Semester – II				
Course Type	**Course Code**	**Title of the Course**	**No. of Credits**	**Teacher**
Core (CR)	MM 15201CR	Discrete Mathematics	04	
	MM 15202CR	Real Analysis – II	04	
	MM 15203CR	Complex Analysis-I	04	
Discipline Centric Electives (DCE)	MM 15204DCE	Theory of Numbers – II	04	
	MM 15205DCE	Fourier Analysis	04	
	MM 15106DCE	Operation Research	04	
	MM 15207DCE	Numerical Analysis	02	
	MM 15208DCE	Bio-Mathematical Modelling	02	
	MM 15209DCE	Integral Equations	02	
Generic Electives (GE)	MM 15210GE	Complex Variables	02	
	MM 15211GE	Riemann Integration	02	
	MM 15212GE	Basic Graph Theory	02	
Open Electives (OE)	MM 15213OE	Matrix Algebra	02	
	MM 15214OE	Differential Equations	02	

General Instructions for the Candidates

1. The two year (4 semester) PG programme is of 96 credit weightage i.e., 24 credits/semester (24x4=96).
2. Out of 24 credits in a semester a candidate has to obtain 12 credits compulsorily from "**Core Courses**", while the remaining 12 credits can be obtained from the "**Electives**" in the following manner:
   - A candidate can obtain a maximum of 6 credits within his/her own Department out of the specializations offered by the Department as **Discipline Centric-Electives**.
   - 6 credits shall be obtained by a candidate from the **Electives** offered by the Department other than his/her own. The candidate shall be free to obtain these 6 credits from the **Generic** or **Open Electives** or **a combination of both**.

SEMESTER-II

DISCRETE MATHEMATICS

Course No: **MM 15201CR**	Max. Marks: 100
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.

Recommended Books:

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, Orient Blackswan, 2012.
6. W. T. Tutte, Graph Theory, Cambridge University Press.
7. D. B. West, Introduction to Graph Theory, Prentice Hall.

REAL ANALYSIS - II

Course No: **MM 15202CR**
Duration of Examination: 2:30 Hrs.
No. of Credits: **04**

Max. Marks: 100
External Exam: 80
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 ЄR, 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 integrability 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 an L-integrable function and its absolute continuity, necessary and sufficient condition for bounded variation, Vitali's covering lemma and a.e., differentiability of a monotone function f and $\int f' \leq f(b) - f(a)$.

Recommended Books:

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

COMPLEX ANALYSIS - I

Course No: **MM 15203CR**	Max. Marks: 100
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 generalizations, 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 a pole, essential singularity, 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 critical points, conformal mapping, linear transformations 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 $w = \frac{1}{2}\left(z + \frac{1}{z}\right)$.

Recommended Books:

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. Z.Nehari, Conformal Mappings.

THEORY OF NUMBERS -II

Course No: **MM 15204DCE**		Max. Marks:	100
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 $x^d \equiv 1 (\mathrm{mod}\, p)$, has exactly d-solutions; If any integer belongs to t (mod p), then exactly $\phi(t)$ incongruent numbers belong to t(mod p), primitive roots, there are ϕ (p-1) primitive roots of an odd prime p, any power of an odd prime has a primitive root, the function λ (m) and its properties, $a^{\lambda(m)} \equiv 1 (\mathrm{mod}\ m)$, 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, 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 $\tau(n)$,$\sigma(n)$, $\phi(n)$ and $\mu(n)$. Mobius inversion formula. Perfect numbers. Necessary and sufficient condition for an even number to be perfect, the function [x] and its properties, average order of magnitudes of $\tau(n)$, $\sigma(n)$, $\phi(n)$, 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, 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.

Recommended Books

1. W. J. Leveque Topics in Number Theory, Vol. I and II Addition Wesley Publishing Company, INC.

2. I. Niven and H.S Zucherman, An introduction of the Theory of Numbers

3. Boevich and Shafeviech, Number Theory,I.R Academic Press.

REFERENCES:

1. T.M Apostal, Analytic Number Theory, Springer International.

2. G.H Hardy and Wright, An introduction to the theory of Numbers.

3. J.P. Serre, A course in Arithmetic, GTM Vol. Springer Verlag 1973.

4. E. Landau, An Elementary Number Theory.

FOURIER ANALYSIS

Course No: **MM 15205DCE**	Max. Marks: 100
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 and 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:

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.

References:

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.

OPERATION RESERACH

Course No: **MM 15206DCE**
Duration of Examination: 2:30 Hrs.
No. of Credits: **04**

Max. Marks: 100
External Exam: 80
Internal Assessment: 20

CREDIT-I

Definition of operation 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. C.W.Curchman, R.L. Ackoff and E.L.Arnoff, (1957) Introduction to Operation 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. S.I.Gauss , Linear Programming, Wiley Eastern.
5. Kanti Swarup, P.K Gupta and M.M.Singh M. M, Operation Research; Sultan Chand & Sons.

NUMERICAL ANALYSIS

Course No. **MM 15207DCE**		Max. Marks:	50
Duration of Examination: 1:30 Hrs.		External Exam:	40
No. of Credits: **02**		Internal Assessment:	10

CREDIT-I

Examples from ODE where analytical solution are difficult or impossible, examples from PDE where analytical solution are difficult or impossible, numerical solution of ordinary differential equations, initial value problems- Picard's and Taylor series methods – Euler's Method- Higher order Taylor methods, Modified Euler's method- Runge-Kutta methods of second and fourth order.

CREDIT-II

Boundary- value problems –finite difference method, forward, backward and central difference methods, second order finite difference and cubic spline methods. numerical solution of Partial differential equations, difference methods for elliptic partial differential equations – difference schemes for Laplace and Poisson's equations, difference methods for parabolic equations in one-dimensional system.

Recommended Books:

1. M.K. Jain, Numerical solution of differential equations, Wiley Eastern (1979), Second Edition.
2. C.F. Gerald and P.O. Wheatley, Applied Numerical Methods, Low- priced edition, Pearson Education Asia (2002), Sixth Edition.
3. D.V. Griffiths and I.M. Smith, Numerical Methods for Engineers, Blackwell Scientific Publications (1991).

BIO-MATHEMATICAL MODELLING

Course No. **MM 15208DCE**
Duration of Examination: 1:30 Hrs.
No. of Credits: **02**

Max. Marks:	50
External Exam:	40
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, logistic growth model, discrete models, age structured populations, delay models, Fibonacci's rabbits, the golden ratio, 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 Harwood Ltd.
6. Jaffrey R. Chasnov, Mathematical Biology, Hong Kong Press.

INTEGRAL EQUATIONS

Course No. **MM 15209DCE** | Max. Marks: 50
Duration of Examination: 1:30 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, 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.

References:

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

COMPLEX VARIABLES

Course No. **MM 15210GE**
Duration of Examination: 1:30 Hrs.
No. of Credits: **02**

Max. Marks: 50
External Exam: 40
Internal Assessment: 10

CREDIT-I

Review of complex numbers, De-Movier's theorem and it's applications, functions of a complex variable, continuity and differentiability of complex functions, analytic functions, CR equations, complex integration, Cauchy's theorem (statement only), Cauchy's integral formulae, Liouville's theorem, Fundamental theorem of algebra.

CREDIT-II

Maximum modulus principle (statement only), determination of maximum modulus of e^z, sin z, cos z etc, expansion of an analytic function in a power series, Taylor's and Laurant's theorems (statements only), classification of singularities, zeros of analytic functions, argument principle, Rouche's theorem and its applications.

Books Recomended:

1. W.Rudin, Complex Analysis.
2. Alfhors, Complex Analysis.
3. S. Ponaswamy, Foundations of Complex Analysis.
4. Schaum series, Complex Variables.

RIEMANN INTEGRATION

Course No. **MM 15211GE**	Max. Marks: 50
Duration of Examination: 1:30 Hrs.	External Exam: 40
No. of Credits: **02**	Internal Assessment: 10

CREDIT-I

Bounded functions, partition of an interval, upper and lower Riemann sums, refinement of a partition, behavior of upper and lower sums under a refinement, upper and lower Riemann integrals, definition and existence of R-integral, necessary and sufficient condition for R-integrability of a bounded function, R- integrability of sum, difference, product and quotient of two functions.

CREDIT-II

R- integrability of continuous and monotonic functions, R- integrability of functions having a finite number of discontinuities, If f is R- integrable over [a,b], then so is |f| and $\left|\int_a^b f(x)dx\right| \leq \int_a^b |f(x)|dx$, indefinite integral of an R-integrable function and its properties, fundamental theorem of integral calculus, mean value theorems for integrals.

Books Recommended:

1. S.C.Malik, Mathematical Analysis.
2. S.M.Shah & Saxena, Real Analysis.
3. W.Rudin, Principles of Mathematical Analysis.

BASIC GRAPH THEORY

Course No. **MM 15212GE**		Max. Marks:	50
Duration of Examination: 1:30 Hrs.		External Exam:	40
No. of Credits: **02**		Internal Assessment:	10

CREDIT-I

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, EDT, degree sequences and their characterizations, degree sets.

CREDIT-II

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, Vertex connectivity, edge connectivity, Whitney's theorem, Planar graphs, Kuratowski's two graphs, Euler's formula, Incidence matrix *A(G)*, cycle matrix *B(G)*, fundamental cycle matrix B_f, cut-set matrix *C(G)*, adjacency matrix, matrix tree theorem, types of digraphs.

Books Recommended:

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

MATRIX ALGEBRA

Course No. **MM 15213OE**	Max. Marks: 50
Duration of Examination: 1:30 Hrs.	External Exam: 40
No. of Credits: **02**	Internal Assessment: 10

CREDIT-I

Matrices, types, adjoint and inverse of a matrix, partition of a matrix, matrix polynomials, characteristic equation of a matrix, Caley Hamilton theorem, elementary transformations, rank of a matrix, determination of rank.

CREDIT- II

Normal form with examples, solution of equations, homogenous and non-homogeneous equations, linear dependence and independence, orthogonal and unitary matrices and their determination, eigen values and eigen vectors and their determination, similarity of matrices with examples.

Books Recommended

5 Franz E. Hohn, Elementary Matrix Algebra, American Publishing company Pvt.ltd.
6 Shanti Narayan, A Text Book of Matrices, S. Chand and company Ltd.
7 Rajendra Bhatia , Matrix Analysis Springer.
8 A.Aziz, N.A.Rather and B.A.Zargar, Elementary Matrix Algebra , KBD.

ELEMENTARY DIFFRENTIAL EQUATIONS

Course No. **MM 15214OE**	Max. Marks: 50
Duration of Examination: 1:30 Hrs.	External Exam: 40
No. of Credits: **02**	Internal Assessment: 10

CREDIT-I

Introduction: order and degree of a differential equation, formation and solution of a differential equation, variable separable method, homogeneous and Bernoulli's differential equations, exact differential equations, integrating factors, linear differential equations with constant coefficients, particular integrals.

CREDIT-I

Applications of first order differential equations, growth and decay, dynamics of tumor growth, radioactivity and carbon dating, Newton' s law of cooling, second order differential equations, diffusion equation including Laplace, Heat and wave equations.

Recommended Books:

1. Zafar Ahsan, Differential Equations and Their Applications, second edition, PHI, New Delhi.
2. H.T.H. Piaggo, Differential Equation, PHI New Delhi.
3. K.S.Rawat, Differential Equations, Sarup and Sons, New Delhi.