b. Existence and uniqueness of (a, b). Relatively prime integers. The equation $ax + by = c$ has integral solution iff (a, b) divides c (a, b, c are integers). Congruence relation modulo n. Prime integers. Euclid's first theorem: If some prime p divides ab, then p divides either a or b. Euclid's second theorem: There are infinitely many prime integers. Unique factorization theorem. Linear Congruences. Fundamental Theorem of Arithmetic. Chinese Remainder Theorem and simple problems. Little Theorem of Fermat & Euler's generalization. Arithmetic functions, some arithmetic functions such as φ, τ, σ and their properties. Applications: RSA Cryptosystem and digital signature.
2. **Complex Numbers**: De-Moivre's Theorem and its applications, Exponential, Sine, Cosine and Logarithm of a complex number. Definition of a^z $(a \neq 0)$. Inverse circular and hyperbolic functions.
3. **Theory of Equations**: Polynomials with real co-efficients: Fundamental Theorem of Classical Algebra (statement only). The n-th degree polynomial equation has exactly n roots. Nature of roots of an equation (surd or complex roots occur in pairs). Statements of Descartes' rule of signs. Sturm's Theorem and their applications. Multiple roots.

Course Structure	DSE

4. Relation between roots and coefficients. Symmetric functions of roots. Transformation of equations. Reciprocal equations. Cardan's method of solving a cubic equation. Ferrari's method of solving a biquadratic equation. Binomial equation. Special roots.
5. **Inequality**: Inequalities $AM \geq GM \geq HM$ and their generalizations. The theorem of weighted means and m-th power theorem. Cauchy's inequality (statement only) and its direct applications.

Group – B [25 Marks]
(Abstract Algebra – I)

1. **Relation & function**: Revision of basic ideas on relations and functions. Fundamental theorem of equivalence relation, residue class of integers $\mathbb{Z}_n$. Partial order relation, poset, linear order relation. Invertibility and inverse of a mapping.
2. **Groups**: Semigroup, Group, Abelian group. Various examples of groups (Klein's 4-group, group of residue classes of integers, group of symmetries, dihedral group, quaternion group [through matrices]), elementary properties, conditions for a semigroup to be a group, integral power of elements and order of an elements in a group, order of a group. Permutation groups, cycle, transposition, every permutation can be expressed as a product of disjoint cycles (statement only), even and odd permutations, symmetric group, alternating group.
3. **Subgroups:** Necessary and sufficient condition for a subset of a group to be a subgroup. Intersection and union of subgroups. Necessary and sufficient condition for union of two subgroups to be a subgroup. Normalizer, Centralizer, center of a group. Product of two subgroups. Generator of a group, examples of finitely generated groups, cyclic groups, Subgroups of cyclic groups. Necessary and sufficient condition for a finite group to be cyclic. Cosets and Lagrange's theorem on finite group; counter example to establish the failure of converse. Fermat's Little theorem, Normal subgroup of a group and its properties. Quotient group.

References:

1. Titu Andrescu and Dorin Andrica – Complex Numbers from A to Z, Springer (2014)
2. W S Burnside and A W Panton – Theory of Equations (Vol. 1), University Press, Dublin (1924)
3. S K Mapa – Higher Algebra (Classical), Sarat Book Distributors, Kolkata (8th Edition, 2011)
4. Gareth Jones and Josephine M Jones – Elementary Number Theory, Springer (1998)
5. Titu Andrescu and Dorin Andrica – Number Theory, Springer (2009)
6. M K Sen, S Ghosh, P Mukhopadhyay and S Maity – Topics in Abstract Algebra, University Press, Hyderabad (3rd Edition, 2018)
7. D S Malik, John M Mordeson and M K Sen – Fundamentals of Abstract Algebra, McGraw Hill, New York (1997)
8. John B Fraleigh – A First Course in Abstract Algebra, Pearson (7th Edition, 2002)
9. M Artin – Abstract Algebra, Pearson (2nd Edition, 2011)
10. Joseph A Gallian – Contemporary Abstract Algebra, Narosa Publishing House, New Delhi (4th Edition, 1999)
11. Joseph J Rotman – An Introduction to the Theory of Groups, Springer (4th Edition, 1995)
12. I N Herstein – Topics in Algebra, Wiley Eastern Limited, India (1975)

Course Structure	DSE

<u>Question Pattern for End Semester Examination</u>

(Course Code: HMAT1CC01N)

Group – A (Classical Algebra, 40 marks)

(i) Answer **five** objective / MCQ type questions of 2 marks each from 6 given questions.

(ii) Answer **five** questions of 4 marks each from 7 given questions.

(iii) Answer **two** questions of 5 marks each from 4 given questions.

Group – B (Abstract Algebra – I, 25 marks)

(i) Answer **two** objective / MCQ type questions of 2 marks each from 3 given questions.

(ii) Answer **five** questions of 3 marks each from 7 given questions.

(iii) Answer **one** question of 6 marks from 2 given questions. Each question may contain further parts.

Course Structure	DSE

<table>
<tr><td colspan="3" align="center">SEMESTER – 1</td></tr>
<tr><td colspan="3">Name of the Course : Analytical Geometry – 2D, Ordinary Differential Equations</td></tr>
<tr><td colspan="3">Course Code : HMAT1CC02N</td></tr>
<tr><td colspan="2" align="center">Full Marks : 100</td><td align="center">Credit : 6</td></tr>
<tr><td>Theory</td><td colspan="2">Credits : 5
Full Marks : 65+20*</td></tr>
<tr><td>Tutorial</td><td colspan="2">Credits : 1
Full Marks : 15</td></tr>
<tr><td colspan="3" align="center">Number of classes required : 100</td></tr>
<tr><td colspan="3" align="center">*15 Marks are reserved for Internal Assessment (to be taken from the mid-semester exam)
& 5 marks for Attendance</td></tr>
</table>

Course Outcomes: At the end of studying this course a student

- will acquire knowledge on two dimensional analytical geometry (both Cartesian and Polar coordinate system) and will be able to solve problems related to those topics, as a continuation of their previous concepts from plus two level .
- will acquire knowledge on different techniques towards solving first order ordinary differential equations, as a continuation of their previous concepts from plus two level . .
- will acquire knowledge and skill towards solving various second order ordinary differential equations, simultaneous linear differential equations, eigenvalue problems, which are of paramount importance as a tool, not only in mathematics but also in almost all allied science subjects.

Syllabus

Group – A [30 Marks]
(Analytical Geometry – 2D)

1. **Transformation of Rectangular axes**: Translation, Rotation and their combination (rigid motion). Theory of Invariants.
2. **Pair of straight lines**: Condition that the general equation of second degree in two variables may represent two straight lines. Point of intersection of two intersecting straight lines. Angle between two lines given by $ax^2 + 2hxy + by^2 = 0$. Angle bisectors. Properties of the pair of straight lines of the form $ax^2 + 2hxy + by^2 + 2gx + 2fy + c = 0$. Equations of two lines joining the origin to the points in which a line meets a conic.
3. **General equation of second degree in two variables**: Reduction into canonical form. Classification of conics, Lengths and position of the axes.
4. **Circle, Parabola, Ellipse and Hyperbola**: Equations of pair of tangents from an external point, chord of contact, pole and polar, conjugate points and conjugate lines.
5. **Polar equation**: Polar equation of straight lines and circles. Polar equation of a conic referred to a focus as pole. Equations of tangent, normal, chord of contact.

Course Structure	DSE

Group – B [35 Marks]
(Ordinary Differential Equations)

1. First order differential equations: Exact differential equations. Condition of exactness. Integrating factor. Rules for finding integrating factor (statement of relevant results only). Special integrating factors and transformations. The existence and uniqueness theorem of Picard (statement only).

2. Linear equations and equations reducible to linear form.
3. First order higher degree differential equations solvable for x, y and p. Clairaut's equations, their general and singular solutions.
4. Linear differential equations of second order: Wronskian: its properties and applications. Complementary function and particular integral. Symbolic operator D. Solution by operator method, method of variation of parameters. Euler's homogeneous equation and reduction to an equation of constant coefficients.
5. Simple Eigen value problems.
6. Simultaneous linear differential equations. Total differential equations – condition of integrability.
7. Power series solution of an ordinary differential equation about an ordinary point, solution about a regular singular point (up to second order).

References:

1. S L Loney – Co-ordinate Geometry
2. J G Chakravorty and P R Ghosh – Advanced Analytical Geometry, U N Dhur & Sons Pvt. Ltd, Kolkata (13th Edition 2012)
3. R M Khan – Analytical Geometry of Two and Three Dimensions and Vector Analysis, New Central Book Agency (P) Ltd., Kolkata (5th edition, 2012)
4. Arup Mukherjee and N K Bej – Analytical Geometry of two & Three Dimensions (Advanced Level), Books and Allied (P) Ltd., Kolkata (2010)
5. S L Ross – Differential Equations, John Wiley & Sons, India (3rd Edition, 2004)
6. N Mandal – Differential Equations (Ordinary and Partial), Books and Allied (P) Ltd., Kolkata (2nd Edition, 2018)
7. S Balachandra Rao and H R Anuradha – Differential Equations with Applications and Programs, Universities Press, Hyderabad (2009)

Question Pattern for End Semester Examination

(Course Code: HMAT1CC02N)

Group – A (*Analytical Geometry – 2D, 30 marks*)

(i) Answer **four** objective / MCQ type questions of 2 marks each from 5 given questions.

(ii) Answer **two** questions of 5 marks each from 4 given questions.

(iii) Answer **two** questions of 6 marks each from 4 given questions.

Group – B (*Ordinary Differential Equations, 35 marks*)

(i) Answer **four** objective / MCQ type questions of 2 marks each from 5 given questions.

(ii) Answer **three** questions of 5 marks each from 5 given questions.

(iii) Answer **two** questions of 6 marks each from 4 given questions.

Course Structure	DSE

SEMESTER – 2		
Name of the Course : Real Analysis – I		
Course Code : HMAT2CC03N		
Full Marks : 100		Credit: 6
Theory	Credits : 5 Full Marks : 65+20*	
Tutorial	Credits : 1 Full Marks : 15	
Number of classes required : 100		
*15 Marks are reserved for Internal Assessment (to be taken from the mid-semester exam) & 5 marks for Attendance		

Real Analysis – I [65 Marks]

Course Outcomes: At the end of studying this course a student

- will acquire knowledge on real number system from axiomatic stand point.
- will acquire knowledge on different facets of sequence and series of real numbers and the fundamental concept of their convergence through some of the most celebrated theorems of this area.
- will acquire knowledge and skill towards solving various problems related to the concepts of limit, continuity and differentiability of a real valued function of real variables. These cornerstone ideas will lay foundation for future development of real analysis as presented in CC 7 of Semester – 3.

Syllabus

1. **Real Number System**: Field Axioms. Concept of ordered field. Bounded set, L.U.B. (supremum) and G.L.B. (infimum) of a set. Properties of L.U.B. and G.L.B. of sum of two sets and scalar multiple of a set. Least upper bound axiom or completeness axiom. Characterization of $\mathbb{R}$ as a complete ordered field. Definition of an Archimedean ordered field. Archimedean property of $\mathbb{R}$. $\mathbb{Q}$ is Archimedean ordered field but not ordered complete. Linear continuum.
2. **Sets in** $\mathbb{R}$:
   (i) Intervals. Neighbourhood of a point. Interior point. Open set. Union, intersection of open sets. Every open set can be expressed as disjoint union of open intervals.
   (ii) Limit point and isolated point of a set. Criteria for L.U.B. and G.L.B. of a bounded set to be limit point of the set. Bolzano-Weierstrass theorem on limit point. Definition of derived set. Derived set of a bounded set A is contained in the closed interval [inf A, sup A]. Closed set. Complement of open set and closed set. Union and intersection of closed sets as a consequence. No nonempty proper subset of $\mathbb{R}$ is both open and closed.
   (iii) Dense set in $\mathbb{R}$ as a set having non-empty intersection with every open interval. $\mathbb{Q}$ and $\mathbb{R}\backslash\mathbb{Q}$ are dense in $\mathbb{R}$.
3. **Countability of sets**: Countability and uncountability of a set. Subset of a countable set is countable. Every infinite set has a countably infinite subset. Cartesian product of two countable sets is countable. $\mathbb{Q}$ is countable. Non-trivial intervals are uncountable. $\mathbb{R}$ is uncountable.

Course Structure	DSE

4. **Sequences of real numbers**:
   (i) Definition of a sequence as function from $\mathbb{N}$to$\mathbb{R}$. Bounded sequence. Convergence (formalization of the concept of limit as an operation in $\mathbb{R}$) and non-convergence. Examples. Every convergent sequence is bounded and limit is unique. Algebra of limits.
   (ii) Sequential criterion of the limit point of a set in $\mathbb{R}$. Monotone sequences and their convergence. Sandwich rule. Nested interval theorem. Limit of some important sequences : $\left\{n^{\frac{1}{n}}\right\}_n$, $\{x^n\}_n$, $\left\{x^{\frac{1}{n}}\right\}_n$, $\{x_n\}_n$ with $\frac{x_{n+1}}{x_n} \to l$ and $|l| < 1$, $\left\{\left(1+\frac{1}{n}\right)^n\right\}_n$, $\left\{1+\frac{1}{1!}+\frac{1}{2!}+\cdots+\frac{1}{n!}\right\}_n$, $\{a^{x_n}\}_n (a > 0)$.
   Cauchy's first and second limit theorems.

   (iii) Subsequence. Subsequential limits, limsup as the L.U.B. and liminf as the G.L.B of a set containing all the subsequential limits. Alternative definition of limsup and liminf of a sequence using inequalities.
   A bounded sequence $\{x_n\}_n$ is convergent iff $sup x_n = liminf x_n$. Every sequence has a monotone subsequence. Bolzano-Weierstrass' theorem. Cauchy's general principle of convergence.
5. **Limits and Continuity of real-valued functions of a real variable**:
   (i) Limit of a function at a point (the point must be a limit point of the domain set of the function). Sequential criteria for the existence of finite and infinite limit of a function at a point. Algebra of limits. Sandwich rule. Important limits like $\frac{\sin x}{x}, \frac{\log(1+x)}{x}, \frac{a^x-1}{x}$ $(a > 0)$ as $x \to 0$
   (ii) Continuity of a function at a point. Continuity of a function on an interval and at an isolated point. Familiarity with the figures of some well-known functions :
   $$y = x^a \left(a = 2,3,\frac{1}{2},-1\right), |x|, \sin x, \cos x, \tan x, \log x, e^x$$
   Algebra of continuous functions as a consequence of algebra of limits. Continuity of composite functions. Examples of continuous functions. Continuity of a function at a point does not necessarily imply the continuity in some neighbourhood of that point.
   (iii) Bounded functions. Neighbourhood properties of continuous functions regarding boundedness and maintenance of same sign. Continuous function on $[a, b]$is bounded and attains its bounds. Intermediate value theorem.
   (iv) Discontinuity of function, type of discontinuity. Step function. Piecewise continuity. Monotone function. Monotone function can have only jump discontinuity. Set of points of discontinuity of a monotone function is at most countable. Monotone bijective function from an interval to an interval is continuous and its inverse is also continuous.
   (v) Definition of uniform continuity and examples. Lipschitz condition and uniform continuity. Functions continuous on a closed and bounded interval is uniformly continuous. A necessary and sufficient condition under which a continuous function on a bounded open interval I will be uniformly continuous on I. A sufficient condition under which a continuous function on an unbounded open interval I will be uniformly continuous on I (statement only).
6. **Infinite Series of real numbers:**
   (i) Convergence, Cauchy's criterion of convergence.
   (ii) Series of non-negative real numbers: Tests of convergence – Cauchy's condensation test. Comparison test (ordinary form and upper limit and lower limit criteria), Ratio Test, Root test, Gauss's test (proof not required).
   (iii) Series of arbitrary terms: Absolute and conditional convergence.
   (iv) Alternating series: Leibnitz test.
   (v) Abel's and Dirichlet's test (statements and applications).

Course Structure	DSE

7. **Derivatives of real valued functions of a real variable:**
   (i) Definition of derivability. Meaning of sign of derivative. Chain rule.
   (ii) Successive derivative: Leibnitz theorem.
   (iii) Theorems on derivatives: Darboux theorem, Rolle's Theorem, Mean value theorems of Lagrange and Cauchy – as an application of Rolle's Theorem. Taylor's theorem on closed and bounded interval with Lagrange's and Cauchy's form of remainder deduced from Lagrange's and Cauchy's mean value theorem respectively. Maclaurin's theorem as a consequence of Taylor's theorem. Statement of Maclaurin's Theorem on infinite series expansion. Expansion of e^x, $\log(1+x)$, $(1+x)^m$, $\sin x$, $\cos x$ with their range of validity.
   (iv) Statement of L'Hospital's rule and its consequences. Point of local extremum (maximum, minimum) of a function in an interval. Sufficient condition for the existence of a local maximum/minimum of a function at a point (statement only). Determination of local extremum using first order derivative. Application of the principle of maximum/minimum in geometrical problems.

References:

1. Tom M Apostol – Mathematical Analysis, Narosa Publishing House
2. Tom M Apostol – Calculus (Vol I & II), John Wiley and Sons
3. W Rudin – Principles of Mathematical Analysis, McGraw-Hill (1976)
4. R G Bartle and D R Sherbert – Introduction to Real Analysis, John Wiley and Sons (Asia) Pvt. Ltd., Singapore (3rd Edition, 2002)
5. C C Pugh – Real Mathematical Analysis, Springer (2002)
6. Terence Tao – Analysis I, Hindustan Book Agency (2006)
7. Richard R Goldberg – Method of Real Analysis, John Wiley and Sons (1976)
8. S C Malik & S Arora – Mathematical Analysis, New Age International, New Delhi (4th Edition, 2014)

Question Pattern for End Semester Examination

(Course Code: HMAT2CC03N)

(i) Answer **eight** objective / MCQ type questions of 2 marks each from 9 given questions.

(ii) Answer **three** questions of 3 marks each from 5 given questions.

(iii) Answer **four** questions of 10 marks each from 6 given questions. Each may contain further parts.

Course Structure	DSE

SEMESTER – 2		
Name of the Course : Abstract Algebra – II, Linear Algebra – I		
Course Code : HMAT2CC04N		
Full Marks : 100		Credit: 6
Theory	Credits : 5 Full Marks : 65+20*	
Tutorial	Credits : 1 Full Marks : 15	
Number of classes required : 100		
*15 Marks are reserved for Internal Assessment (to be taken from the mid-semester exam) & 5 marks for Attendance		

Course Outcomes: At the end of studying this course a student

- will acquire knowledge on deeper structural issues related to group theory in continuation with their earlier exposure in CC 1 of Semester – 1.
- will acquire elementary knowledge on different algebraic structures of double composition and their interrelations.
- will acquire knowledge and skill towards solving problems on matrix theory, which is of paramount importance as a tool, for their future CC 6 [Semester – 3] and CC 9 [Semester – 4] on Linear Algebra, a subject necessary for almost all allied science subjects.

Syllabus

Group – A [35 Marks]
(Abstract Algebra – II)

1. **Groups**: Homomorphism and Isomorphism of Groups. Kernel of a Homomorphism. First Isomorphism Theorem. Classification of finite and infinite cyclic groups. Cayley's theorem, properties of isomorphisms. Second and Third isomorphism theorems. Direct product of groups (basic ideas and simple applications).
2. **Rings and Fields**: Definition and examples of rings, properties of rings, subrings, necessary and sufficient condition for a non empty subset of a ring to be a subring, integral domains and fields, subfield, necessary and sufficient condition for a nonempty subset of a field to be a subfield, characteristic of a ring. Ideal, ideal generated by a subset of a ring, factor rings, operations on ideals, prime and maximal ideals. Ring homomorphisms, properties of ring homomorphisms. First, second and third isomorphism theorems on ring, Correspondence theorem.

Group – B [30 Marks]
(Linear Algebra – I)

1. Matrices of real and complex numbers; algebra of matrices, symmetric and skew-symmetric matrices, Hermitian and skew-Hermitian matrices, orthogonal and unitary matrices.
2. $n \times n$ Determinants, Laplace expansion, Vandermonde's determinant. Symmetric and skew-symmetric determinants (no proof of theorems required, problems on determinants up to order 4). Adjoint of a square matrix. For a square matrix A, $.adj\ A = adj\ A.A = (detA)I_n$. Invertible matrix, non-singularity. Inverse of an orthogonal matrix. Jacobi's 1st and 2nd theorems on determinants and its applications.

Course Structure	DSE

3. Elementary operations on matrices. Echelon matrix. Rank of a matrix. Determination of rank of a matrix (relevant results are to be stated only). Elementary matrices, fully reduced Normal form. Rank factorization. Evaluation of determinant by Gaussian elimination. Triangular factorization $A = LU, A = LDV, PA = LU$ and $EA = R$.
4. Congruence of matrices – statement and application of relevant results, Normal form of a matrix under congruence.

References:

1. Titu Andrescu and Dorin Andrica – Complex Numbers from A to Z, Springer (2014)
2. W S Burnside and A W Panton – Theory of Equations (Vol. 1), University Press, Dublin (1924)
3. S K Mapa – Higher Algebra (Classical), Sarat Book Distributors, Kolkata (8^{th} Edition, 2011)
4. Gareth Jones and Josephine m Jones – Elementary Number Theory, Springer (1998)
5. Titu Andrescu and Dorin Andrica – Number Theory, Springer (2009)
6. M K Sen, S Ghosh, P Mukhopadhyay and S Maity – Topics in Abstract Algebra, University Press, Hyderabad (3^{rd} Edition, 2018)
7. D S Malik, John M Mordeson and M K Sen – Fundamentals of Abstract Algebra, McGraw Hill, New York (1997)
8. John B Fraleigh – A First Course in Abstract Algebra, Pearson (7^{th} Edition, 2002)
9. M Artin – Abstract Algebra, Pearson (2^{nd} Edition, 2011)
10. Joseph A Gallian – Contemporary Abstract Algebra, Narosa Publishing House, New Delhi (4^{th} Edition, 1999)
11. Joseph J Rotman – An Introduction to the Theory of Groups, Springer (4^{th} Edition, 1995)
12. I N Herstein – Topics in Algebra, Wiley Eastern Limited, India (1975)
13. Kenneth Hoffman and Ray Alden Kunze – Linear Algebra, Prentice-Hall of India Pvt. Ltd. (2^{nd} Edition, 1971)
14. Stephen H Friedberg, Arnold J Insel and Lawrence E Spence – Linear Algebra, Prentice- Hall of India Pvt. Ltd., New Delhi (4^{th} Edition, 2004)
15. Gilbert Strang – Linear Algebra and its Applications, Thomson (2007)
16. Gilbert Strang – Fundamentals of Linear Algebra, Cambridge University Press (2007)
17. S Lang – Introduction to Linear Algebra, Springer (2^{nd} Edition, 2005)
18. S Kumaresan – Linear Algebra – A Geometric Approach, Prentice Hall of India (1999)

Course Structure	DSE

Question Pattern for End Semester Examination

(Course Code: HMAT2CC04N)

Group – A (Abstract Algebra – II, 35 marks)

i) Answer **five** objective / MCQ type questions of 2 marks each from 6 given questions.

ii) Answer **five** questions of 5 marks each from 7 given questions. Each question may contain further parts.

Group – B (Linear Algebra – I, 30 marks)

i) Answer **three** objective / MCQ type questions of 2 marks each from 4 given questions.

ii) Answer **three** questions of 8 marks each from 5 given questions. Each may contain further parts.

Course Structure	DSE

SEMESTER – 3		
Name of the Course : Analytical Geometry – 3D, Vector Analysis		
Course Code : HMAT3CC05N		
Full Marks : 100		Credit : 6
Theory	Credits : 5 Full Marks : 65+20*	
Tutorial	Credits : 1 Full Marks : 15	
Number of classes required : 100		
*15 Marks are reserved for Internal Assessment (to be taken from the mid-semester exam) & 5 marks for Attendance		

Course Outcomes: At the end of studying this course a student

- will acquire knowledge on three dimensional analytical geometry (only Cartesian coordinate system) and will be able to solve problems related to those topics, as a continuation of their previous concepts from plus two level .
- will acquire general ideas on various curvilinear coordinate systems.
- will acquire knowledge and skill towards solving various problems related to vector algebra and vector calculus, which has useful applications in various branches of Mathematics and Physics, as a continuation of their previous concepts from plus two level .

Syllabus

Group – A [30 Marks]
(Analytical Geometry – 3D)

1. (a) Revision on plane and straight line in 3D.
   (b) Transformation of rectangular axes by translation, rotation and their combination.
2. Sphere: General equation, Circle, Sphere through a circle, sphere through the intersection of two spheres. Radical plane. Tangent line, tangent plane and normal.
3. Cone: Right circular cone. General homogeneous second degree equation represents a cone. Section of a cone by a plane as a conic and as a pair of straight lines. Condition for three perpendicular generators. Reciprocal cone.
4. Cylinder: General equation of a cone. Generators parallel to either of the axes. Right circular cylinder.
5. Ellipsoid, Hyperboloid, Paraboloid: Canonical equations only.
6. General quadric surface: Tangent plane, Normal, Enveloping cone and enveloping cylinder.
7. Ruled surface. Generating lines of hyperboloid of one sheet and hyperbolic paraboloid.
8. Introduction to curvilinear coordinate system.

Group – B [35 Marks]
(Vector Analysis)

1. Vector triple product and product of four vectors.
2. Direct application of Vector Algebra in (i) Geometrical and Trigonometrical problems, (ii) Work done by a force and (iii) Moment of a force about a point.

Course Structure	DSE

3. Vector functions of one scalar variable, vector differentiation with respect to a scalar variable. Derivative of a vector. Second derivative of a vector. Derivatives of sums and products, velocity and acceleration as derivative.
4. Concept of scalar and vector fields. Directional derivative. Gradient, divergence, curl, Laplacian and their physical significance.
5. Line integrals as integrals of vectors, circulation, irrotational vector, work done, conservative force and potential function. Statements and verification of Green's theorem, Stokes' theorem and divergence theorem

References:

1. J G Chakravorty and P R Ghosh – Advanced Analytical Geometry, U N Dhur & Sons Pvt. Ltd, Kolkata (13th Edition 2012)
2. R M Khan – Analytical Geometry of Two and Three Dimensions and Vector Analysis, New Central Book Agency (P) Ltd., Kolkata (5th edition, 2012)
3. Arup Mukherjee and N K Bej – Analytical Geometry of two & Three Dimensions (Advanced Level), Books and Allied (P) Ltd., Kolkata (2010)
4. M R Speigel – Schaum's outline of Vector Analysis.
5. Prasun Kumar Nayak – Vector Algebra and Analysis with Applications, Universities Press, Hyderabad (2017)
6. A A Shaikh – Vector Analysis with Applications, Narosa Publishing House (2009)

Question Pattern for End Semester Examination

(Course Code: HMAT3CC05N)

Group – A (Analytical Geometry – 3D), 30 marks)

i) Answer **three** objective / MCQ type questions of 2 marks each from 4 given questions.

ii) Answer **three** questions of 8 marks each from 5 given questions. Each may contain further parts.

Group – B (Vector Analysis, 35 marks)

(i) Answer **five** objective / MCQ type questions of 2 marks each from 6 given questions.

(ii) Answer **five** questions of 5 marks each from 7 given questions. Each question may contain further parts.

SEMESTER – 3		
Name of the Course : Linear Algebra – II, Application of Calculus		
Course Code : HMAT3CC06N		
Full Marks : 100		Credit: 6
Theory	Credits : 5 Full Marks : 65+20*	
Tutorial	Credits : 1 Full Marks : 15	
Number of classes required : 100		
*15 Marks are reserved for Internal Assessment (to be taken from the mid-semester exam) & 5 marks for Attendance		

Course Outcomes: At the end of studying this course a student

- will acquire knowledge on Vector Space theory that will allow them to appreciate Linear algebra as a tool for learning Geometry of higher dimensional spaces through the language of Algebra. They will also be able to solve problems related to matrix theory up to orthogonalization. This will be continued further in CC 9 of Semester – 4.
- will be geared up towards appreciating the mathematical theory behind the Linear Programming problems to be taught in DSE 3 of Semester – 6.
- will acquire skills towards solving various problems on Geometry through the powerful tools of Differential and Integral Calculus which is of paramount importance in Mathematics and Physics.

Syllabus

Group – A [30 Marks]
(Linear Algebra – II)

1. Vector / Linear space: Definitions and examples, Subspace, Union and intersection of subspaces. Linear sum of two subspaces. Linear combination, independence and dependence, linear span. Generators of vector space, finite dimensional real and complex vector space, basis. Deletion theorem, Extension theorem and Replacement Theorem. Dimension of a vector space. Extraction of basis. Vector space over a finite field.
2. Row space, column space, null space and left null space of a matrix. Row rank and column rank of matrix. Equality of row rank, column rank and rank of a matrix. Fundamental theorem of Linear algebra (Part I and Part II). Every matrix transforms its row space into column space. Linear homogeneous system of equations: Solution space, related results using idea of rank, linear non-homogeneous system of equations – solvability and solution by Gauss-Jordan elimination. Free and basic variables, pivots.
3. Inner Product Space: Norm, Euclidean and Unitary Vector Space, Definition and examples, Triangle inequality and Cauchy-Schwarz Inequality, Orthogonality of vectors, Orthonormal basis, Gram-Schmidt Process of orthonomalization, orthogonal complement.

Course Structure	DSE

Group – B [35 Marks]
(Application of Calculus)

1. **Applications of Differential Calculus** :
   (i) Tangents and normals: Sub-tangent and sub-normal. Angle of intersection of curves. Pedal equation of a curve, pedal of a curve.
   (ii) Curvature: Radius of curvature, centre of curvature, chord of curvature, evolute of a curve.
   (iii) Rectilinear Asymptotes (Cartesian, polar and parametric curve).
   (iv) Envelope of family of straight lines and of curves (problems only).
   (v) Concavity, convexity, singular points, nodes, cusps, points of inflexion, simple problems on species of cusps of a curve (Cartesian curves only).

2. **Applications of Integral Calculus**:
   (i) Area enclosed by a curve.
   (ii) Determination of C.G
   (iii) Moments and products of inertia (Simple problems only).

3. Familiarity with the figure of following curves: Periodic curves with suitable scaling, Cycloid, Catenary, Lemniscate of Bernoulli, Astroid, Cardiode, Folium of Descartes, equiangular spiral.

References:

1. Kenneth Hoffman and Ray Alden Kunze – Linear Algebra, Prentice-Hall of India Pvt. Ltd. (2nd Edition, 1971)
2. Stephen H Friedberg, Arnold J Insel and Lawrence E. Spence – Linear Algebra, Prentice- Hall of India Pvt. Ltd., New Delhi (4th Edition, 2004)
3. Gilbert Strang – Linear Algebra and its Applications, Thomson (2007)
4. Gilbert Strang – Fundamentals of Linear Algebra, Cambridge University Press (2007)
5. S Lang – Introduction to Linear Algebra, Springer (2nd Edition, 2005)
6. S Kumaresan – Linear Algebra -A Geometric Approach, Prentice Hall of India (1999)
7. D Sengupta – Application of Calculus, Books & Allied (P) Ltd, Kolkata (2013)

Course Structure	DSE

Question Pattern for End Semester Examination

(Course Code: HMAT3CC06N)

Group – A (Linear Algebra – II, 30 marks)

(i) Answer **three** objective / MCQ type questions of 2 marks each from 4 given questions.

(ii) Answer **three** questions of 8 marks each from 5 given questions. Each question may contain further parts.

Group – B (Application of Calculus, 35 marks)

(i) Answer **five** objective / MCQ type questions of 2 marks each from 6 given questions.

(ii) Answer **three** questions of 5 marks each from 5 given questions from Article – 1. Each question may contain further parts.

(iii) Answer **two** questions of 5 marks each from 4 given questions from Article - 2. Each question may contain further parts.

Course Structure	DSE

SEMESTER – 3		
Name of the Course : Real analysis – II		
Course Code : HMAT3CC07N		
Full Marks : 100		Credit: 6
Theory	Credits : 5 Full Marks : 65+20*	
Tutorial	Credits : 1 Full Marks : 15	
Number of classes required : 100		
*15 Marks are reserved for Internal Assessment (to be taken from the mid-semester exam) & 5 marks for Attendance		

Real analysis – II [65 Marks]

Course Outcomes: At the end of studying this course which is a continuation of CC 3 of Semester – 2, a student

- will acquire knowledge on various ideas of compactness related to real number system.
- will acquire knowledge on different facets of the celebrated concept of Riemann Integration, which is a generalization of their earlier knowledge of Newtonian Integration done during plus two level.
- will acquire working knowledge and skill towards solving various problems related to the series and sequence of functions and power series.

Syllabus

1. Compactness in $\mathbb{R}$: Open cover of a set. Compact set in $\mathbb{R}$, a set is compact iff it is closed and bounded. Sequential compactness, Frech$\acute{e}$t compactness. Compactness and continuity.
2. Partition and refinement of partition of a closed and bounded interval. Upper Darboux sum $U(P,f)$ and lower Darboux sum $L(P,f)$ and associated results. Upper integral and lower integral. Darboux's theorem. Darboux's definition of integration over a closed and bounded interval. Riemann's definition of integrability. Equivalence with Darboux definition of integrability (statement only). Necessary and sufficient condition for Riemann integrability.
3. Concept of negligible set (or set of measure zero). Examples of negligible sets: any subset of a negligible set, finite set, countable union of negligible sets. Lebesgue-Vitalli theorem on Riemann integration. Example of Riemann integrable functions.
4. Integrability of sum, scalar multiple, product, quotient, modulus of Riemann integrable functions. Properties of Riemann integrable functions arising from the above results.
5. Function defined by definite integral and its properties. Anti-derivative (primitive or indefinite integral). Properties of Logarithmic function defined as the definite integral $\int_1^x \frac{dt}{t}, x > 0$.
6. Fundamental theorem of Integral Calculus. First Mean Value theorem of integral calculus. Statement and applications of Second Mean Value theorem of integral calculus.
7. Sequence of functions, Series of functions, Power series.

Course Structure	DSE

References:

1. Tom M Apostol – Mathematical Analysis, Narosa Publishing House
2. Tom M Apostol – Calculus (Vol I & II), John Wiley and Sons
3. W Rudin – Principles of Mathematical Analysis, McGraw-Hill (1976)
4. R G Bartle and D. R. Sherbert – Introduction to Real Analysis, John Wiley and Sons (Asia) Pvt. Ltd., Singapore (3rd Edition, 2002)
5. CC Pugh – Real Mathematical Analysis, Springer (2002)
6. Terence Tao – Analysis I, Hindustan Book Agency (2006)
7. Richard R Goldberg – Method of Real Analysis, John Wiley and Sons (1976)
8. S C Mallik& S Arora – Mathematical Analysis, New Age International, New Delhi (2014)

Question Pattern for End Semester Examination

(Course Code: HMAT3CC07N)

(i) Answer **ten** objective / MCQ type questions of 2 marks each from 11 given questions.

(ii) Answer **one** question of 5 marks from 2 given questions from Article – 1. Each question may contain further parts.

(iii) Answer **five** questions of 5 marks each from 7 given questions from Articles – 2 to 6. Each question may contain further parts.

(iv) Answer **three** questions of 5 marks each from 5 given questions from Article – 7. Each question may contain further parts.

Course Structure	DSE

SEMESTER – 4		
Name of the Course : Analytical Dynamics of a Particle		
Course Code : HMAT4CC08N		
Full Marks : 100		Credit: 6
Theory	Credits : 5 Full Marks : 65+20*	
Tutorial	Credits : 1 Full Marks : 15	
Number of classes required : 100		
*15 Marks are reserved for Internal Assessment (to be taken from the mid-semester exam) & 5 marks for Attendance		

Analytical Dynamics of a Particle [65 Marks]

Course Outcomes: At the end of studying this course a student will acquire knowledge and ability to solve problems related to

- rectilinear motion of a particle.
- planar motion of a particle and also motion of a particle in three dimensions.
- linear dynamical system of particles.

Syllabus

1. **Rectilinear motion**: Laws of motion, motion in a straight line under constant and variable forces, SHM, motion of elastic strings and springs, damped and forced oscillations, motion in a resisting medium, motion under gravity when the resistance of atmosphere varies as some integral powers of velocity. .
2. **Motion in a plane**: Expressions of velocity and acceleration in Cartesian and polar coordinates. Tangent and normal accelerations. Equations of motion in Cartesian and polar coordinates. Equations of motion of a particle moving in a plane with respect to a set of rotating axes.
3. **Motion of a system of particles**. Conservation of linear momentum.
4. **Planar motion of a particle**: Motion of a projectile in a resisting medium under gravity, orbits in a central force field, Stability of nearly circular orbits. Motion under the attractive inverse square law, Kepler's laws on planetary motion. Slightly disturbed orbits, motion of artificial satellites. Constrained motion of a particle on smooth and rough curves, motion when mass varies.
5. **Motion of a particle in three dimensions**: Motion on a smooth sphere, cone and on any surface of revolution.
6. **Linear Dynamical Systems**: Plane autonomous systems, fixed or critical points, phase portraits. Concept of Poincare phase plane. Simple example of damped oscillator and a simple pendulum. The two variable cases of a linear plane autonomous system. Characteristic polynomial, focal, nodal and saddle points.

Course Structure	DSE

References:

1. S L Loney – An Elementary Treatise on the Dynamics of particle and of Rigid Bodies, Cambridge University Press.
2. D T Greenwood – Principle of Dynamics, PHI, New Delhi.
3. S Ganguly & S Saha – Analytical Dynamics of a Particle, New Central Book Agency (P) Ltd, Kolkata.

Question Pattern for End Semester Examination

(Course Code: HMAT4CC08N)

(i) Answer **five** objective / MCQ type questions of 2 marks each from 6 given questions.

(ii) Answer **six** questions of 8 marks each from 8 given questions from Articles – 1 to 5. Each question may contain further parts.

(iii) Answer **one** question of 7 marks from 2 given questions from Article – 6. Each question may contain further parts.

Course Structure	DSE

SEMESTER – 4		
Name of the Course : Linear Algebra – III		
Course Code : HMAT4CC09N		
Full Marks : 100		Credit: 6
Theory	Credits : 5 Full Marks : 65+20*	
Tutorial	Credits : 1 Full Marks : 15	
Number of classes required : 100		
*15 Marks are reserved for Internal Assessment (to be taken from the mid-semester exam) & 5 marks for Attendance		

Linear Algebra – III [65 Marks]

Course Outcomes: At the end of studying this course, which is a continuation of CC 6 of Semester – 3, a student will

- acquire knowledge on the interplay of the theory of Vector Space and that of the Matrix, that will allow them to appreciate Linear Transformation among vector spaces and matrices to be the two sides of the same coin.
- will acquire knowledge on Vector spaces over the field of Complex number, towards a better appreciation of the power of matrix theory.
- will acquire knowledge on eigen values and (orthogonal) eigen vectors of a matrix or a linear transformation, that will allow them to understand the abstract coordinatization of higher dimensional spaces through spectral resolution for studying its geometry. These ideas and related analysis will be continued further in DSE – II of Semester – 5.

Syllabus

1. Linear transformation on vector space: Definition, null space, range, rank and nullity, rank-nullity theorem, simple applications, non-singular linear transformation, inverse of linear transformation. An $m \times n$ real matrix as a linear transformation from $\mathbb{R}^n$to $\mathbb{R}^m$. Linear Transformation in $\mathbb{R}^2$, matrices of rotation, matrices of projection and reflection on θ-line.
2. Natural isomorphism $\varphi: V \to \mathbb{R}^n$(for an n-dimensional vector space V) and co-ordinate vector $[x]_\alpha$ with respect to an ordered basis α of V. Matrices of linear transformations: $T: V_\alpha \to W_\beta$ corresponds to unique $[T]_\alpha^\beta$ such that $[T(x)]_\beta = [T]_\alpha^\beta [x]_\alpha$ [finite dimensional cases]. Looking back to some simple matrix properties in the light of linear transformation: product of two matrices, rank of a matrix, inverse of matrix. Change of basis, similarity of matrices.
3. Orthogonal projection and least square, $A = QR$ factorization, function space and Fourier Series.
4. Characteristic equation of a matrix, Eigen values, Eigen vectors of a matrix and those of a linear operator. Cayley-Hamilton theorem, properties of Eigen values and Eigen vectors. Eigen space of a linear operator, Leverrier-Fadeev method for Eigen vectors of a matrix, Eigen values of Circulant matrix and corresponding Eigen vector and its relation with Vandermonde determinant.
5. Diagonalizability and Diagonalization of a matrix or a linear operator (statement and application of relevant results). Looking back at geometry of real and complex Eigen values and Eigen vectors. Orthogonal diagonalization of symmetric matrix. Some Applications.

Course Structure	DSE

6. Dual spaces, dual basis, adjoint transformation and transpose of a matrix. Invariant subspace, Annihilator of a subspace.
7. Normal and self-adjoint operators, unitary and orthogonal operators, Schur's lemma and triangularization, Schur decomposition, Spectral theorem of normal operator (matrix). Applications.
8. Real Quadratic Form involving three variables. Reduction to Normal Form (Statements of relevant theorems and applications). Rank, signature and Index of a real quadratic form.

References:

1. Kenneth Hoffman and Ray Alden Kunze – Linear Algebra, Prentice-Hall of India Pvt. Ltd. (2nd Edition, 1971)
2. Stephen H Friedberg, Arnold J Insel and Lawrence E Spence – Linear Algebra, Prentice- Hall of India Pvt. Ltd., New Delhi (4th Edition, 2004)
3. Gilbert Strang – Linear Algebra and its Applications, Thomson (2007)
4. Gilbert Strang – Fundamentals of Linear Algebra, Cambridge University Press (2007)
5. S Lang – Introduction to Linear Algebra, Springer (2nd Edition, 2005)
6. S Kumaresan – Linear Algebra-A Geometric Approach, Prentice Hall of India (1999)
7. Michael Taylor – Linear Algebra, Springer (3rdEdition, 2015)
8. Jin Ho Kwak and S Hong – Linear Algebra, Springer (2004)
9. F Zhang – Matrix Theory**,** Springer(2011)

Question Pattern for End Semester Examination

(Course Code: HMAT4CC09N)

(i) Answer **five** objective / MCQ type questions of 2 marks each from 6 given questions.

(ii) Answer any **five** questions of 11 marks each from 7 given questions. Each question may contain further parts.

Course Structure	DSE

SEMESTER – 4		
Name of the Course : Real Analysis – III, Multivariate Calculus		
Course Code : HMAT4CC10N		
Full Marks : 100		Credit: 6
Theory	Credits : 5 Full Marks : 65+20*	
Tutorial	Credits : 1 Full Marks : 15	
Number of classes required : 100		
*15 Marks are reserved for Internal Assessment (to be taken from the mid-semester exam) & 5 marks for Attendance		

Course Outcomes: At the end of studying this course, which is a continuation of CC 7 of Semester – 3, a student

- will acquire knowledge on various types of improper integral and their convergence
- will acquire rudimentary knowledge and working skill on Fourier Series representation of functions, which is one of the pivotal concepts of mathematics as a whole.
- will acquire knowledge and skill towards solving various problems related to multivariate calculus, which is a powerful tool for understanding the geometry of real n-dimensional space.

Syllabus

Group – A [25 Marks]
(Real Analysis – III)

1. **Improper integral**:
   (i) Range of integration- finite or infinite. Necessary and sufficient condition for convergence of improper integral in both cases.
   (ii) Tests of convergence: Comparison and μ-test. Absolute and non-absolute convergence and inter-relations. Statement of Abel's and Dirichlet's test for convergence on the integral of a product.
   (iii) Convergence and properties of Beta and Gamma function.
2. **Fourier series**
   Trigonometric series. Statement of sufficient condition for a trigonometric series to be a Fourier series. Fourier coefficients for periodic functions defined on $[-\pi, \pi]$. Statement of Dirichlet's condition of convergence. Statement of theorem of sum of Fourier series.
3. **Multiple integral**: Concept of upper sum, lower sum, upper integral, lower-integral and double integral (no rigorous treatment is needed). Statement of existence theorem for continuous functions. Iterated or repeated integral, change of order of integration. Triple integral. Cylindrical and spherical coordinates. Change of variables in double integrals and triple integrals. Transformation of double and triple integrals (problems only). Determination of volume and surface area by multiple integrals (problems only).
4. Differentiation under the integral sign, Leibniz's rule (problems only).

Course Structure	DSE

Group – B [40 Marks]
(Multivariate Calculus)

1. Concept of neighbourhood of a point in $\mathbb{R}^n (n > 1)$, interior point, limit point, open set and closed set in $\mathbb{R}^n (n > 1)$.
2. Functions from $\mathbb{R}^n (n > 1)$ to $\mathbb{R}^m (m \geq 1)$, limit and continuity of functions of two or more variables. Partial derivatives, total derivative and differentiability, sufficient condition for differentiability, higher order partial derivatives and theorems on equality of mixed partial derivatives for a function of two variables. Chain rule for one and two independent parameters, Euler's theorems and its converse, directional derivatives, the gradient, maximal and normal property of the gradient, tangent planes.
3. Jacobian of two and three variables, simple properties including function dependence. Concept of Implicit function: Statement and simple application of implicit function theorem for two variables. Differentiation of Implicit function.
4. Taylor's theorem for functions two variables. Extreme points and values of functions of two variables. Lagrange's method of undetermined multipliers for function of two variables (problems only). Constrained optimization problems.

References:

1. Tom M Apostol – Mathematical Analysis, Narosa Publishing House
2. Tom M Apostol – Calculus (Vol I & II), John Wiley and Sons
3. W Rudin – Principles of Mathematical Analysis, McGraw-Hill (1976)
4. R G Bartle and D R Sherbert – Introduction to Real Analysis, John Wiley and Sons (Asia) Pvt. Ltd., Singapore (3rd Edition, 2002)
5. C C Pugh – Real Mathematical Analysis, Springer (2002)
6. Terence Tao – Analysis I, Hindustan Book Agency (2006)
7. Richard R Goldberg – Method of Real Analysis, John Wiley and Sons (1976)
8. S C Mallik & S Arora – Mathematical Analysis, New Age International, New Delhi (4th Edition, 2014)
9. E Marsden, A J Tromba and A Weinstein – Basic Multivariable Calculus, Springer (2005)

Course Structure	DSE

Question Pattern for End Semester Examination

(Course Code: HMAT4CC10N)

Group – A (Real Analysis – III, 25 marks)

(i) Answer **two** objective / MCQ type questions of 2 marks each from 3 given questions.

(ii) Answer **three** questions of 7 marks each from 5 given questions. Each question may contain further parts.

Group – B (Multivariate Calculus, 40 marks)

(i) Answer **five** MCQ type questions of 2 marks each from 6 given questions.

(ii) Answer **six** questions of 5 marks each from 9 given questions. Each question may contain further parts.

Course Structure	DSE

SEMESTER – 5		
Name of the Course : Partial Differential Equations, Complex Analysis		
Course Code : HMAT5CC11N		
Full Marks : 100		Credit: 6
Theory	Credits : 5 Full Marks : 65+20*	
Tutorial	Credits : 1 Full Marks : 15	
Number of classes required : 100		
*15 Marks are reserved for Internal Assessment (to be taken from the mid-semester exam) & 5 marks for Attendance		

Course Outcomes: At the end of studying this course a student

- will acquire elementary knowledge and skill of solving problems on certain types of linear and non-linear partial differential equations.
- will acquire elementary knowledge of certain types of second order partial differential equations and their applications in mathematical Physics.
- will acquire some of the elementary but fundamental knowledge of Complex analysis.

Syllabus

Group – A [35 Marks]
(Partial Differential Equations)

1. Partial differential equations of the first order, Lagrange's method of solution, non-linear first order partial differential equations, Charpit's general method of solution and some special types of equations which can be solved easily by methods other than the general method.
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.
3. The Cauchy problem, Cauchy-Kowalewskaya theorem (statement only), Cauchy problem of finite and infinite string. Initial and boundary value problems. Semi-infinite string problem. 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.

Group – B [30 Marks]
(Complex Analysis)

1. Stereographic projection. Regions in the complex plane. Limits, limits involving the point at infinity. Continuity of functions of complex variable.
2. Derivatives, differentiation formulas, Cauchy-Riemann equations, sufficient conditions for differentiability. Analytic functions, exponential function, logarithmic function, trigonometric functions, hyperbolic functions. Möbius transformation.

Course Structure	DSE

3. Power series: Cauchy-Hadamard theorem. Determination of radius of convergence. Uniform and absolute econvergence of power series. Analytic functions represented by power series. Uniqueness of power series.
4. Contours, complex integration along a contour and its examples, upper bounds for moduli of contour integrals. Cauchy- Goursat theorem (statement only) and its consequences, Cauchy integral formula.

References:

1. Ian N Sneddon – Elements of Partial Differential equations, Mcgraw-Hill International Edition (1957)
2. N Mandal – Differential Equations (Ordinary and Partial), Books & Allied (P) Ltd., Kolkata (2nd Edition,2017)
3. K Sankara Rao – Introduction to Partial Differential Equations, PHI, (3rd Edition, 2017)
4. Dipak K Ghosh – Introduction to Partial Differential Equation and Laplace Transform, New Central Book Agency (P) Ltd., Kolkata (2017)
5. James Ward Brown and R V Churchill – Complex Variables and Applications, McGraw Hill (8th Edition, 2009)
6. S Ponnusamy – Foundations of Complex Analysis, Springer (2012)
7. Lars Ahlfors – Complex Analysis, McGraw Hill (3rd Edition, 1979)

Question Pattern for End Semester Examination

(Course Code: HMAT5CC11N)

Group – A (Partial Differential Equations, 35 marks)

(i) Answer **five** objective / MCQ type questions of 2 marks each from 6 given questions.

(ii) Answer **five** questions of 5 marks each from 7 given questions. Each question may contain further parts.

Group – B (Complex Analysis, 30 marks)

i) Answer **five** objective / MCQ type questions of 2 marks each from 6 given questions.

ii) Answer **four** questions of 5 marks each from 6 given questions. Each may contain further parts.

Course Structure	DSE

<table>
<tr><td colspan="3" align="center">SEMESTER – 5</td></tr>
<tr><td colspan="3">Name of the Course : Metric Space, Analytical Statics</td></tr>
<tr><td colspan="3">Course Code : HMAT5CC12N</td></tr>
<tr><td colspan="2" align="center">Full Marks : 100</td><td align="center">Credit: 6</td></tr>
<tr><td>Theory</td><td colspan="2">Credits : 5
Full Marks : 65+20*</td></tr>
<tr><td>Tutorial</td><td colspan="2">Credits : 1
Full Marks : 15</td></tr>
<tr><td colspan="3" align="center">Number of classes required : 100</td></tr>
<tr><td colspan="3" align="center">*15 Marks are reserved for Internal Assessment (to be taken from the mid-semester exam)
& 5 marks for Attendance</td></tr>
</table>

Course Outcomes: At the end of studying this course a student

- will acquire knowledge on various aspects of the theory of Metric spaces, which is a generalization of their previous knowledge on Real Analysis.
- will acquire knowledge and skill for solving problems on Analytical Statics related to coplanar forces.
- will acquire knowledge and skill for solving problems on Analytical Statics related to three dimensional forces.

Syllabus

Group – A [35 Marks]
(Metric Space)

1. Definition and examples of metric spaces. Open ball. Open set. Closed set as complement of open set. Interior point and interior of a set. Limit point and closure of a set. Boundary point and boundary of a set. Properties of interior, closure and boundary. Bounded set and diameter of a set. Distance between two sets. Subspace of a metric space.
2. First countability of a metric space, second countability, separability and Lindelöff property and their equivalence.
3. Convergent sequence. Cauchy sequence. Every convergent sequence is Cauchy and bounded, but the converse is not true. Completeness. Cantor's intersection theorem. $\mathbb{R}$ is a complete metric space. $\mathbb{Q}$ is not complete.
4. Continuous mappings, sequential criterion of continuity. Uniform continuity.
5. Compactness, Sequential compactness, Heine-Borel theorem in $\mathbb{R}$. Finite intersection property, continuous functions on compact sets.
6. Concept of connectedness and some examples of connected metric space, connected subsets of $\mathbb{R}$, $\mathbb{C}$.
7. Contraction mappings, Banach Fixed point Theorem and its application to ordinary differential equations.

Course Structure	DSE

Group – B [30 Marks]
(Analytical Statics)

1. **Coplanar Forces**: Astatic Equilibrium, Astatic Centre, Positions of equilibrium of a particle lying on a smooth plane curve under action of given force. Action at a joint in a frame work.
2. **Friction**: Laws of Friction, Angle of friction, Cone of friction, To find the positions of equilibrium of a particle lying on a (i) rough plane curve and rough space curve, (ii) rough surface under the action of any given forces.
3. **Centre of Gravity**: General formula for the determination of C.G. Determination of position of C.G. of any arc, area of solid of known shape by method of integration.
4. **Virtual work**: Workless constraints - examples, virtual displacements and virtual work. The principle of virtual work, Deductions of the necessary and sufficient conditions of equilibrium of an arbitrary force system in plane and space, acting on a rigid body.
5. **Stability of equilibrium**: Conservative force field, energy test of stability, condition of stability of a perfectly rough heavy body lying on a fixed body. Rocking stones.
6. **Forces in the three dimensions**: Moment of a force about a line. Axis of a couple. Resultant of any two couples acting on a body. Resultant of any number of couples acting on a rigid body. Reduction of a system of forces acting on a rigid body. Resultant force is an invariant of the system but the resultant couple is not an invariant. Conditions of equilibrium of a system of forces acting on a body. Deductions of the conditions of equilibrium of a system of forces acting on a rigid body from the principle of virtual work. Poinsot's central axis. A given system of forces can have only one central axis. Wrench, Pitch, Intensity and Screw. Condition that a given system of forces may have a single resultant. Invariants of a given system of forces. Equations of the central axis of a given system of forces.

References:

1. S Kumaresan – Topology of Metric Spaces, Narosa Publishing House (2nd Edition, 2011)
2. P K Jain and K Ahmad – Metric Spaces, Narosa Publishing House.
3. Satish Shirali and Harikishan LVasudeva – Metric Spaces, Springer (2006)
4. Manabendra Nath Mukherjee – Elements of Metric Spaces, Academic Publishers, Kolkata (4th Edition, 2015)
5. S L Loney – An Elementary Treatise on Statics, Cambridge University Press (2016)
6. M C Ghosh – Analytical Statics, ShreedharPrakashani, Kolkata (2000)
7. S A Mollah – Analytical Statics, Books & Allied (P) Ltd, Kolkata (2013)
8. S Pradhan & S Sinha – Analytical Statics, Academic Publishers, Kolkata (4th Edition, 2017)

Course Structure	DSE

Question Pattern for End Semester Examination

(Course Code: HMAT5CC12N)

Group – A (Metric Space, 35 marks)

(i) Answer **five** MCQ type questions of 2 marks each from 6 given questions.

(ii) Answer **five** questions of 5 marks each from 7 given questions. Each question may contain further parts.

Group – B (Analytical Statics, 30 marks)

i) Answer **three** objective / MCQ type questions of 2 marks each from 4 given questions.

ii) Answer **four** questions of 6 marks each from 6 given questions. Each may contain further parts.

Discipline Specific Electives (DSE)

DSE – 1

SEMESTER – 5	
Name of the Course : Computer Programming with C & Mathematica	
Course Code : HMAT5DS11L	
Full Marks : 100	Credit: 6
Theory	Credits : 5 Full Marks : 65+20*
Tutorial	Credits : 1 Full Marks : 15
Number of classes required : 100	
*15 Marks are reserved for Internal Assessment (to be taken from the mid-semester exam) & 5 marks for Attendance	

Computer Programming with C & Mathematica

Course Outcomes: At the end of studying this course a student

- will acquire fundamental operational knowledge on various aspects of the important computer programming language C and side by side they will be exposed to hands on computer oriented skill development using the language taught.
- will acquire basic skill for solving problems using C language in the computer laboratory, that will help them to solve such problems on various Numerical Methods later in Course Code HMAT6CC14L of Semester – 6.
- will learn the fundamental commands and structure of Mathematica & C. The course covers the basic syntax and semantics of Mathematica & C, including basic data types, variables, control structures and functions or similar concepts, and visualization of results and processed data.

Computer Programming with C & Mathematica [Theory] [50 Marks]

Syllabus

Group – A: Programming with C [25 Marks]

1. An overview of theoretical computers, history of computers, overview of architecture of computer, compiler, assembler, machine language, high level language, object oriented language, programming language and importance of C programming.

Course Structure	DSE

2. Constants, Variables and Data type of C-Program: Character set. Constants and variables data types, expression, assignment statements, declaration.
3. Operation and Expressions: Arithmetic operators, relational operators, logical operators.
4. Decision Making and Branching: decision making with if statement, if-else statement, Nesting if statement, switch statement, break and continue statement.
5. Control Statements While statement, do-while statement, for statement.
6. Arrays: One-dimension, two-dimension and multidimensional arrays, declaration of arrays, initialization of one and multi-dimensional arrays.
7. User-defined Functions: Definition of functions, Scope of variables, return values and their types, function declaration, function call by value, nesting of functions, passing of arrays to functions, Recurrence of function.
8. Introduction to Library functions: stdio.h, math.h, string.h, stdlib.h, time.h etc.

Group – B: Mathematica [25 Marks]

1. Introduction to Mathematica, Use of Mathematica as a Calculator, Numerical and symbolic computations using mathematical functions such as square root, trigonometric functions, logarithms, exponentiations etc.
2. Graphical representations of few functions through plotting in a given interval, like plotting of polynomial functions, trigonometric functions, Plots of functions with asymptotes, superimposing multiple graphs in one plot like plotting a curve along with a tangent on that curve (if it exists), polar plotting of curves.
3. Mathematica commands for differentiation, higher order derivatives, plotting $f(x)$ and $f'(x)$ together, integrals, definite integrals etc.
4. Introduction to Programming in Mathematica, relational and logical operators, conditional statements, loops and nested loops.

References:

1. C Xavier – C Language and Numerical Methods, New Age International Pvt. Ltd., New Delhi (2003)
2. C B Gottfried – Programming with C, Schaum's outlines (2nd Edition, 1996)
3. E Balagurusamy – Programing in Ansi C, Tata McGraw-Hill Education (2004)
4. John Loustau – Elements of Numerical Analysis with Mathematica, World Scientific (2017)
5. Stephen Wolfram – An Elementary Introduction to the Wolfram Language, Wolfram Media (2017)
6. Cliff Hastings, Kelvin Mischo, Michael Morrison – Hands-on Start to Wolfram Mathematica and Programming with the Wolfram Language (2nd Edition, 2016)

Course Structure	DSE

<u>Question Pattern for End Semester Examination</u>

(Course Code: HMAT5DS11L [Theory])

Group – A (Programming with C, 25 marks)

(i) Answer **two** objective / MCQ type questions of 2 marks each from 3 given questions.

(ii) Answer **three** questions of 7 marks each from 5 given questions. Each question may contain further parts.

Group – B (Mathematica, 25 marks)

(i) Answer **two** objective / MCQ type questions of 2 marks each from 3 given questions.

(ii) Answer **three** questions of 7 marks each from 5 given questions. Each question may contain further parts.

Course Structure	DSE

Computer Programming with C & Mathematica (Laboratory) [30 Marks]

Syllabus

- **Standard mathematical problem solving using C program.**
- **List of practical (using Mathematica)**
  1. Plotting of graphs of function
  2. Plotting the graphs of polynomial of degree 4 and 5, the derivative graph, the second derivative graph and comparing them.
  3. Plotting parametric curves (Eg. trochoid, cycloid, epicycloids, hypocycloid).
  4. Plotting of recursive sequences.
  5. Study the convergence of sequences through plotting.
  6. Verify Bolzano-Weierstrass theorem through plotting of sequences and hence identify convergent subsequences from the plot.
  7. Study the convergence/divergence of infinite series by plotting their sequences of partial sum.
  8. Cauchy's root test by plotting n-th roots.
  9. Ratio test by plotting the ratio of n-th and $(n+1)$-th term.
  10. Without using inbuilt functions write programs for average of integers, mean, median, mode, factorial, checking primes, checking next primes, finding all primes in an interval, finding gcd, lcm, finding convergence of a given sequence, etc.
  11. Use of inbuilt functions that deal with matrices, determinant, inverse of a given real square matrix (if it exists), solving a system of linear equations, finding roots of a given polynomial, solving differential equations.
  12. Fitting a Polynomial Function (up to third degree)

Question Pattern for End Semester Examination

[Course Code: HMAT5DS11L (Practical)]

(i) Answer **six** questions of 3 marks each from 7 given questions. All problems to be done on computer by using Mathematica only. Allotted time is three hours.

(ii) 6 marks reserved for practical note book.

(iii) 6 marks reserved for viva voce.

Course Structure	DSE

OR

SEMESTER – 5	
Name of the Course : Boolean Algebra & Automata Theory	
Course Code : HMAT5DS12N	
Full Marks : 100	Credit: 6
Theory	Credits : 5 Full Marks : 65+20*
Tutorial	Credits : 1 Full Marks : 15
Number of classes required : 100	
*15 Marks are reserved for Internal Assessment (to be taken from the mid-semester exam) & 5 marks for Attendance	

Boolean Algebra & Automata Theory [65 Marks]

Course Outcomes: At the end of studying this course a student

- will acquire fundamental knowledge on the ordered algebraic structure called Lattice and via this structure, the concept of Boolean Algebra will be introduced.
- will acquire basic knowledge of application of Boolean algebra in electronics through the theory of switching circuits and various logic gates
- will learn the rudimentary concepts of theoretical computer science through the basic Automata Theory including pushdown automata and Turing machine.

Syllabus

Group – A [20 marks]
(Boolean Algebra)

1. 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.
2. Definition, examples and properties of modular and distributive lattices, Boolean algebras, Boolean polynomials, minimal and maximal forms of Boolean polynomials, Karnaugh diagrams, Quine-McCluskey method, Logic gates, switching circuits and applications of switching circuits.

Group – B [45 Marks]
(Automata Theory)

1. **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.

Course Structure	DSE

2. **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.
3. Turing Machines: Turing machine as a model of computation, programming with a Turing machine, variants of Turing machine and their equivalence.
4. Undecidability: Recursively enumerable and recursive languages, undecidable problems about Turing machines: halting problem. Post correspondence problem, and undecidability problems about CFGs.

References:

1. K D Joshi – Foundations of Discrete Mathematics, New Age International (P) Ltd., New Delhi (2003)
2. V K Balakrishnan – Introductory Discrete Mathematics, Dover Publications, INC, New York (1991)
3. B A Davey and H A Priestley – Introduction to Lattices and Order, Cambridge University Press (1990)
4. John E Hopcroft and Jeffrey D Ullman – Introduction to Automata Theory, Languages and Computation, Addison-Wesley (2001)
5. John Martin – Introduction to Languages and The Theory of Computation, McGraw Higher Ed (3rd Edition, 2009)
6. Peter Linz – An Introduction to Formal Languages and Automata, Jones & Bartlett Learning (6th Edition, 2016)

Question Pattern for End Semester Examination

(Course Code: HMAT5DS12N)

Group – A (Boolean Algebra, 20 marks)

(i) Answer **two** objective / MCQ type questions each of 2 marks from 3 given such questions.

(ii) Answer **two** questions of 8 marks each from 4 given questions. Each question may contain further parts.

Group – B (Automata Theory, 45 marks)

(i) Answer **five** objective / MCQ type questions of 2 marks each from 6 given questions.

(ii) Answer **seven** questions of 5 marks each from 9 given questions. Each question may contain further parts.

Course Structure	DSE

DSE – 2

SEMESTER – 5		
Name of the Course : Advanced Algebra		
Course Code : HMAT5DS21N		
Full Marks : 100		Credit: 6
Theory	Credits : 5 Full Marks : 65+20*	
Tutorial	Credits : 1 Full Marks : 15	
Number of classes required : 100		
*15 Marks are reserved for Internal Assessment (to be taken from the mid-semester exam) & 5 marks for Attendance		

Advanced Algebra [65 Marks]

Course Outcomes: At the end of studying this course a student

- will acquire fundamental knowledge on certain advanced topics of Group and Ring theory as a continuation of what they have already learned in various compulsory core courses. This will help the motivated students to pursue Algebra at the higher level of study in post graduate.
- will acquire basic knowledge and problem solving skills on certain advanced topics of linear algebra like the SVD, generalized inverse, Moore-Penrose inverse, Jordan and rational canonical form of a non-diagonalizable matrix etc.
- will acquire some knowledge that will help the students to solve problems in various national entrance examinations for their next level of study and also for the NET examination conducted by CSIR after their completion of master's degree.

Syllabus

1. **Group Theory**: Cauchy's theorem for finite Abelian group, fundamental theorem of finite Abelian groups, Group actions, applications of group actions, Generalized Cayley's theorem, Index theorem. Groups acting on themselves by conjugation, Class equation and consequences, p-groups, statement of Sylow's theorems and consequences, Cauchy's theorem, Simple group, simplicity of A_n for $n \geq 5$, non-simplicity tests.

2. **Ring Theory**: Principal ideal domain, principal ideal ring, prime element, irreducible element, greatest common divisor (gcd), least common multiple (lcm), expression of gcd, examples of a ring R and a pair of elements $a, b \in R$ such that gcd(a, b) does not exist, Euclidean domain, relation between Euclidean domain and principal ideal domain.
   Ring embedding and quotient field, regular rings and their examples, properties of regular ring, ideals in regular rings.
   Polynomial rings, division algorithm and consequences, factorization domain, unique factorization domain, irreducible and prime elements in a unique factorization domain, relation between principal

ideal domain, unique factorization domain, factorization domain and integral domain, Eisenstein criterion and unique factorization in $\mathbb{Z}[x]$.

3. **Linear Algebra**: Singular value decomposition of $m \times n$ matrix, polar decomposition of a square matrix, pseudo-inverse or Moore-Penrose generalized inverse of a $m \times n$ matrix.
   The minimal polynomial for a linear operator (matrix), relationship with characteristic polynomial, Cayley-Hamilton theorem, invariant factors and elementary divisors, Smith normal form, generalized Eigen vector, computation of Jordan and rational canonical forms.

References:

1. M K Sen, S Ghosh, P Mukhopadhyay and S Maity – Topics in Abstract Algebra, University Press, Hyderabad (3rd Edition, 2018)
2. D S Malik, John M Mordeson and M K Sen – Fundamentals of Abstract Algebra, McGraw Hill, New York (1997)
3. John B Fraleigh – A First Course in Abstract Algebra, Pearson (7th Edition, 2002)
4. M Artin – Abstract Algebra, Pearson (2nd Edition, 2011)
5. Joseph A Gallian – Contemporary Abstract Algebra, Narosa Publishing House, New Delhi (4th Edition, 1999)
6. Joseph J Rotman – An Introduction to the Theory of Groups, Springer (4th Edition, 1995)
7. I N Herstein – Topics in Algebra, Wiley Eastern Limited, India (1975)
8. Kenneth Hoffman and Ray Alden Kunze – Linear Algebra, Prentice-Hall of India Pvt. Ltd. (2nd Edition, 1971)
9. Stephen H Friedberg, Arnold J Insel and Lawrence E Spence – Linear Algebra, Prentice- Hall of India Pvt. Ltd., New Delhi (4th Edition, 2004)
10. Gilbert Strang – Linear Algebra and its Applications, Thomson (2007)
11. Gilbert Strang – Fundamentals of Linear Algebra, Cambridge University Press (2007)
12. S Lang – Introduction to Linear Algebra, Springer (2nd Edition, 2005)
13. S Kumaresan – Linear Algebra- A Geometric Approach, Prentice Hall of India (1999)

Question Pattern for End Semester Examination

(Course Code: HMAT5DS21N)

(i) Answer **five** objective / MCQ type questions of 2 marks each from 6 given questions.

(ii) Answer any **two** questions of 10 marks each from 4 given questions from Article 1. Each question may contain further parts.

(iii) Answer any **three** questions of 5 marks each from 5 given questions from Article 2. Each question may contain further parts

(iv) Answer any **two** questions of 10 marks each from 4 given questions from Article 3. Each question may contain further parts

Course Structure	DSE

OR

SEMESTER – 5	
Name of the Course : Bio Mathematics	
Course Code : HMAT5DS22N	
Full Marks : 100	Credit: 6
Theory	Credits : 5 Full Marks : 65+20*
Tutorial	Credits : 1 Full Marks : 15
Number of classes required : 100	
*15 Marks are reserved for Internal Assessment (to be taken from the mid-semester exam) & 5 marks for Attendance	

Bio Mathematics [65 Marks]

Course Outcomes: At the end of studying this course a student

- will acquire fundamental knowledge on Mathematical biology and the modeling process. This will help the motivated students to pursue at the higher level of study in Applied Mathematics.
- will acquire basic knowledge and problem solving skills on certain advanced topics like Prey predator systems and Lotka-Volterra equations, populations in competitions, epidemic models etc.
- will acquire some knowledge on different mathematical models on Biology.

Syllabus

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 ina chemostat, harvesting a single natural population, Prey predator systems and Lotka-Volterra equations, populations in competitions, epidemic models (SI, SIR, SIRS, SIC)
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 diffusiveinstability, spreading colonies of microorganisms, Blood flow in circulatory system, travelling wave solutions and spread of genes in a population.

Course Structure	DSE

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.

References:

1. L E Keshet – Mathematical Models in Biology, SIAM (1988)
2. J D Murray – Mathematical Biology, Springer (1993)
3. Y C Fung – Biomechanics, Springer-Verlag (1990)
4. F Brauer, P V D Driessche and J Wu – Mathematical Epidemiology, Springer (2008)
5. M Kot – Elements of Mathematical Ecology, Cambridge University Press (2001)

Question Pattern for End Semester Examination

(Course Code: HMAT5DS22N)

(i) Answer **five** objective/MCQ type questions of 2 marks each from 6 given questions.

(ii) Answer any **two** questions of 10 marks each from 4 given questions from Article 1. Each question may contain further parts.

(iii) Answer any **three** questions of 5 marks each from 5 given questions from Article 2. Each question may contain further parts

(iv) Answer any **two** questions of 10 marks each from 4 given questions from Article 3. Each question may contain further parts

Course Structure	DSE

SEMESTER – 6		
Name of the Course : Probability, Statistics		
Course Code : HMAT6CC13N		
Full Marks : 100		Credit: 6
Theory	Credits : 5 Full Marks : 65+20*	
Tutorial	Credits : 1 Full Marks : 15	
Number of classes required : 100		
*15 Marks are reserved for Internal Assessment (to be taken from the mid-semester exam) & 5 marks for Attendance		

Course Outcomes: At the end of studying this course a student

- will acquire knowledge on various aspects of the theory of Probability, as a continuation of their previous concepts from plus two level .
- will acquire knowledge and skill for solving problems related to various probability distribution functions.
- will acquire knowledge and skill for solving problems on certain mathematical topics of Statistics.

Syllabus

Group – A [35 Marks]
(Probability)

1. Random experiment, Sample space, probability as a set function, probability axioms, probability space. Finite sample spaces. Conditional probability, Bayes theorem, independence. 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, beta and gamma function.
2. Joint cumulative distribution function and its properties, joint probability density functions, marginal and conditional distributions, expectation of function of two random variables, moments, covariance, correlation coefficient, independent random variables, joint moment generating function (jmgf) and calculation of covariance from jmgf, characteristic function. Conditional expectations, linear regression for two variables, regression curves. Bivariate normal distribution.
3. Chebyshev's inequality, Convergence in Probability, 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.

Course Structure	DSE

Group – B [30 Marks]
(Statistics)

1. **Sampling and Sampling Distributions**: Populations and Samples, Random Sample, distribution of the sample, simple random sampling with and without replacement. Sample characteristics. Statistic, Sample moments. Sample variance, Sampling from the normal distributions, Chi-square, t and F-distributions, sampling distribution of $\bar{X}, s^2, \frac{\sqrt{n}}{s}(\bar{X}-\mu), \frac{\sqrt{n}}{\sigma}(\bar{X}-\mu)$.
2. **Estimation of parameters**: Point estimation. Interval Estimation- Confidence Intervals for mean and variance of Normal Population. Mean-squared error. Properties of good estimators - unbiasedness, consistency, sufficiency, Minimum-Variance Unbiased Estimator (MVUE).
3. **Method of Maximum likelihood**: Likelihood function, ML estimators for discrete and continuous models.
4. **Statistical hypothesis**: Simple and composite hypotheses, null hypotheses, alternative hypotheses, one sided and two-sided hypotheses. The critical region and test statistic, type I error and type II error, level of significance. Power function of a test, most powerful test. Simple hypothesis versus simple alternative: Neyman-Pearson lemma (Statement only).
5. **Bivariate frequency Distribution**: Bivariate data, Scatter diagram, Correlation, Linear Regression, principle of least squares and fitting of polynomials and exponential curves.

References:

1. A Gupta – Ground work of Mathematical Probability and Statistics, Academic publishers, Kolkata
2. Alexander M Mood, Franklin A Graybill and Duane C Boes – Introduction to the Theory of Statistics, Tata McGraw Hill (3rd Edition, 2007).
3. E Rukmangadachari – Probability and Statistics, Pearson (2012)
4. A Banerjee, S K De and S Sen – Mathematical Probability, U N Dhur & Sons Private Ltd, Kolkata
5. S K De and S Sen – Mathematical Statistics, U N Dhur & Sons Private Ltd, Kolkata

Question Pattern for End Semester Examination

(Course Code: HMAT6CC13N)

Group – A (Probability, 35 marks)

i) Answer **five** objective/MCQ type questions of 2 marks each from 6 given questions.

ii) Answer **five** questions of 5 marks each from 7 given questions. Each may contain further parts.

Group – B (Statistics, 30 marks)

(i) Answer **three** objective/MCQ type questions of 2 marks each from 4 given questions.

(ii) Answer **four** questions of 6 marks each from 6 given questions. Each question may contain further parts.

Course Structure	DSE

SEMESTER – 6	
Name of the Course : Numerical Methods (Theory), Numerical Methods (Laboratory Based)	
Course Code : HMAT6CC14L	
Full Marks : 100	Credit: 6
Theory	Credits : 5 Full Marks : 65+20*
Tutorial	Credits : 1 Full Marks : 15
Number of classes required : 100	
*15 Marks are reserved for Internal Assessment (to be taken from the mid-semester exam) & 5 marks for Attendance	

Numerical Methods (Theory) [50 Marks]

Course Outcomes: At the end of studying this course a student

- will acquire fundamental theoretical knowledge on various aspects of the theory of numerical analysis, that will lay the foundation for solving such problems via computer programming to be done side by side using their knowledge of programming language C already acquired from the course DSE 1 of Semester – 5.
- will acquire basic skill for solving problems (both on paper and via computer) related to various numerical methods on interpolation, numerical differentiation and integration, differential equations and finding roots of an equation.
- will acquire basic knowledge and computer oriented skill for solving problems related to certain topics of numerical linear algebra.

Syllabus

1. Representation of real numbers – floating point and fixed point. Sources of Errors, Rounding of numbers, significant digits and Error Propagation in arithmetic operations. Numerical Algorithms - stability and convergence.
2. Approximation: Classes of approximating functions, Types of approximations - polynomial approximation, The Weierstrass polynomial approximation theorem (statement only).
3. Interpolation: Lagrange and Newton's methods. Error bounds. Finite difference operators. Newton(Gregory) forward and backward difference interpolation.
4. Central Interpolation: Gauss forward and backward interpolation formulae, Stirling's and Bessel's formulas. Different interpolation zones, Error estimation. Hermite interpolation.
5. Numerical differentiation: Methods based on interpolations, methods based on finite differences.
6. Numerical Integration: Newton Cotes formula, Trapezoidal rule, Simpson's1/3 -rd rule, Simpson's3/8 -th rule, Weddle's rule, Boole's Rule, midpoint rule. Composite trapezoidal rule, composite Simpson's1/3 -rd rule, composite Weddle's rule. Gaussian quadrature formula.

Course Structure	DSE

7. Transcendental and polynomial equations: Bisection method, Secant method, method of Regula-falsi, fixed point iteration, Newton-Raphson method. Condition of convergence (if any), Order of convergence, Rate of convergence of these methods. Modified Newton-Raphson method for multiple roots, Complex roots of an algebraic equation by Newton-Raphson method.
8. System of linear algebraic equations: Direct methods: Gaussian elimination and Gauss Jordan methods, Pivoting strategies. Iterative methods: Gauss Jacobi method, Gauss Seidel method and their convergence analysis. Matrix inversion: Gaussian elimination (operational counts).
9. The algebraic eigen value problem: Power method.
10. Ordinary differential equations: The method of successive approximations (Picard), Euler's method, the modified Euler method, Runge-Kutta methods of orders two and four.

References:

1. K E Atkinson – Elementary Numerical Analysis, John Wiley & Sons (1985)
2. F B Hildebrand – Introduction to Numerical Analysis, Dover Publications, INC (2nd Edition, 1974)
3. D C Sanyal and K Das – A Text Book Of Numerical Analysis, U N Dhur & Sons Private Ltd, Kolkata
4. Michelle Schatzman – Numerical Analysis – A Mathematical Introduction, Oxford University Press (2002)
5. M K Jain, S R K Iyengar and R K Jain – Numerical Methods for Scientific and Engineering Computation, New Age International (P) Ltd., New Delhi (1996)

Question Pattern for End Semester Examination

(Course Code: HMAT6CC14L [Theory])

(i) Answer **four** objective / MCQ type questions of 2 marks each from 5 given questions.

(ii) Answer **six** questions of 7 marks each from 8 given questions. Each question may contain further parts.

Course Structure	DSE

Numerical Methods (Laboratory Based) [30 Marks]

Syllabus

List of practical (using C)

1. **Interpolation**
   - (i) Lagrange Interpolation
   - (ii) Newton's forward, backward and divided difference interpolations
2. **Numerical Integration**
   - (i) Trapezoidal Rule
   - (ii) Simpson's one third rule
3. **Solution of transcendental and algebraic equations**
   - (i) Bisection method
   - (ii) Newton Raphson method (Simple root, multiple roots, complex roots)
   - (iii) Method of Regula-Falsi.
4. **Solution of system of linear equations**
   - (i) Gaussian elimination method
   - (ii) Matrix inversion method
   - (iii) Gauss-Seidel method
5. **Method of finding Eigenvalue by Power method** (up to 4×4)
6. **Fitting a Polynomial Function** (up to third degree)
7. **Solution of ordinary differential equations**
   - (i) Euler method
   - (ii) Modified Euler method
   - (iii) Runge-Kutta method (order 4)

Question Pattern for End Semester Examination

(Course Code: HMAT6CC14L [Practical])

(i) Answer **six** questions of 3 marks each from 7 given questions. All problems to be done on computer by using C programming only. Allotted time is three hours.

(ii) 6 marks reserved for practical note book.

(iii) 6 marks reserved for viva voce.

Course Structure	DSE

Discipline Specific Electives (DSE)

DSE – 3

SEMESTER – 6	
Name of the Course : Linear Programming Problem & Game Theory	
Course Code : HMAT6DS31N	
Full Marks : 100	Credit: 6
Theory	Credits : 5 Full Marks : 65+20*
Tutorial	Credits : 1 Full Marks : 15
Number of classes required : 100	
*15 Marks are reserved for Internal Assessment (to be taken from the mid-semester exam) & 5 marks for Attendance	

Linear Programming Problem & Game Theory [65 Marks]

Course Outcomes: At the end of studying this paper a student

- will acquire fundamental knowledge on the theory of basic and basic feasible solutions and their properties, convex sets based on the knowledge of linear algebra studied in previous semesters.
- will acquire the skills on the solution of a Linear Programming Problem by Simplex Method. Also acquire knowledge on duality, transportation problem, assignment problem and travelling salesman problem.
- will acquire some knowledge on the basic theory of game problems and their solution by different methods which has many applications in Economics.

Syllabus

1. Basic solution and Basic Feasible Solution (B.F.S) with reference to L.P.P. Matrix formulation of L.P.P. Degenerate and Non-degenerate B.F.S.
2. Hyperplane, Convex set, extreme points, convex hull and convex polyhedron. Supporting and separating hyperplane. The collection of feasible solutions of a L.P.P. constitutes a convex set. The extreme points of the convex set of feasible solutions correspond to its B.F.S. and conversely. The objective function has its optimal value at an extreme point of the convex polyhedron generated by the set of feasible solutions (the convex polyhedron may also be unbounded). In the absence of degeneracy, if the L.P.P. admits of an optimal solution then at least one B.F.S. must be optimal. Reduction of a F.S. to a B.F.S.
3. Slack and surplus variables. Standard form of L.P.P. Theory of simplex method. Feasibility and optimality conditions. Two phase method. Degeneracy in L.P.P. and its resolution.

Course Structure	DSE

4. Duality theory: The dual of the dual is the primal. Relation between the objective values of dual and the primal problems. Relation between their optimal values. Complementary slackness, Duality and simplex method and their applications.
5. Transportation and Assignment problems. Mathematical justification for optimality criterion. Hungarian method. Travelling Salesman problem.
6. Concept of game problem. Rectangular games. Pure strategy and mixed strategy. Saddle point and its existence. Optimal strategy and value of the game. Necessary and sufficient condition for a given strategy to be optimal in a game. Concept of Dominance. Fundamental Theorem of rectangular games.
7. Algebraic method. Graphical method and Dominance method of solving Rectangular games. Inter-relation between theory of games and L.P.P.

References:

1. G Hadley – Linear Programming, Addison-Wesley Publishing Company, London (1972)
2. Hamdy A Taha – Operations Research – An Introduction, Prentice hall of India Pvt. Ltd., New Delhi (1999)
3. N S Kambo – Mathematical Programming Techniques, Affiliated East-West Press Pvt. Ltd., New Delhi (1997)
4. P K Gupta and Manmohan – Linear Programming and Theory of Games, Sultan Chand & Sons, New Delhi (1997)
5. Mokhtar S Bazaraa, John J Jarvis and Hanif D Sherali – Linear Programming and Network Flows, John Wiley and Sons (4th Edition, 2010)
6. J G Chakravorty & P R Ghosh – Linear Programming & Game Theory, Moulik Library Publisher, Kolkata

Question Pattern for End Semester Examination

(Course Code: HMAT6DS31N)

(i) Answer **five** objective / MCQ type questions of 2 marks each from 6 given questions.

(ii) Answer any **two** questions of 10 marks each from 4 given questions from Articles 1 to 3. Each question may contain further parts.

(iii) Answer any **two** questions of 10 marks each from 4 given questions from Articles 4 and 5. Each question may contain further parts.

(iv) Answer any **three** questions of 5 marks each from 5 given questions from Article 6. Each question may contain further parts.

Course Structure	DSE

OR

Advanced Mechanics [65 Marks]

SEMESTER – 6	
Name of the Course : Advanced Mechanics	
Course Code : HMAT6DS32N	
Full Marks : 100	Credit: 6
Theory	Credits : 5 Full Marks : 65+20*
Tutorial	Credits : 1 Full Marks : 15
Number of classes required : 100	
*15 Marks are reserved for Internal Assessment (to be taken from the mid-semester exam) & 5 marks for Attendance	

Course Outcomes: At the end of studying this course a student

- will acquire fundamental knowledge on Generalized coordinates and its applications.
- will acquire knowledge on non-holonomic systems, Hamiltonian etc which will help the students in the next level of study in Applied Mathematics.
- will acquire some knowledge on generating function, Poisson Bracket, Hamilton's characteristics function etc.

Syllabus

1. Degrees of freedom, reactions due to constraints. D' Alembert's principle; Lagrange's first kind equations; Generalized coordinates; Generalized forces; Lagrangian; Second kind Lagrange's equations of motion; cyclic coordinates; velocity dependent potential; Principle of energy; Rayleigh's dissipation function.
2. Action Integral; Hamilton's principle; Lagrange's equations by variational methods; Hamilton's principle for non-holonomic system; Symmetry properties and conservation laws; Noether's theorem. Canonically conjugate coordinates and momenta; Legendre transformation; Routhian approach; Hamiltonian.
3. Hamilton's equations from variational principle; Poincare-Cartan integral invariant; Principle of stationary action; Fermat's principle.
4. Canonical transformation; Generating function; Poisson Bracket; Equations of motion; Action-angle variables; Hamilton-Jacobi's equation; Hamilton's principal function; Hamilton's characteristics function; Liouville's theorem.

Course Structure	DSE

References:

1. H Goldstein – Classical Mechanics, Narosa Publ., New Delhi (1998)
2. N C Rana and P S Joag – Classical Mechanics, Tata McGraw Hill (2002)
3. E T Whittaker – A Treatise of Analytical Dynamics of Particles and Rigid Bodies, Cambridge Univ. Press, Cambridge (1977)
4. T W B Kibble and F H Berkshire – Classical Mechanics, Addison-Wesley Longman (4^{th} Edition, 1996)
5. V I Arnold – Mathematical Methods of Classical Mechanics, Springer (2^{nd} Edition, 1997)
6. N G Chetaev –Theoretical Mechanics, Springer(1990)
7. M Calkin – Lagrangian and Hamiltonian Mechanics, World Sci. Publ., Singapore(1996)
8. J L Synge and B A Griffith – Principles of Mechanics, McGraw Hill (1970)

Question Pattern for End Semester Examination

(Course Code: HMAT6DS32N)

(i) Answer **five** objective / MCQ type questions of 2 marks each from 6 given questions.

(ii) Answer any **one** question of 10 marks each from 2 given questions from Article 1. Each question may contain further parts.

(iii) Answer any **three** questions of 10 marks each from 5 given questions from Articles 2 and 3. Each question may contain further parts.

(iv) Answer any **three** questions of 5 marks each from 5 given questions from Article 4. Each question may contain further parts.

Course Structure	DSE

DSE – 4

SEMESTER – 6		
Name of the Course : Rigid Dynamics		
Course Code : HMAT6DS41N		
Full Marks : 100		Credit: 6
Theory	Credits : 5 Full Marks : 65+20*	
Tutorial	Credits : 1 Full Marks : 15	
Number of classes required : 100		
*15 Marks are reserved for Internal Assessment (to be taken from the mid-semester exam) & 5 marks for Attendance		

Rigid Dynamics [65 Marks]

Course Outcomes: At the end of studying this course a student

- will acquire fundamental knowledge on Principle of Energy, Principle of conservation of energy, moment of inertia.
- will acquire knowledge on motion of a rigid body in two dimensions.
- will acquire some knowledge on the motion of a rigid body under impulsive forces.

Syllabus

1. Momental ellipsoid, Equimomental system. Principal axis. D'Alembert's principle. D'Alembert's equations of motion. Principles of moments. Principles of conservations of linear and angular momentum. Independence of the motion of centre of inertia and the motion relative to the centre of inertia. Principle of energy. Principle of conservation of energy.
2. Equation of motion of a rigid body about a fixed axis. Expression for kinetic energy and moment of momentum of a rigid body moving about a fixed axis. Compound pendulum. Interchangeability of the points of a suspension and centre of oscillation. Minimum time of oscillation.
3. Equations of motion of a rigid body moving in two dimensions. Expression for kinetic energy and angular momentum about the origin of rigid body moving in two dimensions. Necessary and sufficient condition for pure rolling. Two dimensional motion of a solid of revolution moving on a rough horizontal plane.
4. Equations of motion under impulsive forces. Equation of motion about a fixed axis under impulsive forces. To show that (i) of there is a definite straight line such that the sum of the moments of the external impulses acting on a system of particles about it vanishes, then the total angular momentum of the system about that line remains unaltered, (ii) the change of K.E. of a system of particles moving in any manner under the application of impulsive forces is equal to the work done by the impulsive forces.

Course Structure	DSE

References:

1. E T Whittaker – A Treatise of Analytical Dynamics of Particles and Rigid Bodies, Cambridge Univ. Press, Cambridge (1977)
2. S L Loney – An Elementary Treatise on the Dynamics of a Particle and of Rigid Bodies, Cambridge University Press (1960).
3. B D Sharma, B S Tyagi and Brahma Nand – Dynamics of Rigid Bodies, Kedar Nath Ram Nath, Meerat, U.P. (2018)

Question Pattern for End Semester Examination

(Course Code: HMAT6DS41N)

(i) Answer **one** objective / MCQ type question of 2 marks from 2 given questions.

(ii) Answer **one** objective / MCQ type question of 3 marks from 2 given questions

(iii) Answer **four** questions of 7 marks each from 6 given questions to be set at least one from each Article. Each question may contain further parts.

(iv) Answer **four** questions of 8 marks each from 6 given questions to be set at least one from each Article. Each question may contain further parts

Course Structure	DSE

OR

SEMESTER – 6	
Name of the Course : Point Set Topology	
Course Code : HMAT6DS42N	
Full Marks : 100	Credit: 6
Theory	Credits : 5 Full Marks : 65+20*
Tutorial	Credits : 1 Full Marks : 15
Number of classes required : 100	
*15 Marks are reserved for Internal Assessment (to be taken from the mid-semester exam) & 5 marks for Attendance	

Point Set Topology [65 Marks]

Course Outcomes: At the end of studying this course a student

- will acquire fundamental knowledge on general topological spaces as a continuation and generalization of their earlier knowledge of real and complex analysis and metric spaces.
- will acquire very important knowledge that will help the students to solve problems in various national entrance examinations towards their next level of study and also for the NET examination conducted by CSIR after their completion of masters' degree.

Syllabus

1. Topological spaces, basis and sub-basis for a topology, neighbourhoods of a point, interior points, limit points, derived set, boundary of a set, closed sets, closure and interior of a set, dense subsets, subspace topology, finite Product topology, Continuous functions, open maps, closed maps, homeomorphisms, topological invariants, metric topology, isometry and metric invariants.
2. First countability, T_1 and T_2 separation axioms of topological spaces, convergence and cluster point of a sequence in topological spaces and some related concepts on first countable as well as on T_2 spaces. Heine's continuity criterion.
3. Connected spaces, connected sets in $\mathbb{R}$, components, Compact spaces, compactness and T_2, compact sets in $\mathbb{R}$, Heine-Borel Theorem for $\mathbb{R}^n$, real valued continuous function on connected and compact spaces, the concept of compactness in metric space, sequentially compactness of a metric space X and the Bolzano-Weierstrass property of X are equivalent.

References

1. J R Munkres – Topology - A First Course, Prentice Hall of India Pvt. Ltd (2000)
2. J Dugundji – Topology, Allyn and Bacon (1966)
3. G F Simmons – Introduction to Topology and Modern Analysis, McGraw Hill (1963)
4. J L Kelley – General Topology, Van Nostrand Reinhold Co. (1995)
5. J Hocking and G Young – Topology, Addison-Wesley Reading (1961)

Course Structure	DSE

Question Pattern for End Semester Examination

(Course Code: HMAT6DS42N)

(i) Answer **five** objective / MCQ type questions of 2 marks each from 6 given questions.

(ii) Answer any **four** questions of 5 marks each from 6 given questions from Article 1. Each question may contain further parts.

(iii) Answer any **three** questions of 5 marks each from 5 given questions from Article 2. Each question may contain further parts

(iv) Answer any **four** questions of 5 marks each from 6 given questions from Article 3. Each question may contain further parts

Course Structure	DSE

Generic Elective (GE)

[To be taken by the students of other discipline]

Semester	Course Name	Course Code	Credits
1	Modern Algebra, Differential Calculus, Linear Programming	HMAT1GE01N	6
2	Modern Algebra, Differential Calculus, Linear Programming	HMAT2GE01N	6
3	Linear Algebra, Integral Calculus, Differential Equations	HMAT3GE02N	6
4	Linear Algebra, Integral Calculus, Differential Equations	HMAT4GE02N	6
	Grand Total		24

GE Course Structure	Course Structure	DSE

Semester-wise detailed syllabus

SEMESTER – 1	
Name of the Course : Modern Algebra, Differential Calculus, Linear Programming	
Course Code : HMAT1GE01N	
Full Marks : 100	Credit: 6
Theory	Credits : 5 Full Marks : 65+20*
Tutorial	Credits : 1 Full Marks : 15
Number of classes required : 100	
*15 Marks are reserved for Internal Assessment (to be taken from the mid-semester exam) & 5 marks for Attendance	

&

SEMESTER – 2	
Name of the Course : Modern Algebra, Differential Calculus, Linear Programming	
Course Code : HMAT2GE01N	
Full Marks : 100	Credit: 6
Theory	Credits : 5 Full Marks : 65+20*
Tutorial	Credits : 1 Full Marks : 15
Number of classes required : 100	
*15 Marks are reserved for Internal Assessment (to be taken from the mid-semester exam) & 5 marks for Attendance	

Course Outcomes: At the end of studying this course a student

- will acquire fundamental knowledge on the elementary theory of Group, Ring and Field necessary for proper understanding of certain topics of various core courses of other major subjects.
- will acquire very important knowledge on differential calculus that will help the students to understand the applications of calculus to their respective major subjects.
- will acquire fundamental knowledge on linear programming problems and their applications as a continuation of their earlier knowledge in plus two level.

Syllabus

Group – A [15 Marks]
(Modern Algebra)

(i) Introduction of Group Theory: Definition and examples taken from various branches (example from number system, residue class of integers modulo n, roots of unity, 2×2 real matrices, non-singular real matrices of fixed order, groups of symmetries of an equilateral triangle, a square). Elementary properties using definition of Group. Definition and examples of sub-group (statement of necessary and sufficient condition and its applications). Order of an element of a finite group, statement and applications of Lagrange's theorem on finite group.

(ii) Definition and examples of (i) Ring (ii) Field (iii) Sub-ring (iv) Sub-field.

(iii) Rank of a matrix: Determination of rank either by considering minors or by sweep-out process. Consistency and solution of a system of linear equations with not more than 3 variables by matrix method.

(iv) Real Quadratic Form involving not more than three variables, its rank, index and signature (problems only).

Group – B [30 marks]
(Differential Calculus)

(i) Sequence of real numbers: Definition of bounds of a sequence and monotone sequence. Limit of a sequence. Statements of limit theorems. Concept of convergence and divergence of monotone sequences – applications of the theorems, in particular, definition of e. Statement of Cauchy's general principle of convergence andits application.

(ii) Real-valued functions defined on an interval, limit of a function (Cauchy's definition). Algebra of limits. Continuity of a function at a point and in an interval. Acquaintance (on proof) with the important properties of continuous functions on closed intervals. Statement of existence of inverse function of a strictly monotone function and its continuity.

(iii) Derivative - its geometrical and physical interpretation. Sign of derivative-Monotonic increasing and decreasing functions. Relation between continuity and derivability.

(iv) Successive derivative – Leibnitz's theorem and its application.

(v) Functions of two and three variables: Geometrical representations. Limit and Continuity (definition only) for function of two variables. Partial derivatives. Knowledge and use of chain rule. Exact Differential (emphasis on solving problems only). Functions of two variables - Successive partial Derivatives: Statement of Schwarz's Theorem on Commutative property of mixed derivatives. Euler's Theorem on homogeneous functions of two and three variables.

(vi) Statement of Rolle's Theorem and its geometrical interpretation. Mean value theorems of Lagrange and Cauchy. Statements of Taylor's and Maclaurin's Theorems with Lagrange's and Cauchy's from of remainders. Taylor's and Maclaurin's Infinite series of functions like e^x, $sin\, x$, $cos\, x$, $(1 + x)^n$, $\log_e(1+x)$ with restrictions wherever necessary.

(vii) Indeterminate Forms: L'Hospital's Rule: Statement and Problems only.

(viii) Application of the principle of Maxima and Minima for a function of single variable in geometrical, physical and other problems.

(ix) Maxima and minima of functions of not more than three variables. Lagrange's Method of undetermined multiplier - Problems only.

GE Course Structure	Course Structure	DSE

(x) Infinite series of constant terms: Convergence and Divergence (definition). Cauchy's principle as applied to infinite series (application only). Series of positive terms: Statements of comparison test. D'AIembert's Ratio test. Cauchy's n-th root test and Raabe's test – applications. Alternating series. Statement of Leibnitz test and its applications.

Group – C [20 Marks]
(Linear Programming)

(i) Mathematical preliminaries: Euclidean Space, Linear dependence and independence of vectors, Spanning set and basis, replacing a vector in basis, Basic solution of a system of linear algebraic equations.

(ii) Slack and Surplus variables. L.P.P. in matrix form. Feasible and Basic Feasible Solutions (B.F.S.). Degenerate and Non-degenerate B.F.S. Hyperplane, convex combination, line and line segment in E^n. Convex set, extreme points, convex hull and polyhedron.

(iii) Theorems (with proof): The set of all feasible solutions of a L.P.P. is a convex set. The objective function of a L.P.P. assumes its optimal value at an extreme point of the convex set of feasible solutions, a B.F.S. of a L.P.P. corresponds to an extreme point of the convex set of feasible solutions.

(iv) Fundamental Theorem of L.P.P. (Statement only). Reduction of a feasible solution to a B.F.S. Standard form of a L.P.P. Solution by simplex method and method of penalty.

(v) Concept of Duality. The dual of the dual is the primal. Relation between the objective values of dual and the primal problems. Dual problems with at most one unrestricted variable, one constraint of equality.

(vi) Transportation and Assignment problems and their optimal solutions.

References:

1. Sobhakar Ganguly and Manabendra Nath Mukherjee – A Treatise on Basic Algebra, Academic Publishers, Kolkata (3rd Edition)
2. S K Mapa – Higher Algebra (Abstract and Linear), Sarat Book House, Kolkata
3. B C Das and B N Mukherjee – Differential Calculus, U N Dhur & Sons Pvt. Ltd., Kolkata
4. K C Maity & R K Ghosh – Differential Calculus, New Central Book Agency (P) Ltd, Kolkata
5. J G Chakravorty & P R Ghosh –Linear Programming, Moulik Library Publisher, Kolkata
6. D C Sanyal & K Das – Linear Programming, U N Dhur & Sons Pvt. Ltd., Kolkata

GE Course Structure	Course Structure	DSE

Question Pattern for End Semester Examination

(Course Code: HMAT1GE01N & HMAT2GE01N)

Group – A (Modern Algebra, 15 marks)

(i) Answer (with reason) **two** objective / MCQ type questions of 2 marks (1 mark for correct option and 1 mark for reason) each from 4 given questions.

(ii) Answer **one** question of 3 marks from two given questions.

(iii) Answer **two** questions of 4 marks each from four given questions.

Group – B (Differential Calculus, 30 marks)

(i) Answer (with reason) **four** objective / MCQ type questions of 2 marks (1 mark for correct option and 1 mark for reason) each from 6 given questions.

(ii) Answer **two** questions of 3 marks each from four given questions.

(iii) Answer **four** questions of 4 marks each from six given questions.

Group – C (Linear Programming, 20 marks)

(i) Answer (with reason) **two** objective / MCQ type questions of 2 marks (1 mark for correct option and 1 mark for reason) each from 3 given questions.

(ii) Answer **four** questions of 4 marks each from seven given questions.

GE Course Structure	Course Structure	DSE

SEMESTER – 3	
Name of Course: Linear Algebra, Integral Calculus, Differential Equations	
Course Code: HMAT3GE02N	
Full Marks: 100	Credit: 6
Theory	Credits : 5 Full Marks : 65+20*
Tutorial	Credits : 1 Full Marks : 15
Number of classes required : 100	
*15 Marks are reserved for Internal Assessment (to be taken from the mid-semester exam) & 5 marks for Attendance	

&

SEMESTER – 4	
Name of Course:	
Course Code: HMAT4GE02N	
Full Marks: 100	Credit: 6
Theory	Credits : 5 Full Marks : 65+20*
Tutorial	Credits : 1 Full Marks : 15
Number of classes required : 100	
*15 Marks are reserved for Internal Assessment (to be taken from the mid-semester exam) & 5 marks for Attendance	

Course Outcomes: At the end of studying this course a student

- will acquire fundamental knowledge and problem solving skills on certain topics on Linear Algebra mostly through matrix theory, which is of paramount importance as a useful mathematical tool for various subjects like Physics, Statistics, Economics etc.
- will acquire very important knowledge on integral calculus that will help the students to understand the applications of calculus to their respective major subjects.
- will acquire rudimentary knowledge and problem solving skill on certain classes of differential equations and their applications, which is indispensable as a tool for various other branches of science .

Syllabus

Group – A [30 Marks]
(Linear Algebra)

(i) Concept of Vector space over a Field: Examples, Concepts of Linear combinations, Linear dependence and independence of a finite number of vectors, Sub- space, Concepts of generators and basis of a finite dimensional vector space. Problems on formation of basis of a vector space (No proof required).

(ii) Statement and applications of Deletion theorem, Extension theorem and Replacement theorem on finite dimensional vector spaces.

(iii) Real Inner product spaces, norms, statement of Cauchy-Schwarz's inequality, Gram-Schmidt orthonormalisation process, orthogonal basis (Stress should be given on solving problems).

(iv) Characteristic equation of square matrix of order not more than three; determinations of Eigen Values and Eigen Vectors (problems only). Statement and illustration of Cayley-Hamilton Theorem.

(v) Linear transformations, matrix of a linear transformation, similarity and change of basis (General ideas and problems).

(vi) Diagonalization of matrix – problems only (relevant theorems to be stated).

Group – B [15 Marks]
(Integral Calculus)

(i) Reduction formulae like $\int x^n e^{ax} dx, \int \sin^n x\, dx, \int cos^n x\, dx, \int \tan^n x\, dx, \int_0^{\pi/2} \sin^n x\, dx,$ $\int_0^{\pi/2} \cos^n x\, dx, \int_0^{\pi/4} \tan^n x\, dx, \int \sin^n x \cos^m x\, dx$ etc. and associated problems ($m,\ n$ are non-negative integers).

(ii) Definition of Improper Integrals: Statements of (i) μ-test (ii) Comparison test (Limit from excluded) and simple problems only. Use of Beta and Gamma functions (convergence and important relations being assumed).

(iii) Working knowledge of multiple integrals.

Group – C [20 Marks]
(Differential Equations)

(i) First order differential equations: Exact equations and those reducible to such equations.

(ii) Linear differential equations and Bernoulli's equations.

(iii) Clairaut's equations: General and Singular solutions.

(iv) Applications: Geometric applications, orthogonal trajectories.

(v) Second order linear differential equations with constant co-efficients (solution by operator method). Euler's Homogeneous equations.

References

1. Sobhakar Ganguly and Manabendra Nath Mukherjee – A Treatise on Basic Algebra, Academic Publishers, Kolkata (3rd Edition)
2. S K Mapa – Higher Algebra (Abstract and Linear), Sarat Book House, Kolkata
3. Stephen H Friedberg, Arnold J Insel and Lawrence E Spence – Linear Algebra, Prentice- Hall of India Pvt. Ltd., New Delhi (4th Edition, 2004)
4. B C Das and B N Mukherjee – Integral Calculus, U N Dhur & Sons Pvt. Ltd., Kolkata
5. K C Maity & R K Ghosh – Integral Calculus, New Central Book Agency (P) Ltd, Kolkata
6. K C Maity & R K Ghosh – Differential Equations, New Central Book Agency (P) Ltd, Kolkata
7. J G Chakravorty & P R Ghosh – Differential Equations, U N Dhur & Sons Pvt. Ltd., Kolkata

GE Course Structure	Course Structure	DSE

Question Pattern for End Semester Examination

(Course Code: HMAT3GE02N & HMAT4GE02N)

Group – A (Linear Algebra, 30 marks)

(i) Answer (with reason) **three** objective / MCQ type questions of 2 marks (1 mark for correct option and 1 mark for reason) each from 2 given questions.

(ii) Answer **four** questions of 6 marks each from 6 given questions. Each question may contain further parts.

Group – B (Integral Calculus, 15 marks)

(i) Answer (with reason) **one** objective / MCQ type questions of 2 marks (1 mark for correct option and 1 mark for reason) each from 2 given questions.

(ii) Answer **one** question of 3 marks from 2 given questions.

(iii) Answer **two** questions of 5 marks each from 4 given questions. Each question may contain further parts.

Group – C (Differential Equations, 20 marks)

(i) Answer (with reason) **two** objective / MCQ type questions of 2 marks (1 mark for correct option and 1 mark for reason) each from 3 given questions.

(ii) Answer **four** questions of 4 marks each from 7 given questions. Each question may contain further parts.

GE Course Structure	Course Structure	DSE