Choice based Credit System (CBCS)
Scheme and course structure for
M.A/M.Sc Mathematics 4th semester effective from academic session 2015 and onwards

Course Code	Course Name	Credits
MM14401CR	Partial Differential Equations	4
MM14402CR	Differential Geometry	4
MM14403CR	Advanced Abstract Algebra-II	4

OPTIONAL COURSES (SEMESTER –IV)

Course Code	Course Name	Credits
MM14404EA	Analytic Theory of Polynomials	4
MM14405EA	Mathematical Statistics	4
MM14406EA	Functional Analysis-II	4
MM14407EA	Non-Linear Analysis	4
MM14408EA	Advanced Topics in Topology and Modern Analysis	4
MM14409EA	Project	4
MM14410EO	Other Allied + Open	

General Instructions for the Candidates

1. The two year (4 semester) PG programmes is of 96 credit weightage i.e., 24 credits/semester (24x4=96).
2. A candidate has compulsory to opt for 12 credits from the core component in each semester.
3. A candidate has a choice to opt for any 12 credits(3 papers) out of minimum of 16 credits(4 papers) offered as Electives(Allied), except for a particular semester as mentioned by the Department where a candidate is required to gain a minimum of 4 credits(1 paper) from Elective(Open) offered by any other Department.
4. A candidate has compulsorily to obtain a minimum of 4 credits (1 paper) from Elective (Open) from outside the parent Department in any of the semesters.
5. A candidate can earn more than the minimum required credits (i.e., more than 96 credits for four semester programme) which shall be counted towards the final result of the candidate.
6. Project will consists of two components:
   a) Writing of Dissertation on a certain chosen topic.
   b) Viva-Voce.

   (Each component will carry 50 marks).
7. The Academic Tour shall be conducted by the Department every year for outgoing students (4th semester).

Course No: **MM14401CR**	Max. Marks: 100
Course Name:- Partial Differential Equations	
Duration of Examination: 2:30 Hrs.	External Exam: 80
No. of Credits: **04**	Internal Assessment: 20

CREDIT-I

Introduction to partial differential equations; partial differential equations of first order; linear and non-linear partial differential equations; Lagrange's method for the solution of linear partial differential equations; Charpits method and Jacobi methods for the solution of non-linear partial differential equations; Initial-value problems for Quasi-linear first-order equations; Cauchy's method of characteristics.

CREDIT-II

Origin of second order partial differential equations; linear partial differential equations with constant coefficients; Methods for solution second order partial differential equations; classification of second order partial differential equations; canonical forms; adjoint operators; Riemann's method; Monge's method for the solution of non-linear partial differential equations.

CREDIT-III

Derivation of Laplace and Heat equations; Boundary value problems; Drichlet's and Neumann problems for a circle and sphere; Solutions by separation of variables method; cylindrical coordinates and spherical polar coordinate system; Maximum-Minimum principle; Uniqueness theorem; Sturm-Liouville Theory.

CREDIT-IV

Derivation of wave equation; D'Alembert's solution of one dimensional wave equation; Separation of variables method; periodic solutions; method of eigen functions; Duhamel's principle for wave equation; Laplace and Fourier transforms and their applications to partial differential equations; Green function method and its applications.

References

1. Robert C. McOwen; Partial Differential Equations-Methods and Applications, Pearson Education, Delhi, 2004.
2. L.C. Evans; Partial Differential Equations, GTM, AMS, 1998
3. Diran Basmadjian; The Art of Modelling in Science and Engineering, Chapman & Hall/CRC, 1999.
4. E. DiBenedetto, Partial Differential Equations, Birkhauser, Boston, 1995.
5. F. John, Partial Differential Equations, 3rd ed., Narosa Publ. Co., New Delhi,1979.
6. E. Zauderer, Partial Differential Equations of Applied Mathematics, 2nd ed., John Wiley and Sons, New York, 1989

Course No**: MM14402CR**		Max. Marks:	100
Course Name:- Differential Geometry			
Duration of Examination: 2:30 Hrs.		External Exam:	80
No. of Credits: **04**		Internal Assessment:	20

CREDIT-I

Curves: Differentiable curves, Regular point, Parameterization of curves, arc-length, and arc-length is independent of parameterization, unit speed curves. Plane curves: Curvature of plane curves, osculating circle, centre of curvature. Computation of curvature of plane curves. Directed curvature, Examples: Straight line, circle, ellipse, tractrix, evolutes and involutes. Space curves: Tangent vector, unit normal vector and unit binormal vector to a space curve. Curvature and torsion of a space curve. The Frenet-Serret theorem. First Fundamental theorem of space curves. Intrinsic equation of a curve. Computation of curvature and torsion. Characterization of Helices and curves on sphere in terms of their curvature and torsion. Evolutes and involutes of space curves**.**

CREDIT-II

Surfaces; Regular surfaces with examples, coordinate charts or curvilinear coordinates, change of coordinates, tangent plane at a regular point, normal to the surface, orient able surface, differentiable mapping between regular surfaces and their differential. Fundamental form or a metric of a surface, line element, invariance of a line element under change of coordinates, angle between two curves, condition of orthogonality of coordinate curves. Area of bounded region, invariance of area under change of coordinates.

CREDIT-III

urvature of a Surface: Normal curvature, Euler's work on principal curvature,. Qualitative behavior of a surface near a point with prescribed principal curvatures. The Gauss map and its differential. The differential of Gauss is self-adjoint. Second fundamental form. Normal curvature interms of second fundamental form. Meunier theorem. Gaussian curvature, Weingarten equation. Gaussian curvature K(p)= (eg-f2)/EG-F2 .surface of revolution. Surfaces with constant positive or negative Gaussian curvature. Gaussian curvature in terms of area. Line of curvature, Rodrigue's formula for line of curvature, Equivalence of Surfaces: Isometry between surfaces, local isometry, and characterization of local isometry.

CREDIT-IV

Christoffel symbols. Expressing Christoffel symbols in terms of metric coefficients and their derivative. Theorema egrerium (Gaussian curvature is intrinsic). Isometric surfaces have same Gaussian curvatures at corresponding points. Gauss equations and Manardi Codazzi equations for surfaces. Fundamental theorem for regular surface. (Statement only).

Geodesics: Geodesic curvature, Geodesic curvature is intrinsic, Equations of Geodesic, Geodesic on sphere and pseudo sphere. Geodesic as distance minimizing curves. Gauss-Bonnet theorem (statement only).Geodesic triangle on sphere. Implication of Gauss-Bonnet theorem for Geodesic triangle.

Recommended Books:

1. John Mc Cleary: Geometry from a differentiable Viewpoint. (Cambridge Univ. Press**)**

Suggested Readings:

1. W. Klingenberg: A course in Differential Geometry (Spring Verlag)
2. C.E. Weatherburn: Differential Geometry of Three dimensions.
3. T. Willmore : An Introduction to Differential Geometry
4. J. M. Lee : Riemannian Manifolds, An Introduction to Curvature (Spri

Course No: **MM14403CR**	Max. Marks:	100
Course Name:- Advanced Abstract Algebra—II		
Duration of Examination: 2:30 Hrs.	External Exam:	80
No. of Credits: **04**	Internal Assessment:	20

CREDIT-I

Relation and Ordering, partially ordered sets, Lattices, properties of Lattices, Lattices as algebraic Systems, sub-lattices, direct product and homomorphism, Modular Lattices, complete Lattices, bounds of Lattices, Distributive Lattice, Complemented Lattices.

CREDIT-II

Modules, Sub-modules, Quotient Modules, Homomorphism and Isomorphism theorem. Cyclic Modules, Simple Modules, Semi-Simple Modules, Schuler's Lemma, Free Modules. Ascending chain condition and Maximum condition, and their equivalence. Descending chain condition and Minimum condition, and their equivalence. direct sums of modules. Finitely generated modules.

CREDIT-III

Fields: Prime fields and their structure, Extensions of fields, Algebraic numbers and Algebraic extensions of a field, Roots of polynomials, Remainder and Factor theorems, Splitting field of a polynomial, Existence and uniqueness of splitting fields of polynomials , Simple extension of a field.

CREDIT-IV

Separable and In-separable extensions, The primitive element theorem, Finite fields, Perfect fields, The elements of Galois theory. Automorphisms of fields, Normal extensions, Fundamental theorem of Galois theory, Construction with straight edge and compass, R^n is a field iff $n = 1, 2$.

Recommended Books:

1. I.N.Heristein : Topics in Algebra.
2. K.S.Miller : Elements of Modern Abstract Algera.
3. Surjeet Singh and Qazi Zameer-ud-din: Modern Algebra, Vikas Publishers Pvt. Limited.

Course No: **MM14404EA**		Max. Marks:	100
Course Name:- Analytic Theory of Polynomials			
Duration of Examination: 2:30 Hrs.		External Exam:	80
No. of Credits: **04**		Internal Assessment:	20

CREDIT-I

Introduction, The fundamental theorem of algebra(Revisited) Symmetric polynomials, The Continuity theorem, Orthogonal Polynomials, General Properties, The Classical Orthogonal Polynomials, Tools from Matrix Analysis.

CREDIT-II

Critical points in terms of zeros, Fundamental results and critical points, Convex Hulls and Gauss-Lucas theorem, Some applications of Gauss-Lucas theorem. Extensions of Gauss-Lucas theorem, Average distance from a line or a point. Real polynomials and Jenson's theorem, Extensions of Jenson's theorem.

CREDIT-III

Derivative estimates on the unit interval, Inequalities of S. Bernstein and A. Markov , Extensions of higher order derivatives, Two other extensions, Dependence of the bounds on the zeros, Some special classes, L^p analogous of Markov's inequality.

CREDIT-IV

Coefficient Estimates, Polynomials on the unit circles. Coefficients of real trigonometric polynomials. Polynomials on the unit interval.

Recommended Books:

1. Analytic theory of Polynomials by Q.I. Rahman and G.Schmeisser.

2. Geometry of polynomials by Morris Marden.

3. Topics in polynomials :extremal properties, problems, inequalities, zeroes by
4. 4. G.V.Milovanovic,D.S.Mitrinovic and Th. M. Rassias

5.Problems and theorems in Analysis II by G.Polya and G.Szego (Springer

Verlag New York Heidelberg Berlin).

Course No: **MM14405EA**		Max. Marks:	100
Course Name:- Mathematical Statistics			
Duration of Examination: 2:30 Hrs.		External Exam:	80
No. of Credits: **04**		Internal Assessment:	20

CREDIT-I

Some Special Distributions, Bernoulli, Binomial, Trinomial, Multinomial, Negative Binomial, Poisson, Gamma, Chi-square, Beta, Cauchy, Exponential, Geometric, Normal and Bivariate Normal Distributions.

CREDIT-II

Distribution of Functions of Random Variables, Distribution Function Method, Change of Variables Method, Moment generating function Method, t and F Distributions, Dirichelet Distribution, Distribution of Order Statistics, Distribution of X and $\frac{nS^2}{\sigma^2}$, Limiting distributions, Different modes of convergence, Central Limit theorem.

CREDIT-III

Interval Estimation, Confidence Interval for mean, Confidence Interval for Variance, Confidence Interval for difference of means and Confidence interval for the ratio of variances. Point Estimation, Sufficient Statistics, Fisher-Neyman criterion, Factorization Theorem, Rao- Blackwell Theorem, Best Statistic (MvUE), Complete Sufficient Statistic, Exponential class of pdfs.

CREDIT-IV

Rao-Crammer Inequality, Efficient and Consistent Estimators, Maximum Likelihood Estimators (MLE's).Testing of Hypotheses, Definitions and examples, Best or Most powerful (MP) tests, Neyman Pearson theorem, Uniformly most powerful (UMP) Tests, Likelihood Ratio Test, Chi-square Test.

Recommended Books

1. Hogg and Craig : An Introduction to Mathematical Statistics
2. Mood and Grayball : An Introduction to Mathematical Statistics

Suggested Readings:

1. C.R.Rao : Linear Statistical Inference and its Applications
2. V.K.Rohatgi : An Introduction to Probability and Statistics.

Course No. **MM14406EA**		Max. Marks:	100
Course Name:- Functional Analysis-II			
Duration of Examination: 2:30 Hrs.		External Exam:	80
No. of Credits: **04**		Internal Assessment:	20

CREDIT-I

Relationship between analytic and geometric forms of Hahn-Banach Theorem, Applications of Hahn-Banach Theorem: Banach limits, Markov-Kakutani theorem for a commuting family of maps, Complemented subspaces of Banach spaces, Complentability of dual of a Banach space in its bidual, uncomplementability of co in l_∞.

CREDIT-II

Dual of Subspaces, Quotient spaces of a normed linaedr space. Weak and Weak* topologies on a Banach space, Goldstine's theorem, Banach Alaoglu theorem and its simple consequences. Banch's closed range theorem, injective and surjective bounded linear mappings between Banach spaces.

CREDIT-III

l_∞ and C[0,1] as universal separable Banach spaces, l_1 as quotient universal seperable Banach spaces, Reflexivity of Banach spaces and weak compactness, Completeness of Lp[a,b]. Extreme points, Krein-Milman theorem and its simple consequences.

CREDIT-IV

Dual of l_∞ , C(X) and L_p spaces. Mazur-Ulam theorem on isometries between real normed spaces, Muntz theoremin C[a,b].

Recommended Books:

1. J. B. Conway; A First Course in Functional Analysis (Springer Verlag).
2. R.E. Megginson; An Introduction to Banach Space theory (Springer Verlag, GTM, Vol. 183)
3. Lawrence Bagget; Functional Analysis, A Primer (Chapman and Hall, 1991).

Reference Books:

1. Ballobas, B; Linear Analysis (Camb. Univ.Pres)
2. Beauzamy, B; Introduction to Banach Spaces and their geometry (North Holland).
3.. Walter Rudin; Functional Analysis (Tata McGrawHill).

Course No: **MM14407EA**		Max. Marks:	100
Course Name:- Non Linear Analysis			
Duration of Examination: 1:15 Hrs.		External Exam:	80
No. of Credits: **04**		Internal Assessment:	20

CREDIT-I

Convex Sets, Best Approximation Properties, Topological Properties, Separation, Nonexpansive Operators, Projectors onto Convex Sets, Fixed Points of Nonexpansive Operators, Averaged Nonexpansive Operators, Fejer Monotone Sequences, Convex Cones, Generalized Interiors, Polar and Dual Cones, Tangent and Normal Cones, Convex Functions: Variants,: Between Linearity and Convexity, Uniform and Strong Convexity, Quasiconvexity

CREDIT-II

Gateaux Derivative, Frechet Derivative, Lower semicontinuous Convex Functions, Subdifferential of Convex Functions, Directional Derivatives, Characterization of Convexity and Strict Convexity, Directional Derivatives and Subgradients, Gateaux and Frechet Differentiability, Differentiability and Continuity

CREDIT-III

Monotone Operators, Strong Notions of Monotonicity such as Para, Cyclic, Strict, Uniform and Strong Monotonicity, Maximal Monotone Operator and their Properties, Bivariate Functions and Maximal Monotonicity, Debrunner-Flor Theorem, Minty Theorem, Rockfeller's Cyclic Monotonicity Theorem, Monotone Operators on *R*.

CREDIT-III

Reisz-Representation Theorem, Projection Mappings and their Properties, Characterization of Projection onto Convex sets and their Geometrical Interpretation,

Billinear Forms and its Applications, Lax-Milgram Lemma, Minimization of Functionals,Variational Inequalities, Relationship Between Abstract Minimization Problems and Variational Inequalities, Lions Stampacchia Theorem for Existence of Solution of Variational Inequality.

Book Recommended:

1. Bauschke, H. H. and Combettes, P.L.: Convex Analysis and Monotone Operator Theory in Hilbert Spaces, Springer New York, 2011.
2. D. Kinderlehrer and G. Stampacchia, An Introduction to Variational Inequalities and Their Applications, Academic Press, New York, 1980.
3. Siddiqi, A.H., . Ahmed, K and Manchanda, P. Introduction to Functional Analysis with Applications, Anamaya Publishers, New Delhi-2006.

Reference Book:

1. Ekland, I and Temam R, Convex Analysis and Variational Problems: W.Takahashi, Nonlinear Functional Analysis, North-Holland Publishing Company-Ammsterdam, 1976.
2. Joshi, M.C. and Bose, R.K.: Nonlinear Functional Analysis and its Applications
   Willey Eastern Limited, 1985.

Course No. **MM14408EA**		Max. Marks:	100
Course Name:- Advanced Topics in Topology and Modern Analysis			
Duration of Examination: 2:30 Hrs.		External Exam:	80
No. of Credits: **04**		Internal Assessment:	20

CREDIT-I

Uniform spaces. Definition and examples, uniform topology, and metrizability complete regularity of uniform spaces, pre-compactness and compactness in uniform spaces, uniform continuity.

CREDIT-II

Uniform continuity, uniform continuous maps on compact spaces Cauchy convergence and completeness in uniform spaces, initial uniformity, simple applications to function spaces, Arzela- Ascoli theorem.

CREDIT-III

Abstract Harmonic Analysis, Definition of a topological group and its basic properties. Subgroups and quotient groups. Product groups and projective limits. Properties of topological groups involving connectedness. Invariant metrics and Kakutani theorem, Structure theory for compact and locally compact Abelian groups.

CREDIT-IV

Some special theory for compact and locally compact Abelian groups, Haar integral and Haar measure, invariant means defined for all bounded functions, convolution of functions and measures. Elements of representation theoy, Unitary representations of locally compact groups.

Recommended Books:

1. I.M. James Uniform Spaces, Springer Verlag.
2. K.D. Joshi, Introduction to General Topology.
3. S.K.Berberian, Lectures on Operator Theory and Functional Analysis, Springer Verlag.
4. G.B. Folland, Real Analysis, John Wiley.

Suggested Readings:

1. G. Murdeshwar, General Topology,

2. E. Hewitt & K.A Ross, Abstract harmonic Analysis-I, Springer Verlag.

Course No: **MM14409EA** Max. Marks: 100

Course Name:- Project

Duration of Examination: 2:30 Hrs. External Exam: 80

No. of Credits: **04** Internal Assessment: 20

Course No: **MM14410EO**	Max. Marks: 100
Course Name:- Open Elective	
Duration of Examination: 2:30 Hrs.	External Exam: 80
No. of Credits: **04**	Internal Assessment: 20