Choice based Credit System (CBCS)
Scheme and course structure for
M.A/M.Sc Mathematics 2nd semester effective from academic session 2014 and onwards

Course Code	***Course Name***	***Credits***
MM14201CR	Discrete Mathematics	4
MM14202CR	Real Analysis-II	4
MM14203CR	Complex Analysis-I	4

OPTIONAL COURSES (SEMESTER –II)

Course Code	***Course Name***	***Credits***
MM14204EA	Theory of Numbers-II	4
MM14205EA	Operations Research	4
MM14206EA	Fourier Analysis	4
MM14207EA	Linear Algebra	2
MM14208EA	Numerical Analysis	2
MM14209EA	Mathematical Modelling	2
MM14210EA	Integral Equations	2
MM14211EO	Other Allied + Open	4

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.

Course No: **MM14201CR**		Max. Marks:	100
Course Name:- **Discrete Mathematics**			
Duration of Examination: 2:30 Hrs.		External Exam:	80
No. of Credits: **04**		Internal Assessment:	20

CREDIT-I

Graphs, traversibility and degrees

Introduction of graphs, paths and cycles, operations on graphs, bipartite graphs and Konigs theorem, Euler graphs and Euler's theorem, Konigsberg bridge problem, Hamiltonian graphs and Dirac's theorem, degree sequences, Wang-Kleitman theorem, Havel-Hakimi theorem, Hakimi's theorem, Erdos-Gallai theorem, degree sets

CREDIT-II

Trees and Signed graphs

Trees and their properties, centres in trees, binary and spanning trees, degrees in trees, Cayley's theorem, fundamental cycles, generation of trees, Helly property, signed graphs, balanced signed graphs and characterizations

CREDIT-III

Connectivity and Planarity

Cut-sets and their properties, Vertex connectivity, edge connectivity, Whitney's theorem, Menger's theorem (vertex and edge form), properties of a bond, block graphs, Planar graphs, Kuratowski's two graphs, Embedding on a sphere, Euler's formula, Kuratowski's theorem, geometric dual, Whitney's theorem on duality, regular polyhedras,

CREDIT-IV

Matrices and Digraphs

Incidence matrix $A(G)$, modified incidence matrix A_f, cycle matrix $B(G)$, fundamental cycle matrix B_f, cut-set matrix $C(G)$, fundamental cut set matrix C_f, relation between A_f , B_f and C_f , path matrix, adjacency matrix, matrix tree theorem, Types of digraphs, types of connectedness, Euler digraphs, Hamiltonian digraphs, arborescence, matrices in digraphs, Camions theorem, tournaments, characterization of score sequences, Landau's theorem, oriented graphs and Avery's theorem.

References

1. R. Balakrishnan, K. Ranganathan, A Text Book of Graph Theory, Springer-Verlag, New York
2. B. Bollobas, Extremal Graph Theory, Academic Press,
3. F. Harary, Graph Theory, Addison-Wesley
4. Narsingh Deo, Graph Theory with Applications to Engineering and Computer Science, Prentice Hall
5. S. Pirzada, An Introduction to Graph Theory, Universities Press, OrientBlackswan, 2012
6. W. T. Tutte, Graph Theory, Cambridge University Press
7. D. B. West, Introduction to Graph Theory, Prentice Hall

Course No: **MM14202CR**	Max. Marks:	100
Course Name:- **Real Analysis-II**		
Duration of Examination: 2:30 Hrs.	External Exam:	80
No. of Credits: **04**	Internal Assessment:	20

CREDIT-I

Measure theory: Definition of outer measure and its basic properties, Outer measure of an interval as its length. Countable additivity of the outer measure, Borel measurable sets and Lebesgue measurability of Borel sets, Cantor set, existence of non- measurable sets and of measurable sets which are not Borel, Outer measure of monotonic sequences of sets.

CREDIT-II

Measurable functions and their characterization. Algebra of measurable functions, Stienhauss theorem on sets of positive measure, Ostrovisk's theorem on measurable solution of $f(x+y)= f(x) + f(y)$,$x,y \in R$. Convergence a.e., convergence in measure and almost uniform convergence, their relationship on sets of finite measure, Egoroff's theorem.

CREDIT-III

Lebesgue integral of a bounded function. Equivalence of L-integrability and measurability for bounded functions, Riemann integral as a Lebesgue integral, Basic properties of Lebesgue –integral of a bounded function. Fundamental theorem of calculus for bounded derivatives. Necessary and sufficient condition for Riemann inerrability on [a, b].L- integral of non- negative measurable functions and their basic properties.Fatou's lemma and monotone convergence theorem. L–integral of an arbitrary measurable function and basic properties. Dominated convergence theorem and its applications.

CREDIT-IV

Absolute continuity and bounded variation, their relationships and counter examples. Indefinite integral of a L-integrable functions and its absolute continuity. Necessary and sufficient condition for bounded variation. Vitali'scovering lemma and a.e. differentiability of a monotone function f and $\int f' \leq f(b)-f(a)$.

Recommended Books:

1. Royden, L. :Real Analysis (PHI).
2. Goldberg , R. : Methods of Real Analysis.
3. Barra,De. G. : Measure theory and Integration (Narosa).
4. Rana ,I.K. : An Introduction to Measure and Integration.
5. Rudin, W. Principles of Mathematical Analysis.
6. Chae, Lebesgue Integration.
7. T.M.Apostol : Mathematical Analysis.
8. S.M.Shah and Saxena : Real Analysis.

Course No: **MM14203CR** Max. Marks: 100
Course Name:- **Complex Analysis-I**
Duration of Examination: 2:30 Hrs. External Exam: 80
No. of Credits: **04** Internal Assessment: 20

CREDIT-I

Continuity and differentiability of complex functions, C-R equations and analytic functions. Necessary and sufficient condition for a function to be analytic,Complex integration, Cauchy Goursat theorem, . Cauchy's integral formula, higher order derivatives. Morera's theorem, Cauchy's inequality**.**

CREDIT-II

Liouville's Theorem and its generalization, Fundamental Theorem of Algebra, Taylor's Theorem, Maximum Modulus Theorem, Schwarz Lemma and its generealizations, Zeros of an analytic function and their isolated character, Identity Theorem, Argument Principle , Rouche's Theorem and its applications.

CREDIT-III

Laurant's Theorem, Classification of Singularities, Removable Singularity, Riemann's Theorem, Poles and behaviour of a function at at a pole, Essential singulariy, Casorati-Weiersstras Theorem on essential singularity, Infinite Products, Convergence and divergence of infinite product, Absolute convergence, Necessary and sufficient conditions for convergence and absolute convergence.

CREDIT-IV

Mobius transformations. Their properties and classification. Fixed Points, Cross Ratio, Inverse points and Crictical Points. Conformal Mapping. Linear transformatios carry circles to circles and inverse points to inverse points, Mappings of (i) upper half plane on to the unit disc, (ii) unit disc on to the unit disc, (iii) left half plane on to the unit disc and (iv) circle on to a circle. The transformations $w=z^2$ and $w=\frac{1}{2}(z+\frac{1}{z})$.

<u>Recommended Books:</u>

1. L.Ahlfors, Complex Analysis.
2. E.C.Titchmarsh , Theory of functions .
3. J.B.Conway, Functions of a Complex Variable-1.
4. Richard Silverman, Complex Analysis.
5. H.A.Priestly, Introduction to complex Analysis.
6. Nehari Z, Conformal mappings.

Course No: **MM14204EA**		Max. Marks:	100
Course Name:- **Theory of Numbers-II**			
Duration of Examination: 2:30 Hrs.		External Exam:	80
No. of Credits: **04**		Internal Assessment:	20

CREDIT-I

Integers belonging to a given exponent mod p and related results. Converse of Fermat's Theorem. If $d/p-1$, the Congruence $x^d \equiv 1(\bmod p)$, has exactly d-solutions. If any integer belongs to t (mod p), then exactly ϕ(t) incongruent numbers belong to t(mod p). Primitive roots. There are ϕ (p-1) primitive roots of a odd prime p. Any power of an odd prime has a primitive root. The function λ (m) and its properties. $a^{\lambda(m)} \equiv 1$(mod m), where (a , m)=1.There is always an integer which belongs to λ(m) (mod m). Primitive λ-roots of m.The numbers having primitive roots are 1,2, 4, p^{α} and $2p^{\alpha}$.where p is an odd prime.

CREDIT-II

Quadratic residues. Euler criterion. The Legendre symbol and its properties. Lemma of Gauss. If p is an odd prime and (a, 2p) =1,

then $\left(\frac{a}{p}\right) = (-1)^t$ where t = $\sum_{j=1}^{(p-1)/2}\left[\frac{ja}{p}\right]$, and $\left(\frac{2}{p}\right) = (-1)^{(p^2-1)/8}$

The law of a Quadratic Reciprocity, Characterization of primes of which 2,-2, 3,-3, 5, 6 and 10 are quadratic residues or non residues. Jacobi symbol and its properties. The reciprocity law for Jacobi symbol.

CREDIT-III

Number theoretic functions. Some simple properties of τ(n),σ(n), ϕ(n) and μ(n). Mobius inversion formula. Perfect numbers. Necessary and sufficient condition for an even number to be perfect. The function [x] and its properties. The symbols "O", "o", and " ~" .Euler's constant γ . The series

$\sum_{p} 1/p$ diverges. $\prod_{p\leq n} p<4^n$, for n≥2. Average order of magnitudes of

τ(n), σ(n), ϕ(n). Farey fractions. Rational approximation.

CREDIT-IV

Simple continued fractions. Application of the theory of infinite continued fractions to the approximation of irrationals by rationals. Hurwitz theorem. √5 is the best possible constant in the Hurwitz theorem. Relation between Riemann Zeta function and the set of primes. Characters. The L-Function L(S, x) and its properties. Dirichlet's theorem on infinity of primes in an arithmetic progression (its scope as in Leveque's topics in Number Theory, Vol. II. Chapter VI).

Recommended Books

1. Topics in number theory by W. J. Leveque, Vol. I and II Addition Wesley Publishing Company, INC.
2. An introduction of the Theory of numbers by I. Niven and H.S Zucherman.
3. Number Theory by Boevich and Shafeviech, I.R Academic Press.

Suggested Readings:

1. Analytic Number Theory by T.M Apostal, Springer international.
2. An introduction to the theory of Numbers by G.H Hardy and Wright.
3. A course in Arithmetic, by J.P. Serre, GTM Vol. Springer Verlag 1973.
4. An elementary Number theory of E. Landau.

Course No. **MM14205EA**		Max. Marks:	100
Course Name:- **Operations Research**			
Duration of Examination: 2:30 Hrs.		External Exam:	80
No. of Credits: **04**		Internal Assessment:	20

CREDIT-I

Definition of Operational Research, main phases of OR study, Linear programming problems (LPP), applications to industrial problems –optimal product links and activity levels, convex sets and convex functions, simplex method and extreme point theorems. Big M and two phase methods of solving LPP.

CREDIT-II

Revised simplex method, Assignment problem, Hungarian method, Transportation problem, and Mathematical formulation of transportation problem, methods of solving (North-West Corner rule, Vogel's method and U.V. method.) Concept and applications of duality, formulation of dual problem, duality theorems (weak duality and strong duality theorems), dual simplex method, primal- dual relations, complementary slackness theorems and conditions.

CREDIT-III

Sensitivity Analysis: changes in the coefficients of the objective function and right hand side constants of constraints, adding a new constraint and a new variable. Project management: PERT and CIM: probability of completing a project.

CREDIT-IV

Game theory: Two person zero sum Games, games with pure strategies, Games with mixed strategies, Min. Max. principle, Dominance rule, finding solution of 2 x 2, 2 x m, 2 x m games. Equivalence between game theory and linear programming problem(LPP). Simplex method for game problem.

Recommended Books:

1. Curchman C.W Ackoff R.L and Arnoff E.L (1957) Introduction to Operations Research.
2. F. S Hiller and G.J. Lieberman: Introduction to Operations Research (Sixth Edition), McGraw Hill International, Industries Series, 1995.
3. G. Hadley : Linear programming problem, Narosa publishing House, 1995.
4. Gauss S.I : Linear Programming : Wiley Eastern
5. Kanti Swarup, P.K Gupta and Singh M. M: Operation Research; Sultan Chand & Sons.

Course No: **MM14206EA**	Max. Marks: 100
Course Name:- Fourier Analysis	
Duration of Examination: 2:30 Hrs.	External Exam: 80
No. of Credits: **04**	Internal Assessment: 20

CREDIT-I

Fourier Series

Motivation and definition of Fourier series, Fourier series over the interval of length 2π, change of the interval, the complex exponential Fourier series, criteria for the convergence of Fourier series, Riemann-Lebesgue lemma, convergence at a point of continuity, convergence at a point of discontinuity, uniform convergence and convergence in mean of the Fourier series.

CREDIT-II

Derivatives and Integrals of Fourier Series

Differentiation of Fourier series, differentiation of the sine and cosine series, convergence theorems related to the derived Fourier series, integration of Fourier series, applications of Fourier series to Heat flow and Vibrating string problems.

CREDIT-III

The Fourier Transforms

Definition and examples of Fourier transforms in $L^1(\mathbb{R})$, basic properties of Fourier transforms, Fourier transforms in $L^2(\mathbb{R})$, Convolution theorem, Plancherel's and Parseval's formulae, Poisson summation formula, Shannon-Whittaker sampling theorem, Discrete and fast Fourier transforms with examples.

CREDIT-IV

Applications of Fourier Transforms

Application of Fourier transforms to the central limit theorem in mathematical statistics, solution of ordinary differential equations and integral equations using Fourier transforms, applications of Fourier transforms to Dirchilet's problem in the half-plane, Neumann's problem in the half-plane and Cauchy's problem for the diffusion equation.

Books Recommended:

Text Book:

1. **E.M. Stein and R. Shakarchi,** *Fourier Analysis: An introduction,* **Princeton University Press, 2002.**
2. **K. B. Howell,** *Principles of Fourier Analysis,* **Chapman & Hall/ CRC, Press, 2001.**
3. **Lokenath Debnath,** *Wavelet Transforms and their Applications,* **Birkhauser, 2002.**
4. **G. P. Tolstov,** *Fourier Series,* **Dover, 1972.**

5. **Zygmund,** *Trigonometric Series (2nd Ed., Volume I & II combined),* **Cambridge University Press, 1959.**

Reference Books:

1. **G. Loukas,** *Modern Fourier Analysis,* **Springer, 2011.**
2. **K. Ahmad and F. A. Shah,** *Introduction to Wavelets with Applications,* **Real World Education Publishers, New Delhi, 2013.**
3. **G. B. Folland,** *Fourier Analysis and Its Applications,* **Brooks/Cole Publishing, 1992.**
4. **M. Pinsky,** *Introduction to Fourier Analysis and Wavelets,* **Brooks/Cole Publishing, 2002.**

Course No: **MM14207EA**	Max. Marks: 50
Course Name:- Linear Algebra	
Duration of Examination: 1:15 Hrs.	External Exam: 40
No. of Credits: **02**	Internal Assessment: 10

CREDIT-I

Linear transformation, Algebra of Linear transformations, Linear operators, Invertible linear transformations, Matrix representation of a Linear transformation. Linear Functionals, dual spaces, dual basis, Anhilators, Eigenvalues and eigen-vectors of linear transformation, diagonalization, Similarity of linear transformation.

CREDIT-II

Canonical forms: Triangular form, Invariance, Invariant direct sum decomposition, Primary decomposition, Nilpotent operators, Jordon canonical form, cyclic subspaces, Rational canonical form, Quotient spaces. Bilinear forms, Alternating Bilinear forms, Symmetric bilinear forms, quadratic forms.

Books Recommended:

1. A first course in linear algebra, Robort A.Beezer.
2. Linear Algebra, John B.Fraleigh and Raymond
3. Linear Algebra, A.K.Sharma.
4. Linear Algebra, Vivek Sahai and Vikas Bist.

Course No: **MM14208EA**		Max. Marks:	50
Course Name:- Numerical Analysis			
Duration of Examination: 1:15 Hrs.		External Exam:	40
No. of Credits: **02**		Internal Assessment:	10

CREDIT-I

Numerical solutions of Algebraic and Transcendental equations. Bisection, False position and Iterative Methods. Newton-Raphson method. Lagrange's and Hermite interpolation methods. Solution of systems of linear algebraic equations using Gauss elimination and Gauss-Seidel methods, Finite differences, Numerical differentiation and integration.

CREDIT-II

Numerical solution of ordinary differential equations: Solution by Taylor's series method, Picard's method of successive approximations. Euler's method and Boundary value problems, FDM, The shooting and cubic spline method. Numerical Solution of partial differential equations: finite difference approximation to derivatives, Laplace equations- Jacobi's method, parabolic equations-Iterative method for solution of equations.

Books Recommended:

1. Introduction to Methods of Numerical Analysis by S.S.Sastry.
2. Introduction to Numerical Analysis by Atkinson.

Course No: **MM14209EA**	Max. Marks: 50
Course Name:- **Mathematical Modeling**	
Duration of Examination: 1:15 Hrs.	External Exam: 40
No. of Credits: **02**	Internal Assessment: 10

CREDIT-I

Introduction to Mathematical Modeling, Types of Modeling, Classification of Mathematical models, Formulation, Solution and Interpretation of a Model. Linear growth and decay models, non-linear growth and decay models, continuous population models for single species, delay models, Logistic growth model, Discrete models, Age structured populations, Fibonacci's rabbits, the Golden ratio, Fishery management model, Compartment models, limitations of mathematical models.

CREDIT-II

Mathematical models in Ecology and Epidemiology: Models for interacting populations, types of interactions, Lotka-Voltera system and stability analysis of the interactions like prey-predator, Competition and Symbiosis. Infectious Disease Modelling: Simple and general epidemic models viz SI, SIS, SIR epidemic disease models, vaccination. The SIR endemic disease model.

Books Recommended

1. J. N. Kapur, Mathematical Modelling, New Age International Publishers.
2. J.D. Murray Mathematical Biology (An Introduction, Vol. I and II), Springer Verlag.
3. J.N. Kapur.Mathematical Model in Biology and Medicines.
4. S. I. Rubinow, Introduction to Mathematical Biology, John Wiley and Sons, 1975.
5. M. R. Cullen, Linear Models in Biology, Ellis Horwood Ltd.
6. Jaffrey R. Chasnov, Mathematical Biology, Hong Kong Press.

Course No: **MM14210EA**		Max. Marks:	50
Course Name;- Integral Equations			
Duration of Examination: 1:15 Hrs.		External Exam:	40
No. of Credits: **02**		Internal Assessment:	10

CREDIT-I

Linear Integral Equations of the First and Second kinds, Volterra and Fredholm Integral Equations, Relations Between Differential and Integral Equations, Solution of Volterra and Fredholm Integral Equations by the Methods of Successive Substitutions and Successive Approximations, Iterated and Resolvent Kernels, Neumann Series Reciprocal Functions, Volterra's Solutions of Fredholm Equations.

CREDIT-II

Fredholm Theorems, Fredholm Associated Equation, Solution of Integral Equations Using Fredholm's Determinant and Minor, Homogeneous Integral Equations, Integral Equations with Separable Kernels, The Fredholm Alternatives, Symmetric Kernels, Hilbert Schmidt Theory for Symmetric Kernels, Applications of Integral Equations to Differential Equations: Initial Value Problem, Boundary Value Problem, Dirac-Delta Function, Green's Function Approach.

Books Recomended:

1. R.P. Kanwal: Linear Integral Equations (Theory and Technique), Academic Press Birkhauser-1997.
2. W.V. Lovitt; Linear Integral Equations by, Dover Publications, Inc. New York, 1950.
3. K.F. Riley, M.P. Hobson and S.T. Bence; Mathematical Methods for Physics and Engineering Cambridge University Press, U.K., 1997.

Reference Books:

4. M.D. Raisinghania; Integral Equations and Boundary Value Problems, S.C. Chand India, 2007.
5. Shanti Swarup; Integral Equations (&Boundary Value Problems), Krishna Prakashan Media (P) Ltd. Meerut, India, 2014.

Course No: **MM14211EO**	Max. Marks: 100
Course Name:- Open Elective	
Duration of Examination: 2:30 Hrs.	External Exam: 80
No. of Credits: **04**	Internal Assessment: 20