Syllabus
for
Four-Year (Eight-Semester)
Undergraduate Program
in
Mathematics
(Iniatially this contains Semester-I to Semester-IV Syllabus)

University of Gour Banga
Malda-732103
West Bengal

Syllabus
for
Semester-I to Semester-IV
(Two-Year)
Undergraduate Program
in
Mathematics

Semester	Major Core (MC/DSC)	Interdisciplinary/ Multidisciplinary (IDC/MDC)	Minor Core (MnC)	Ability Enhancement Course (AEC)	Skill Enhancement Course (SEC)	Internship/ Apprenticeship/ Project/ Community Outreach (IAPC)	Value Addition Course (VAC)	Total Credits
I	MTMMJ-MC-01 (4) MTMMJ-MC-02 (4)	MDC-1 (3)	MTMMN-MnC-01 (4)	MIL-1 (2)	MTMMJ-SEC-01 (3)		ENVS (2)	22
II	MTMMJ-MC-03 (4) MTMMJ-MC-04 (4)	MDC-2 (3)	MTMMN-MnC-02 (4)	MIL-2 (2)	MTMMJ-SEC-02 (3)	IAPC (2)* (optional)	VAC-01	22+2*
Students on exit shall be awarded Undergraduate Certificate in Mathematics after securing the requisite 44+2(Completion of IAPC in Semester II*)=46 credits in Semesters I & II.								

Semester	Major Core (MC/DSC)	Interdisciplinary/ Multidisciplinary (IDC/MDC)	Minor Core (MnC)	Ability Enhancement Course (AEC)	Skill Enhancement Course (SEC)	Internship/ Apprenticeship/ Project/ Community Outreach (IAPC)	Value Addition Course (VAC)	Total Credits
III	MTMMJ-MC-05 (4) MTMMJ-MC-06 (4)	MDC-3 (3)	MTMMN-MnC-03 (4)	English Language-1 (2)	MTMMJ-SEC-03 (3)			20
IV	MTMMJ-MC-07 (4) MTMMJ-MC-08 (4) MTMMJ-MC-09 (4)		MTMMN-MnC-04 (4)	English Language-2 (2)		IAPC (2)** (optional)		18+2**
Students on exit shall be awarded Undergraduate Diploma in Mathematics after securing the requisite 84 (Completion of IAPC either in Semester II* or in Semester IV**) credits in Semesters I, II, III & IV. **Note:** Students need to peruse IAPC once either in Semester II or in Semester IV.								

Note: The courses with 50 marks (credits 3 or 4) must have Internal Assessment 10 marks and Semester Examination 40 marks. The courses with 25 marks (credits 2) only have Semester Examination 25 marks.

Pattern of Questions for the Semester Examination (40 marks) in Theoretical Courses: Students have to answer Five questions carrying 2 marks each out of Seven given questions; Six questions carrying 5 marks each out of Nine given questions. Question to be framed from each unit compulsorily for each category of question.

Name of Major Core Papers (Each carries 4 credits or 50 marks)

Semester	Course Code	Course Name
I	MTMMJ-MC-01	Calculus & Geometry
	MTMMJ-MC-02	Algebra
II	MTMMJ-MC-03	Real Analysis I
	MTMMJ-MC-04	Abstract Algebra
III	MTMMJ-MC-05	Real Analysis II
	MTMMJ-MC-06	Linear Algebra
IV	MTMMJ-MC-07	Multivariate Calculus & Vector Calculus
	MTMMJ-MC-08	Differential Equations
	MTMMJ-MC-09	Mechanics

Name of Skill Enhancement Papers (Each carries 3 credits or 50 marks)

Semester	Course Code	Course Name
I	MTMMJ-SEC-01	Number Theory & Boolean Algebra
II	MTMMJ-SEC-02	Set Theory
III	MTMMJ-SEC-03	Graph Theory

Name of Interdisciplinary/Multidisciplinary Papers (Each carries 3 credits or 50 marks)

Semester	Course Code	Course Name
I	MDC-1	##########
II	MDC-2	##########
III	MDC-3	##########

Name of Minor Core Papers (Each carries 4 credits or 50 marks)

Semester	Course Code	Course Name
I	MTMMN-MnC-01	Algebra & Analytical Geometry
II	MTMMN-MnC-02	
III	MTMMN-MnC-03	Calculus & Differential Equations
IV	MTMMN-MnC-04	

SEMESTER I

Duration: 6 Months (Including Examinations)
Total 22 Credits (Marks: 300)
Total No. of Lectures: ** Hours per paper

Semester	Course Code	Course Name	Marks (Credits)
I	MTMMJ-MC-01	Calculus & Geometry	50 (4)
	MTMMJ-MC-02	Algebra	50 (4)
	MDC-1	##########	50 (3)
	MTMMN-MnC-01	Algebra & Analytical Geometry	50 (4)
	MIL-1	##########	25 (2)
	MTMMJ-SEC-01	Number Theory & Boolean Algebra	50 (3)
	ENVS	##########	25 (2)

MTMMJ-MC-01
Calculus & Geometry
Credit: 4
Full Marks: 50 (IA: 10, SE: 40)

Unit-1

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. Properties of continuous functions(statement only) and its related problems on closed intervals. Hyperbolic functions, higher order derivatives, Leibnitz rule of successive differentiation and its applications to problems of type $e^{ax+b}\sin x$, $e^{ax+b}\cos x$, $(ax+b)^n\sin x$, $(ax+b)^n\cos x$, concavity and inflection points, envelopes, asymptotes.

Unit-2

Reduction formulae, derivations and illustrations of reduction formulae of the type integration of $\sin^n x$, $\cos^n x$, $\tan^n x$, $\sec^n x$, $(\log x)^n$, $\sin^n x \sin^m x$, evaluation of definite integrals, integration as the limit of a sum, concept of improper integration, use of Beta and Gamma functions. parametric equations, parametrizing a curve, arc length, arc length of parametric curves, area of surface of revolution.

Unit-3

Reflection properties of conics, translation and rotation of axes and second degree equations, reduction and classification of conics using the discriminant, Point of intersection of two intersecting straight lines. Angle between two lines, Equation of bisectors. Equation of two lines joining the origin to the points in which a line meets a conic. Equations of pair of tangents from an external point, chord of contact, Polar equations of straight lines and conics. Equation of chord joining two points. Equations of tangent and normal.

Unit-4

Spheres, Cylindrical surfaces, Central conicoids, paraboloids, plane sections of conicoids, Generating lines, reduction and classification of quadrics.

Reference Books

1. S.L. Loney, The Elements of Coordinate Geometry, Macmillan and Co., 1895.
2. G.B. Thomas and R.L. Finney, Calculus, 9th Ed., Pearson, 2005.
3. M.J. Strauss, G.L. Bradley and K.J. Smith, Calculus, 3rd Ed., Pearson Education, 2007.
4. H. Anton, I. Bivens and S. Davis, Calculus, 10th Ed., John Wiley and Sons Inc., 2012.
5. R. Courant and F. John, Introduction to Calculus and Analysis (Volumes I & II), Springer, 1989.
6. T.M. Apostol, Calculus (Volumes I & II), John Wiley & Sons, 1967.
7. S. Goldberg, Calculus and mathematical analysis.
8. S. Lang, A First Course in Calculus, Springer 1998.
9. K.A. Ross, Elementary Analysis: The Theory of Calculus, Springer, 2nd ed., 2013.
10. R.J.T. Bell, An Elementary Treatise on Coordinate Geometry of Three Dimensions, Macmillan Publishers India Limited, 2000.

MTMMJ-MC-02
Algebra
Credit: 4
Full Marks: 50 (IA: 10, SE: 40)

Unit-1

Polar representation of complex numbers, n-th roots of unity, De Moivre's theorem for rational indices and its applications. Exponential,Sine, Cosine and Logarithm of a complex number. Inequality: The inequality involving $AM \geq GM \geq HM$, m-th power theorem, Cauchy-Schwartz inequality. Maximum and minimum values of a polynomials.

Unit-2

General properties of equations, Fundamental theorem of classical algebra (statement only) and its application, Transformation of equation, Descarte's rule of signs positive and negative rule, Strum's theorem, Relation between the roots and the coefficients of equations. Symmetric functions. Applications of symmetric function of the roots. Solutions of reciprocal and binomial equations. Algebraic solutions of the cubic (Cardon's) and biquadratic (Ferrari's).

Unit-3

Composition of functions, Invertible functions, One to one correspondence and cardinality of a set. Recurrence relation definition,example, Formation of recurrence relation, Factorial representation, Fibonacci number, Solution upto second order linear recurence relation, Generating function.

Unit-4

Systems of linear equations, row reduction and echelon forms, vector equations, the matrix equation $Ax = b$, solution sets of linear systems, applications of linear systems, linear independence. Real Quadratic Form involving not more than three variables. Characteristic equation of square matrix of order not more than three determination of Eigen Values and Eigen Vectors. Cayley-Hamilton Theorem.

Reference Books

1. T. Andreescu and D. Andrica, Complex Numbers from A to . . . Z, Birkhauser Boston, 2008.

2. D.C. Lay, S.R. Lay and J.J. McDonald, Linear Algebra and its Applications, 5rd Ed., Pearson, 2014.

3. K.B. Dutta, Matrix and linear algebra, Prentice Hall, 2004.

4. K. Hoffman and R. Kunze, Linear algebra, Prentice Hall, 1971.

5. W.S. Burnstine and A.W. Panton, Theory of equations, Nabu Press, 2011.

6. S.H. Friedberg, A.J. Insel and L.E. Spence, Linear Algebra, 4th Ed., PHI, 2004.

7. S. Bernard and J.M. Child, Higher Algebra, Macmillan and Co. 1952.

MTMMN-MnC-01
Algebra & Analytical Geometry
Credit: 4
Full Marks: 50 (IA: 10, SE: 40)

Algebra

Unit-1

Integers, well ordering principle, principle of mathematical induction. Division algorithm ($a = bq + r$, $b \neq 0$, $0 \leq r < b$), greatest common divisor(g.c.d.) of two integers and its simple properties, co-prime integers, Euler's φ-function. Prime numbers, Euclid's theorem, fundamental theorem of arithmetic.

Complex Numbers: De Moivre's Theorem and its applications. Exponential, Sine, Cosine and Logarithm of a complex number. Definition of a^z $(a \neq 0)$.

Unit-2

Polynomials with real coefficients, Fundamental Theorem of 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). Existence of real roots, Descarte's rule of sign and application of intermediate value theorem. Relation between roots and coefficients, symmetric functions of roots. Cardan's method of solution of a cubic equation.

Matrices with real and complex entries. Inverse of a matrix. Elementary row operations and row reduced Echelon matrix. Rank of a matrix. System of linear equation, consistency and inconsistency of system of linear equation, solution of system of linear equations. Symmetric, skew symmetric, Hermitian, Skew-Hermitian, Unitary and orthogonal matrices.

Determinant and its basic properties. Laplace expansion of determinant. Singular and non singular matrix, rank of a matrix in terms of determinants.

Analytical Geometry

Unit-3

Transformations of Rectangular axes: Translation, Rotation and their combinations. Invariants.

General equation of second degree in x and y: Reduction to canonical forms. Classification of conic.

Pair of straight lines: Condition that the general equation of second degree in x and y may represent two straight lines. Point of intersection of two intersecting straight lines. Angle between two lines given by $ax^2 + 2hxy + by^2 = 0$. Equation of bisectors. Equation of two lines joining the origin to the points in which a line meets a conic.

Unit-4
Equations of pair of tangents from an external point, chord of contact, poles and polers in case of General conic: Particular cases for Parabola, Ellipse, Circle, Hyperbola.

Polar equation of straight lines and circles. Polar equation of a conic referred to a focus as pole. Equation of chord joining two points. Equations of tangent and normal.

Three dimensional coordinate system. Straight line, direction cosine, problems on straight lines. Equation of plane and elementary properties. Sphere and its tangent plane. Right circular cone.

Reference Books

1. S. L. Loney, The Elements of Coordinate Geometry, Macmillan and Co., 1895.
2. S. Bernard and J.M. Child, Higher Algebra, Macmillan and Co., 1952.
3. T. Andreescu and D. Andrica, Complex Numbers from A to...Z, Birkhauser, 2006.
4. D.C. Lay, Linear Algebra and its Applications, 3rd Ed., Pearson Education Asia, Indian Reprint, 2007.
5. K.B. Dutta, Matrix and Linear algebra, Prentice-Hall of India Pvt.Ltd., 2004.
6. W.S. Burnside and A.W. Panton, The Theory of equations, Dublin University Press, 1954.
7. R.J.T. Bell, An elementary treatise on coordinate geometry of three dimensions, Macmillan and Co.

MTMMJ-SEC-01
Number Theory & Boolean Algebra
Credit: 3
Full Marks: 50 (IA: 10, SE: 40)

Number Theory
Unit-1
Integers: Principle of Mathematical Induction. Division Algorithm. Representation of integer in an arbitrary base. Prime Integers. Fundamental theorem of Arithmetic. Euclid's Theorem. Linear Diophantine equations.

Congruences: Congruence relation on integers, Basic properties of this relation. Linear Congruence. Chinese Remainder Theorem, System of Linear Congruences.

Unit-2
Application of Congruences: Divisibility test. Computer file, Storage and Hashing functions. Round-Robin Tournaments. Check-digit in an ISBN, Universal Product code, Major Credit Cards. Error detecting capability.
Congruence Classes: Addition and Multiplication of Congruence Classes. Fermat's little Theorem. Euler's Theorem. Wilson's Theorem. Some simple applications.

Boolean Algebra
Unit-3
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.

Unit-4
Definition, examples and properties of modular and distributive lattices, Boolean algebras, Boolean polynomials, minimal and maximal forms of Boolean polynomials, Quinn-McCluskey method, Karnaugh diagrams, Logic Gates, switching circuits and applications of switching circuits.

Reference Books

1. B.A. Davey and H.A. Priestley, Introduction to Lattices and Order, Cambridge University Press, 1990.
2. E.G. Goodaire and M.M. Parmenter, Discrete Mathematics with Graph Theory, (2nd Ed.), Pearson Education (Singapore) P.Ltd., Indian Reprint 2003.
3. R. Lidl and G. Pilz, Applied Abstract Algebra, 2nd Ed., Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.
4. D.M. Burton, Elementary Number Theory, 6th Ed., Tata McGraw Hill, Indian reprint, 2007.
5. N. Robinns, Beginning Number Theory, 2nd Ed., Narosa Publishing House Pvt. Ltd., Delhi, 2007
6. G.A. Jones and J.M. Jones, Elementary Number Theory, Springer International Edition.
7. N. Koblitz, A course in number theory and cryptography, Springer-Verlag, 2nd edition.
8. K.H. Rosen, Elementary Number Theory & Its Applications, AT&T Bell Laboratories, Addition-Wesley Publishing Company, 3rd Edition.
9. K. Ireland and M. Rosen, A Classical Introduction to Modern Number Theory, 2nd edition, Springer-verlag.
10. R.A. Mollin, Advanced Number Theory with Applications, CRC Press, A Chapman & Hall Book.

SEMESTER II

Duration: 6 Months (Including Examinations)
Total 22+2* credits (Marks: 300+25*)
Total No. of Lectures: ** Hours per paper

Semester	Course Code	Course Name	Marks (Credits)
II	MTMMJ-MC-03	Real Analysis I	50 (4)
	MTMMJ-MC-04	Abstract Algebra	50 (4)
	MDC-2	##########	50 (3)
	MTMMN-MnC-02	Algebra & Analytical Geometry	50 (4)
	MIL-2	##########	25 (2)
	MTMMJ-SEC-02	Set Theory	50 (3)
	IAPC	Internship/Apprenticeship/ Project/Community Outreach	25 (2)*
	VAC-01	##########	25 (2)

MTMMJ-MC-03
Real Analysis I
Credit: 4
Full Marks: 50 (IA: 10, SE: 40)

Unit-1

Development of real numbers. The algebraic properties of $\mathbb{R}$, rational and irrational numbers, the order properties of $\mathbb{R}$. Absolute value and the real line, bounded and unbounded sets in $\mathbb{R}$, supremum and infimum, neighbourhood of a point. The completeness property of $\mathbb{R}$, the Archimedean property, density of rational numbers in $\mathbb{R}$, nested intervals property, binary representation of real numbers, uncountability of $\mathbb{R}$. Closed set, open set, closure and interior of a subset of the real line.

Unit-2

Sequences, the limit of a sequence and the notion of convergence, bounded sequences, limit theorems, squeeze theorem, monotone sequences, monotone convergence theorem. Subsequences, monotone subsequence theorem and the Bolzano-Weierstrass theorem, the divergence criterion, limit superior and limit inferior of a sequence, Cauchy sequences, Cauchy's convergence criterion. Infinite series, convergence and divergence of infinite series. Tests for Convergence: Comparison test, root test, ratio test, integral test. Alternating series, absolute and conditional convergence.

Unit-3

Sequential criterion for limits, divergence criteria. Limit theorems, infinite limits and limits at infinity. Continuous functions, sequential criterion for continuity and discontinuity. Algebra of continuous functions. Continuous functions on an interval, intermediate value theorem, location of roots theorem, preservation of intervals theorem. Uniform continuity, non-uniform continuity criteria, uniform continuity theorems.

Unit-4

Differentiability of a function at a point and in an interval, Caratheodory's theorem, chain rule, derivative of inverse functions, algebra of differentiable functions. Mean value theorems, Rolle's

Theorem, Lagrange's mean value theorem, Cauchy's mean value theorem. Applications of mean value theorem to inequalities, relative extremum. The intermediate value property of derivatives, Darboux's theorem. L'Hospital's rule. Taylor's theorem and its application. Expansion of functions.

Reference Books

1. R.G. Bartle and D.R. Sherbert, Introduction to Real Analysis, 3rd Ed., Wiley, 2000.
2. G.G. Bilodeau , P.R. Thie and G.E. Keough, An Introduction to Analysis, 2nd Ed., Jones & Bartlett, 2009.
3. B.S. Thomson, A.M. Bruckner and J.B. Bruckner, Elementary Real Analysis, Prentice Hall, 2001.
4. S.K. Berberian, A First Course in Real Analysis, Springer, 1998.
5. T.M. Apostol, Mathematical Analysis, Narosa, 2002.
6. R. Courant and F. John, Introduction to Calculus and Analysis, Vol I, Springer, 1999.
7. W. Rudin, Principles of Mathematical Analysis, McGraw Hill, 2017.
8. C.C. Pugh, Real Mathematical Analysis, Springer, 2002.
9. T. Tao, Analysis I, Hindustan Book Agency, 2006
10. S. Goldberg, Calculus and mathematical analysis.
11. H.R. Beyer, Calculus and Analysis, Wiley, 2010.
12. S. Lang, Undergraduate Analysis, Springer, 2nd Ed., 1997.
13. A. Kumar and S. Kumaresan, A Basic Course in Real Analysis, CRC Press, 2014.

MTMMJ-MC-04
Abstract Algebra
Credit: 4
Full Marks: 50 (IA: 10, SE: 40)

Unit-1

Definition and examples of groups, elementary properties of groups. Subgroups and examples of subgroups, centralizer, normalizer, center of a group. Properties of cyclic groups, classification of subgroups of cyclic groups. Permutation group, cycle notation for permutations, properties of permutations, even and odd permutations, alternating group.

Unit-2

Cosets, properties of cosets, Lagrange's theorem and consequences including Fermat's Little theorem. Normal subgroup and quotient group. Group homomorphisms, properties of homomorphisms, properties of isomorphisms. First, Second and Third isomorphism theorems (Statement only).

Unit-3

Definition and examples of rings, elementary properties of rings, subrings, integral domains and fields, characteristic of a ring. Ring homomorphisms, properties of ring homomorphisms.

Unit-4

Ideal, First Isomorphism theorem. Isomorphism theorems II and III (Statement and Applications), field of quotients. Elementary properties of field. Introduction to polynomial ring.

Reference Books

1. J.B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.
2. M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.
3. J.A. Gallian, Contemporary Abstract Algebra, 8th Ed., Houghton Mifflin, 2012.
4. J.J. Rotman, An Introduction to the Theory of Groups, 4th Ed., Springer, 1995.
5. I.N. Herstein, Topics in Algebra, Wiley Eastern Limited, 1975.
6. D.S. Malik, J.M. Mordeson and M.K. Sen, Fundamentals of Abstract Algebra, McGraw Hill, 1996.
7. D.S. Dummit and R.M. Foote, Fundamentals of Abstract Algebra, 3rd Ed., Wiley, 2003.
8. M.K. Sen, S. Ghosh, P. Mukhopadhyay and S.K. Maiti, Topics in Abstract Algebra, 3rd Ed., Universities Press, 2019.

MTMMN-MnC-02
Algebra & Analytical Geometry
Credit: 4
Full Marks: 50 (IA: 10, SE: 40)

Algebra

Unit-1

Integers, well ordering principle, principle of mathematical induction. Division algorithm ($a = bq + r$, $b \neq 0$, $0 \leq r < b$), greatest common divisor(g.c.d.) of two integers and its simple properties, co-prime integers, Euler's φ-function. Prime numbers, Euclid's theorem, fundamental theorem of arithmetic.

Complex Numbers: De Moivre's Theorem and its applications. Exponential, Sine, Cosine and Logarithm of a complex number. Definition of a^z $(a \neq 0)$.

Unit-2

Polynomials with real coefficients, Fundamental Theorem of 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). Existence of real roots, Descarte's rule of sign and application of intermediate value theorem. Relation between roots and coefficients, symmetric functions of roots. Cardan's method of solution of a cubic equation.

Matrices with real and complex entries. Inverse of a matrix. Elementary row operations and row reduced Echelon matrix. Rank of a matrix. System of linear equation, consistency and inconsistency of system of linear equation, solution of system of linear equations. Symmetric, skew symmetric, Hermitian, Skew-Hermitian, Unitary and orthogonal matrices.

Determinant and its basic properties. Laplace expansion of determinant. Singular and non singular matrix, rank of a matrix in terms of determinants.

Analytical Geometry

Unit-3
Transformations of Rectangular axes: Translation, Rotation and their combinations. Invariants.

General equation of second degree in x and y: Reduction to canonical forms. Classification of conic.

Pair of straight lines: Condition that the general equation of second degree in x and y may represent two straight lines. Point of intersection of two intersecting straight lines. Angle between two lines given by $ax^2 + 2hxy + by^2 = 0$. Equation of bisectors. Equation of two lines joining the origin to the points in which a line meets a conic.

Unit-4
Equations of pair of tangents from an external point, chord of contact, poles and polers in case of General conic: Particular cases for Parabola, Ellipse, Circle, Hyperbola.

Polar equation of straight lines and circles. Polar equation of a conic referred to a focus as pole. Equation of chord joining two points. Equations of tangent and normal.

Three dimensional coordinate system. Straight line, direction cosine, problems on straight lines. Equation of plane and elementary properties. Sphere and its tangent plane. Right circular cone.

Reference Books

1. S. L. Loney, The Elements of Coordinate Geometry, Macmillan and Co., 1895.
2. S. Bernard and J.M. Child, Higher Algebra, Macmillan and Co., 1952.
3. T. Andreescu and D. Andrica, Complex Numbers from A to...Z, Birkhauser, 2006.
4. D.C. Lay, Linear Algebra and its Applications, 3rd Ed., Pearson Education Asia, Indian Reprint, 2007.
5. K.B. Dutta, Matrix and Linear algebra, Prentice-Hall of India Pvt.Ltd., 2004.
6. W.S. Burnside and A.W. Panton, The Theory of equations, Dublin University Press, 1954.
7. R.J.T. Bell, An elementary treatise on coordinate geometry of three dimensions, Macmillan and Co.

MTMMJ-SEC-02
Set Theory
Credit: 3
Full Marks: 50 (IA: 10, SE: 40)

Unit-1
Sets, subsets, Set operations, The laws of set theory and Venn diagrams. Examples of finite and infinite sets. Finite sets and counting principle. Empty set, properties of empty set. Standard set operations. Classes of sets. Power set of a set.

Unit-2
Difference and Symmetric difference of two sets. Set identities, Generalized unions and intersections. Cardinality of a set, Concept of Countable and Uncountable set.

Unit-3
Relation: Cartesian Product of sets. Composition of relations, Types of relations, Partitions,

Equivalence Relations, Examples of congruence modulo relation and examples in $\mathbb{Z}$. Binary operations on set, Functions.

Unit-4
Partial ordering relations, Poset, n-ary relations, Hasse diagram, greatest and least element in a poset. Lattice, distributive lattice.

Reference Books

1. R.P. Grimaldi, Discrete and combinatorial mathematics: An Applied Introduction, Pearson Education, 2004.
2. P.R. Halmos, Naive Set Theory, Springer, 1974.
3. E. Kamke, Theory of Sets, Dover Publishers, 1950.

IAPC
Internship/Apprenticeship/Project/Community Outreach
Credit: 2
Full Marks: 25

Respective college will decide which course to offer.

SEMESTER III

Duration: 6 Months (Including Examinations)
Total 20 credits (Marks: 275)
Total No. of Lectures: ** Hours per paper

Semester	Course Code	Course Name	Marks (Credits)
III	MTMMJ-MC-05	Real Analysis II	50 (4)
	MTMMJ-MC-06	Linear Algebra	50 (4)
	MDC-3	##########	50 (3)
	MTMMN-MnC-03	Calculus & Differential Equation	50 (4)
	AEC	English Language I	25 (2)
	MTMMJ-SEC-03	Graph Theory	50 (3)

MTMMJ-MC-05
Real Analysis II
Credit: 4
Full Marks: 50 (IA: 10, SE: 40)

Unit-1

Properties of monotone functions. Functions of bounded variation, total variation, continuous functions of bounded variation. Curves and paths, rectifiable paths and arc length.

Unit-2

Riemann integration: upper and lower sums, upper and lower integral, definition and conditions of integrability. Riemann integrability of monotone and continuous functions, elementary properties of the Riemann integral. Intermediate Value theorems for Integrals. Fundamental theorem of Integral Calculus, change of variables.

Unit-3

Periodic function, Fourier coefficient and Fourier series, convergence, Bessel's inequality, Parseval's inequality, Dirichlet's condition, example of Fourier series. Improper integrals: Range of integration, finite or infinite. Necessary and sufficient condition for convergence of improper integral. Tests of convergence : Comparison and M-test. Absolute and non-absolute convergence and interrelations. Statement of Abel's and Dirichlet's test for convergence on the integral of a product. Convergence of Beta and Gamma function and their inter-relation.

Unit-4

Pointwise and uniform convergence of sequence of functions. Theorems on continuity, differentiability and integrability of the limit function of a sequence of functions. Series of functions; Theorems on the continuity and differentiability of the sum function of a series of functions; Cauchy criterion for uniform convergence and Weierstrass M-Test.

Reference Books

1. R. Bartle and D.R. Sherbert, Introduction to Real Analysis, John Wiley and Sons, 2003.
2. K.A. Ross, Elementary Analysis: The Theory of Calculus, Springer, 2004.

3. A. Mattuck, Introduction to Analysis, Prentice Hall, 1999.
4. S.R. Ghorpade and B.V. Limaye, A Course in Calculus and Real Analysis, Springer, 2006.
5. T.M. Apostol, Mathematical Analysis, Narosa Publishing House
6. R. Courant and F. John, Introduction to Calculus and Analysis, Vol II, Springer
7. W. Rudin, Principles of Mathematical Analysis, McGraw Hill, 2017.
8. T. Tao, Analysis II, Hindustan Book Agency, 2006.
9. S. Shirali and H.L. Vasudeva, Metric Spaces, Springer, 2006.
10. G.G. Bilodeau , P.R. Thie and G.E. Keough, An Introduction to Analysis, 2nd Ed., Jones & Bartlett, 2010.
11. B.S. Thomson, A.M. Bruckner and J.B. Bruckner, Elementary Real Analysis,Prentice Hall, 2001.
12. C.C. Pugh, Real Mathematical Analysis, Springer, 2002.
13. H.R. Beyer, Calculus and Analysis, Wiley, 2010.
14. S.K. Berberian, A First Course in Real Analysis, Springer Verlag, New York, 1994.
15. S. Goldberg, Calculus and Mathematical Analysis.
16. G.F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, 2004.
17. S. Lang, Undergraduate Analysis, 2nd Ed., Springer, 1997.

MTMMJ-MC-06
Linear Algebra
Credit: 4
Full Marks: 50 (IA: 10, SE: 40)

Unit-1
Definition and examples of vector spaces, subspaces, linear combination of vectors, linear span, linear dependence and independence, bases and dimension.

Unit-2
Linear transformations, null space, range, rank and nullity of a linear transformation, matrix representation of a linear transformation, algebra of linear transformations. Isomorphisms. Isomorphism theorems, invertibility and isomorphisms, change of coordinate matrix.

Unit-3
Linear operator and its eigen-value and eigen-vectors, characteristic equation, eigenspace, algebraic and geometric multiplicity of eigenvalues. Diagonalization, conditions for diagonalizability. Invariant subspace and Cayley-Hamilton theorem, simple application of Caley-Hamilton theorem.

Unit-4
Inner products and norms, special emphasis on Euclidean spaces. Orthogonal and orthonormal vectors, Gram-Schmidt orthogonalisation process, orthogonal complements. The adjoint of a linear operator, unitary, orthogonal and normal operators.

Reference Books

1. S.H. Friedberg, A.J. Insel and L.E. Spence, Linear Algebra, 4th Ed., PHI, 2004.
2. J.B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.
3. M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.
4. A.R. Rao and P. Bhimasankaram, Linear Algebra, Hindustan Book Agency, 2000.
5. S. Lang, Introduction to Linear Algebra, 2nd Ed., Springer, 2005.
6. G. Strang, Linear Algebra and its Applications, Thomson, 2007.
7. S. Kumaresan, Linear Algebra- A Geometric Approach, PHI, 1999.
8. K. Hoffman and R.A. Kunze, Linear Algebra, 2nd Ed., PHI, 1971.
9. S. Axler, Linear Algebra Done Right, Springer, 2014.
10. S.J. Leon, Linear Algebra with Applications, Pearson, 2015.
11. J.S. Golan, Foundations of Linear Algebra, Springer, 1995.

MTMMN-MnC-03
Calculus & Differential Equations
Credit: 4
Full Marks: 50 (IA: 10, SE: 40)

Calculus

Unit-1

Set, relation, mapping. Real number system, the algebraic and order properties of $\mathbb{R}$. The least upper bound property of real numbers, the Archimedean property.

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 and its application.

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

Unit-2

Real function, the limit of a function, basic limit theorems. Definition of continuity, composite function and continuity, intermediate value property, the process of inversion, the extreme value theorem for continuous function.

Derivative of a function, algebra of derivatives, geometric interpretation of derivative as a slope, chain rule. Successive differentiation.

Mean value theorems for derivatives, Rolle's theorem and Lagrange's mean value theorem. 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, $\sin x$, $\cos x$, $(1+x)^n$, $\log(1+x)$ with restrictions wherever necessary. Indeterminate Forms: L'Hospital's Rule: Statement and Problems

only. Application of the principle of local extrema for a function of single variable in geometrical, physical and to other problems.

Unit -3

Evaluation of definite integrals. Integration as the limit of a sum (with equally spaced as well as unequal intervals), Riemann's definition for definite integrals. Fundamental theorem of calculus and its applications.

Reduction formulae of $\int \sin^n x \cos^m x \, dx$, $\int \frac{\sin^n x}{\cos^m x} \, dx$, $\int \tan^n x \, dx$ and associated problems (m and n are non-negative integers).

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

Differential Equations

Unit-4

Order, degree and solution of an ordinary differential equation (ODE) in presence of arbitrary constants, Formation of ODE. Solution of first order ODE, exact and non exact equations.

First order linear equations, Euler's and Bernoulli's equations. Nonlinear equations: Clairaut's equations, general and singular solutions.

Second order linear equations: Linear homogeneous equations with constant coefficients, Linear non-homogeneous equations, The method of variation of parameters, The Cauchy-Euler equation.

Reference Books

1. G.B. Thomas and R.L. Finney, Calculus, 9th Ed., Pearson Education, Delhi, 2005.
2. G.F. Simmons, Differential Equations with Applications and Historical Notes, Tata McGraw Hill.
3. M.J. Strauss, G.L. Bradley and K. J. Smith, Calculus, 3rd Ed., Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2007.
4. H. Anton, I. Bivens and S. Davis, Calculus, 7th Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.
5. R. Courant and F. John, Introduction to Calculus and Analysis (Volumes I & II), Springer-Verlag, New York, Inc., 1989.
6. T.M. Apostol, Calculus, Volume I and II, Wiley.
7. R.R. Goldberg, Methods of Real Analysis, Oxford and Ibh, 2012.
8. K.A. Ross, Elementary Analysis: The Theory of Calculus, Springer, 2nd ed., 2013.
9. D. Murray, Introductory Course in Differential Equations, Longmans Green and Co.
10. S.L. Ross, Differential Equations, 3rd Ed., John Wiley and Sons, India, 2004.
11. S. Lang, A First Course in Calculus, Springer.

MTMMJ-SEC-03
Graph Theory
Credit: 3
Full Marks: 50 (IA: 10, SE: 40)

Unit-1
Definition, examples and basic properties of graphs, pseudo graphs, complete graphs, bipartite graphs, isomorphism of graphs. Paths and cycles.

Unit-2
Eulerian circuits, Eulerian graph, Hamiltonian cycles and related theorems, Representation of a graph by matrix, the adjacency matrix, incidence matrix.

Unit-3
Weighted graph, Travelling salesman's problem, Chinese postman problem, shortest path, Dijkstra's algorithm, Floyd-Warshall algorithm, Bellman-Ford Algorithm.

Unit-4
Tree forest and their properties, spanning tree, Minimum spanning tree algorithms, Kruskal's algorithm, Connectivity, matching in bipartite graphs, matching in general graphs.

Reference Books

1. J. Clark and D.A. Holton, A First Look at Graph Theory, World Scientific, 2005.
2. D.S. Malik, M.K. Sen and S. Ghosh, Introduction to Graph Theory, Cengage Learning Asia, 2014.
3. E.G. Goodaire and M.M. Parmenter, Discrete Mathematics with Graph Theory, 3rd Edition, Pearson Education India, 2015.
4. N Deo, Graph Theory with Applications to Engineering and Computer Science, Prentice-Hall of India, 1979.
5. J.A. Bondy and U.S.R. Murty, Graph Theory with Applications, Macmillan, 1976.
6. R. Diestel, Graph Theory, Springer-Verlag, 2000.
7. F. Harary, Graph Theory, Narosa, 2001.
8. D.B. West, Introduction to Graph Theory, Prentice Hall, 1996.
9. R.J. Wilson, Introduction to Graph Theory, 3rd Ed., Longman, 1985.

SEMESTER IV

Duration: 6 Months (Including Examinations)
Total 18+2** credits (Marks: 225+25**)
Total No. of Lectures: ** Hours per paper

Semester	Course Code	Course Name	Marks (Credits)
IV	MTMMJ-MC-07	Multivariate Calculus & Vector Calculus	50 (4)
	MTMMJ-MC-08	Differential Equations	50 (4)
	MTMMJ-MC-09	Mechanics	50 (4)
	MTMMN-MnC-04	Calculus & Differential Equation	50 (4)
	AEC	English Language II	25 (2)
	IAPC	Internship/Apprenticeship/ Project/Community Outreach	25 (2)**

MTMMJ-MC-07
Multivariate Calculus & Vector Calculus
Credit: 4
Full Marks: 50 (IA: 10, SE: 40)

Unit-1

Functions of several variables, limit and continuity of functions of two or more variables, directioal derivatives and partial derivatives, Schwartz's and Young's theorem and Euler's theorem for homogenous function, total differentiability and Jacobian, sufficient condition for differentiability, Chain rule, Mean value theorem, Taylor's theorem, Implicit function theorem(statement only), the gradient, tangent planes. Extrema of functions of two variables, method of Lagrange multipliers, constrained optimization problems.

Unit-2

Double integration over rectangular region, double integration over non-rectangular region, changing the order of integration. Triple integrals, Triple integral over a parallelepiped and solid regions. Volume by triple integrals, cylindrical and spherical co-ordinates. Change of variables in double integrals and triple integrals.

Unit-3

Triple product, introduction to vector fields, operations with vector-valued functions, limits and continuity of vector functions, differentiation of vector valued function, gradient, divergence and curl.

Unit-4

Curves and their parameterization, line integration of vector functions, circulation. Surface and volume integration. Gauss's theorem, Green's theorem, Stokes' theorem and their applications.

Reference Books

1. G.B. Thomas and R.L. Finney, Calculus, 9th Ed., Pearson, 2005.
2. M.J. Strauss, G.L. Bradley and K.J. Smith, Calculus, 3rd Ed., Pearson, 2007.

3. J.E. Marsden, A.J. Tromba and A. Weinstein, Basic Multivariable Calculus, Springer, 2005.

4. J. Stewart, Multivariable Calculus, Concepts and Contexts, 4nd Ed., Cengage Learning, 2009.

5. T.M. Apostol, Mathematical Analysis, Narosa, 2002.

6. S.R. Ghorpade and B.V. Limaye, A Course in Multivariable Calculus and Analysis, Springer, 2010.

7. R. Courant and F. John, Introduction to Calculus and Analysis (Vol. II), Springer, 1999.

8. W. Rudin, Principles of Mathematical Analysis, McGraw Hill, 2017.

9. J.E. Marsden and A.J. Tromba, Vector Calculus, W.H. Freeman, 1996.

10. T. Tao, Analysis II, Hindustan Book Agency, 2006.

11. M.R. Speigel, S. Lipschutz and D. Spellman, Schaum's outline: Vector Analysis, McGraw Hill, 2017.

12. C.E. Weatherburn, Elementary Vector Analysis: With Application to Geometry and Physics, CBS Ltd., 1926.

MTMMJ-MC-08
Differential Equations
Credit: 4
Full Marks: 50 (IA: 10, SE: 40)

Unit-1
Exact, linear and Bernoulli's equations. Equations not of first degree, Clairaut's equations, singular solution. Existance & Uniqueness theorem for first order IVP, Picard's Theorem (Statement only). General solution of homogeneous equation of second order, principle of super position for homogeneous equation, Wronskian and its properties. Linear homogeneous and non-homogeneous equations of higher order with constant coefficients, Euler's equation, method of undetermined coefficients, method of variation of parameters, Eigenvalue problem.

Unit-2
Systems of linear differential equations, types of linear systems, differential operators, an operator method for linear systems with constant coefficients, Basic theory of linear systems in normal form, homogeneous linear systems with constant coefficients: Two equations in two unknown functions. Equilibrium points, Interpretation of the phase plane.

Unit-3
Power series solution of a differential equation about an ordinary point, solution about a regular singular point. Legendre polynomials, Bessel functions of the first kind and their properties.

Unit-4
Partial differential equations, basic concepts and definitions. First-order equations: classification, construction and geometrical interpretation. Method of characteristics for obtaining general solution of quasi linear equations. Canonical forms of first-order linear equations. Solution by Lagrange's and Charpit's method.

Reference Books

1. G.F. Simmons, Differential Equations with Applications and Historical Notes, McGraw Hill, 2017.
2. S.L. Ross, Differential Equations, 3rd Ed., Wiley, 2007.
3. C.H. Edwards and D.E. Penny, Differential Equations and Boundary Value Problems Computing and Modeling, Pearson, 2005.
4. M.L. Abel and J.P. Braselton, Differential Equations with MATHEMATICA, 3rd Ed., Elsevier, 2004.
5. D. Murray, Introductory Course in Differential Equations, Orient Longman, 2003.
6. W.E. Boyce and R.C. Diprima, Elementary Differential Equations and Boundary Value Problems, Wiley, 2009.
7. E.A. Coddington, An Introduction to Ordinary Differential Equations, Dover Publications Inc., 1989.
8. H.T.H. Piaggio, Elementary Treaties on Differential Equations and their Applications, G. Bell and Sons, 1920.
9. I.N. Sneddon, Elements of Partial Differential equations, McGraw-Hill, 1957.
10. T. Myint-U and L. Debnath, Linear Partial Differential Equations for Scientists and Engineers, 4th Ed., Springer, 2006.
11. F.H. Miller, Partial Differential Equations, John Wiley & Sons, 1941.

MTMMJ-MC-09
Mechanics
Credit: 4
Full Marks: 50 (IA: 10, SE: 40)

Unit-1

Kinematics of a particle: Velocity, acceleration, angular velocity, linear and angular momentum. Relative velocity and acceleration. Expressions for velocity and acceleration in case of rectilinear motion and planar motion in Cartesian and polar coordinates, tangential and normal components. Uniform circular motion.

Newton laws of motion and law of gravitation: Space, time, mass, force, inertial reference frame, principle of equivalence and g. Vector equation of motion.

Unit-2

Work, power, kinetic energy, conservative forces-potential energy. Existence of potential energy function.
Energy conservation in a conservative field. Stable equilibrium and small oscillations: Approximate equation of motion for small oscillation. Impulsive forces

Unit-3

Problems in particle dynamics: Rectilinear motion in a given force field - vertical motion under uniform gravity, inverse square field, constrained rectilinear motion, vertical motion under gravity in a resisting medium, simple harmonic motion, Damped and forced oscillations, resonance of an oscillating system, motion of elastic strings and springs.

Unit-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. Equations of motion referred to a set of rotating axes.

Reference Books

1. R.D. Gregory, Classical Mechanics, Cambridge University Press, 2006.
2. K.R. Symon, Mechanics, Addison Wesley, 1971.
3. M. Lunn, A First Course in Mechanics, Oxford University Press, 1991.
4. J.L. Synge and B.A. Griffith, Principles of Mechanics, Mcgraw Hill, 1949.
5. T.W.B. Kibble, F.H. Berkshire, Classical Mechanics, Imperial College Press, 2004.
6. D.T. Greenwood, Principle of Dynamics, Prentice Hall, 1987.
7. F. Chorlton, Textbook of Dynamics, E. Horwood, 1983.
8. D. Kleppner and R. Kolenkow, Introduction to Mechanics, Mcgraw Hill, 2017.
9. A.P. French, Newtonian Mechanics, Viva Books, 2011.
10. S.P. Timoshenko and D.H. Young, Engineering Mechanics, Schaum Outline Series, 4th Ed., 1964.
11. D. Chernilevski, E. Lavrova and V. Romanov, Mechanics for Engineers, MIR Publishers, 1984.
12. I.H. Shames and G.K.M. Rao, Engineering Mechanics: Statics and Dynamics, 4th Ed., Pearson, 2009.
13. R.C. Hibbeler, Engineering Mechanics: Statics and Dynamics, 11th Ed., Pearson, 2011.
14. S.L. Loney, An Elementary Treatise on the Dynamics of Particle and of Rigid Bodies, Cambridge University Press, 2017.
15. S.L. Loney, An Elementary Treatise on Statics, Cambridge University Press, 2016.
16. R.S. Verma, A Textbook on Statics, Pothishala, 1962.
17. A.S. Ramsey, Dynamics (Part I & II), Cambridge University Press, 1952.

MTMMN-MnC-04
Calculus & Differential Equations
Credit: 4
Full Marks: 50 (IA: 10, SE: 40)

Calculus

Unit-1

Set, relation, mapping. Real number system, the algebraic and order properties of $\mathbb{R}$. The least upper bound property of real numbers, the Archimedean property.

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 and its application.

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

Unit-2
Real function, the limit of a function, basic limit theorems. Definition of continuity, composite function and continuity, intermediate value property, the process of inversion, the extreme value theorem for continuous function.

Derivative of a function, algebra of derivatives, geometric interpretation of derivative as a slope, chain rule. Successive differentiation.

Mean value theorems for derivatives, Rolle's theorem and Lagrange's mean value theorem. 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, $\sin x$, $\cos x$, $(1+x)^n$, $\log(1+x)$ with restrictions wherever necessary. Indeterminate Forms: L'Hospital's Rule: Statement and Problems only. Application of the principle of local extrema for a function of single variable in geometrical, physical and to other problems.

Unit -3
Evaluation of definite integrals. Integration as the limit of a sum (with equally spaced as well as unequal intervals), Riemann's definition for definite integrals. Fundamental theorem of calculus and its applications.

Reduction formulae of $\int \sin^n x \cos^m x\, dx$, $\int \frac{\sin^n x}{\cos^m x}\, dx$, $\int \tan^n x\, dx$ and associated problems (m and n are non-negative integers).

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

Differential Equations
Unit-4
Order, degree and solution of an ordinary differential equation (ODE) in presence of arbitrary constants, Formation of ODE. Solution of first order ODE, exact and non exact equations.

First order linear equations, Euler's and Bernoulli's equations. Nonlinear equations: Clairaut's equations, general and singular solutions.

Second order linear equations: Linear homogeneous equations with constant coefficients, Linear non-homogeneous equations,The method of variation of parameters, The Cauchy-Euler equation.

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3. M.J. Strauss, G.L. Bradley and K. J. Smith, Calculus, 3rd Ed., Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2007.

4. H. Anton, I. Bivens and S. Davis, Calculus, 7th Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.

5. R. Courant and F. John, Introduction to Calculus and Analysis (Volumes I & II), Springer-Verlag, New York, Inc., 1989.

6. T.M. Apostol, Calculus, Volume I and II, Wiley.

7. R.R. Goldberg, Methods of Real Analysis, Oxford and Ibh, 2012.

8. K.A. Ross, Elementary Analysis: The Theory of Calculus, Springer, 2nd ed., 2013.

9. D. Murray, Introductory Course in Differential Equations, Longmans Green and Co.

10. S.L. Ross, Differential Equations, 3rd Ed., John Wiley and Sons, India, 2004.

11. S. Lang, A First Course in Calculus, Springer.

IAPC
Internship/Apprenticeship/Project/Community Outreach
Credit: 2
Full Marks: 25

Respective college will decide which course to offer.