POST GRADUATE DEPARTMENT OF MATHEMATICS

UNIVERSITY OF KASHMIR, SRINAGAR - 190006

Course Curriculum (Syllabus for CBCS)

For the Academic Years

2014, 2015 & 2016 (For I & II Semesters)

2015, 2016 & 2017 (For III & IV Semesters)

CHOICE BASED CREDIT SYSTEM (CBCS)

CORE COURSES- (SEMESTER –I)

Course Code	***Course Name***	***Credits***
MM- CR -101	Advanced Abstract Algebra-I	4
MM –CR- 102	Real Analysis-I	4
MM- CR- 103	Topology	4

OPTIONAL COURSES (SEMESTER –I)

Course Code	***Course Name***	***Credits***
MM- EA -104	Theory of Numbers-I	4
MM- EA -105	Matrix Algebra	4
MM –EA- 106	Computational Mathematics	4
MM- EA -107	Advanced Calculus	2
MM -EA -108	Probability Theory	2
MM- EO -109	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 (1paper) 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.

CORE COURSES- (SEMESTER –II)

Course Code	***Course Name***	***Credits***
MM -CR -201	Discrete Mathematics	4
MM- CR -202	Real Analysis-II	4
MM- CR- 203	Complex Analysis-I	4

OPTIONAL COURSES (SEMESTER –II)

Course Code	***Course Name***	***Credits***
MM- EA -204	Theory of Numbers-II	4
MM -EA- 205	Operations Research	4
MM –EA- 206	Fourier Analysis	4
MM- EA- 207	Linear Algebra	2
MM -EA- 208	Numerical Analysis	2
MM -EA- 209	Mathematical Modelling	2
MM- EA- 210	Integral Equations	2
MM-EO-211	Other Allied + Open	4

General Instructions for the Candidates

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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.
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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.

CORE COURSES (SEMESTER –III)

Course Code	***Course Name***	***Credits***
MM- CR -301	Ordinary Differential Equations	4
MM- CR -302	Complex Analysis-II	4
MM -CR- 303	Functional Analysis-I	4

OPTIONAL COURSES (SEMESTER –III)

Course Code	***Course Name***	***Credits***
MM -EA -304	Abstract Measure Theory	4
MM -EA- 305	Advanced Graph Theory	4
MM- EA -306	Mathematical Biology	4
MM -EA- 307	Wavelet Theory	4
MM- EO- 308	Other Allied + Open	4

General Instructions for the Candidates

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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 (1paper) 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.

CORE COURSES (SEMESTER –IV)

Course Code	Course Name	Credits
MM -CR -401	Partial Differential Equations	4
MM -CR- 402	Differential Geometry	4
MM- CR -403	Advanced Abstract Algebra-II	4

OPTIONAL COURSES (SEMESTER –IV)

Course Code	Course Name	Credits
MM- EA- 404	Analytic Theory of Polynomials	4
MM- EA- 405	Mathematical Statistics	4
MM -EA- 406	Functional Analysis-II	4
MM- EA- 407	Non-Linear Analysis	4
MM- EA -408	Advanced Topics in Topology and Modern Analysis	4
MM- EA-409	Project	4
MM-EO-410	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).
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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 (1paper) 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 (4^{th} semester).

SEMESTER-I

ADVANCED ABSTRACT ALGEBRA-I

Course No: **MM-CR-101**		Max. Marks:	100
Duration of Examination: 2:30 Hrs.		External Exam:	80
No. of Credits: **04**		Internal Assessment:	20

CREDIT-I

Definitions and examples of Semi-groups and Monoids. Criteria for the semi-groups to be a group; Cyclic groups; Structure theorem for cyclic groups. Endomorphism, Automorphism, Inner Automorphism and Outer Automorphism, Center of a group, Cauchy's and Sylow's theorem for abelian groups. Permutation groups, Symmetric groups, Alternating groups, Simple groups, Simplicity of the Alternating group A_n for $n \geq 5$.

CREDIT-II

Normalizer, conjugate classes, Class equation of a finite group and its applications, Cauchy's theorem and Sylow's theorems for finite groups. Double cosets, Second and third parts of Sylow's theorem. Direct product of groups, Finite abelian groups, normal and subnormal series, Composition series. Jordan Holder theorem for finite groups. Zassenhaus Lemma, Schreir's Refinement theorem, Solvable groups.

CREDIT-III

Brief review of Rings, Integral domain, Ideals. The field of quotients of an Integral domain. Embedding of an Integral domain. Euclidean rings with examples such as $Z[\sqrt{-1}]$, $Z[\sqrt{2}]$, Principal ideal rings(PIR) Unique factorization domains(UFD) and Euclidean domains, Greatest common divisor, Lowest common multiple in rings, Relationships between Euclidean rings, P.I.R.'s and U.F.D.

CREDIT-IV

Polynomial rings: The Division algorithm for polynomials, Irreducible polynomials, Polynomials and the rational field, Primitive polynomials, Contract of a polynomials, Gauss Lemma, Integer monic polynomial, Eisenstein's irreducibility criterion, cyclotomic polynomials; Polynomial rings and Commutative rings.

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 Publishing House Private Limited.
4. P.B,.Bhatacharaya and S.K.Jain : Basic Abstract Algebra.
5. J.B. Fragleigh : A First Course in Abstract Algebra.
6. J.A.Gallian : Contemporary Abstract Algebra.

REAL ANALYSIS - I

Course No: **MM-CR-102**	Max. Marks: 100
Duration of Examination: 2:30 Hrs.	External Exam: 80
No. of Credits: **04**	Internal Assessment: 20

CREDIT-I

Integration : Definition and existence of Riemann – Stieltje's integral , behavior of upper and lower sums under refinement , Necessary and sufficient conditions for RS-integrability of continuous and monotonic functions, Reduction of an RS-integral to a Riemann integral , Basic properties of RS-integrals , Differentiability of an indefinite integral of a continuous functions , The fundamental theorem of calculus for Riemann integrals .

CREDIT-II

Improper Integrals: Integration of unbounded functions with finite limit of integration. Comparison tests for convergence, Cauchy's test. Infinite range of integration. Absolute convergence. Integrand as a product of functions. Abel's and Dirichlet's test.
Inequalities: Arithmetic-geometric means equality, Inequalities of Cauchy Schwartz, Jensen, Holder &Minkowski. Inequality on the product of arithmetic means of two sets of positive numbers**.**

CREDIT-III

Infinite series: Carleman's theorem. Conditional and absolute convergence, multiplication of series, Merten's theorem, Dirichlet's Theorem, Riemann's rearrangement theorem. Young's form of Taylor's theorem, generalized second derivative. Bernstein's theorem and Abel's limit theorem.

CREDIT-IV

Sequence and series of functions: Point wise and uniform convergence, Cauchy criterion for uniform convergence, M_n -test, Weiestrass M-test , Abel's and Dirichlet's test for uniform convergence , uniform convergences and continuity, R- integration and differentiation, Weiestrass Approximation theorem. Example of continuous nowhere differentiable function.

Recommended Books:

1. R. Goldberg : Methods of Real Analysis.
2. W. Rudin : Principles of Mathematical Analysis.
3. J. M. Apostol : Mathematical Analysis.
4. S.M.Shah and Saxena: Real Analysis.
5. A.J.White :Real Analysis , An Introduction.
6. L.Royden :Real Analysis.

TOPOLOGY

Course No: **MM-CR-103**		Max. Marks:	100
Duration of Examination: 2:30 Hrs.		External Exam:	80
No. of Credits: **04**		Internal Assessment:	20

CREDIT-I

Review of countable and uncountable sets, Schroeder-Bernstein theorem, Axiom of Choice and its various equivalent forms, Definition and examples of metric spaces, Open and Closed sets, completeness in metric spaces, Baire's Category theorem, and applications to the (1) Non-existence of a function which is continuous precisely at irrationals (ii) Impossibility of approximating the characteristic of rationals on [0, 1] by a sequence of continuous functions.

CREDIT-II

Completion of a metric space ,Cantor's intersection theorem, with examples to demonstrate that each of the conditions in the theorem is essential, Uniformly continuous mappings with examples and counter examples, Extending Uniformity continuous maps, Banach's contraction principle with applications to the inverse function theorem in R.

CREDIT-III

Topological spaces; Definition and examples, elementary properties, Kuratowski's axioms, continuous mappings and their characterizations ,pasting Lemma, convergence of nets and continuity in terms of nets, Bases and sub bases for a topology, Lower limit topology, concepts of first countability, second countability, separability and their relationships, counter examples and behavior under subspaces, product topology and weak topology, compactness and its various characterizations.

CREDIT-IV

Heine-Borel theorem, Tychnoff's theorem, compactness, sequential compactness and total bounded ness in metric spaces. Lebesgue's covering lemma, continuous maps on a compact space. Separation axioms T_i (i=1,2,3,31/2,4) and their permanence properties, connectedness, local connectedness, their relationship and basic properties, Connected sets in R. Urysohn's lemma. Urysohn's metrization theorem. Tietize's extension theorem, one point compactification.

Recommended Books:

1. G.F.Simmons : Introduction to topology and Modern Analysis.
2. J. Munkres : Topology.
3. K.D. Joshi : Introduction to General Topology.
4. J.L.Kelley : General Topology.
5. Murdeshwar ; General Topology .
6. S.T. Hu : Introduction to General Topology.

THEORY OF NUMBERS-I

Course No. **MM-EA-104**		Max. Marks:	100
Duration of Examination: 2:30 Hrs.		External Exam:	80
No. of Credits: **04**		Internal Assessment:	20

CREDIT-I

Divisibility, the division algorithm and its uniqueness, Greatest common divisor and its properties. The Euclidean algorithm, Prime numbers. Euclid's first theorem, Fundamental Theorem of Arithmetic, Divisor of n, Radix-representation Linear Diophantine equations. Necessary and sufficient condition for solvability of linear Diophantine equations, Positive solutions.

CREDIT-II

Sequence of primes, Euclid's Second theorem, Infinitude of primes of the form 4n+3 and of the form 6n+5. No polynomial f(x) with integral coefficients can represent primes for all integral values of x or for all sufficiently large x. Fermat Numbers and their properties. Fermat Numbers are relatively prime. There are arbitrary large gaps in the sequence of primes. Congruences, Complete Residue System (CRS), Reduced Residue System (RRS) and their properties. Fermat and Euler's theorems with applications.

CREDIT-III

Euler's ф-function, ф (mn) = ф (m) ф (n) where (m, n) =1, $\sum_{d/m}\phi(d)=n$ and $\phi(m)=m\prod_{p}\left(1-\frac{1}{p}\right)$ for m>1. Wilson's theorem and its application to the solution the congruence of $x^2 \equiv -1 \pmod p$, Solutions of linear Congruence's. The necessary and sufficient condition for the solution of $a_1x_1+a_2x_2+\ldots+a_nx_n \equiv c \pmod m$. Chinese Remainder Theorm.Congruences of higher degree F(x) ≡ 0 (mod m), where F(x) is a Polynomials. Congruence's with prime power, Congruences with prime modulus and related results. Lagrange's theorem, viz , the polynomial congruence F(x) ≡ 0 (mod p) of degree n has at most n roots.

CREDIT-IV

Factor theorem and its generalization. Polynomial congruences $F(x_1,x_2....x_n) \equiv 0 \pmod{p}$ in several variables. Equivalence of polynomials. Theorem on the number of solutions of congruences: Chevalley's theorem, Warning's theorem. Quadratic forms over a field of characteristic $\neq 2$ Equivalence of Quadratic forms. Witt's theorem. Representation of Field Elements. Hermite's theorem on the minima of a positive definite quadratic form and its application to the sum of two, three and four squares.

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 Zuckerman.
3. Number Theory by Boevich and Shaferivich, I.R, Academic Press**.**

Suggested Readings:

1. Analytic Number Theory by T.M Apostal, Springer Verlag.
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.

MATRIX ALGEBRA

Course No: **MM-EA-105**	Max. Marks: 100
Duration of Examination: 2:30 Hrs.	External Exam: 80
No. of Credits: **04**	Internal Assessments: 20

CREDIT-I

Eigen values and eigen vectors of a matrix and their determination.. The eigen values of a square matrix A are the roots of its characteristic equation and conversely.Similarity of matrices. Two similar matrices have the same eigen values. Algebraic and geometric multiplicity of a characteristic root. Necessary and sufficient condition for a square matrix of order n to be similar to a diagonal matrix. Orthogonal reduction of real matrices.

CREDIT-II

Orthogonality of the eigen vectors of a hermetion matrix. The necessary and sufficient condition for a square matrix of order n to be a similar diagonal matrix is that it has a set n linearly independent eigen vectors. If A is a real symmetric matrix then there exists an orthogonal matrix P such that $P^{-1}AP$ = P`AP ia a diagonal matrix whose diagonal elements are the eigen values of A.Semi – diagonal or triangular form. Schur's theorem. Normal matrices, Necessary and sufficient condition for a square matrix to be unitarily similar to a diagonal matrix

CREDIT-III

Quadratic forms: The Kroneckers and Lagranges reduction .Reduction by orthogonal transformation of real quadratic forms .Necessary and sufficient condition for a quadratic form to be positive definite. Rank , Index and signature of a quadratic form. If A=$[a_{ij}]$ is a positive definite matrix of order n , then $|A| \le a_{11} a_{22} \ldots a_{nn}$.

CREDIT-IV

Gram matrices. The Gram matrix BB` is always positive definite or positive semi-definite. Hadmard's inequality. If B=$[b_{ij}]$is an arbitrary non- singular real square matrix of order n, then $|B| \le \prod_{i=1}^{n}[\sum_{k=1}^{n} b_{ik}]$ Functions of symmetric matrices: Positive definite square root of a positive definite matrix. The infinite n-fold integral

$$I_n = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\cdots\int_{-\infty}^{\infty} e^{-X'AX}\, dX ,$$

where $dX = dx_1 dx_2 \cdots dx_n$. If A is a positive definite matrix , then $I_n = \dfrac{\pi^{n/2}}{|A|^{1/2}}$

If A and B are positive definite matrices, then

$$|\lambda A + (1-\lambda)B| \geq |A|^{\lambda} |B|^{1-\lambda} \qquad \text{for} \quad 0 \leq \lambda \leq 1$$

REFERENCES

1 Introduction to Matrix Analysis by Richard Bellman , McGraw Hill Book Company.
2 Elementary Matrix Algebra by Franz E. Hohn, American Publishing company Pvt.ltd.
3 A Text Book of Matrices by Shanti Narayan, S. Chand and company Ltd.
4 Matrix Anaylsis by Rajendra Bhatia , Springer.

COMPUTATIONAL MATHEMATICS

Course No. **MM-EA-106**	Max. Marks: 100
Duration of Examination: 2:30 Hrs.	External Exam: 80
No. of Credits: **04**	Internal Assessment: 20

CREDIT-I

Introduction to Programming and Problem Solving – The Basic Model of Computation, Algorithms, Flow-charts, Programming Languages, Compilation, Linking and Loading, Testing and Debugging, Documentation.

Programming in c Language – Character set, Variables and Identifiers, Built-in Data Types, Variable Definition, Arithmetic Operators and Expressions, Constants and Literals, Simple Assignment Statement, Basic Input/Output statements, Simple C Programs.

Conditional Statements and Loops – Decision making with a program, Conditions, Relational Operators, Logical Connectives, *if* statement, *if-else* statement, Loops: *while* loop, *do-while* loop, *for* loop, Nested Loops, Infinite Loops, switch Statement, Structured Programming.

CREDIT-II

Arrays – One Dimensional Arrays: Array Manipulation; Searching, Insertion, Deletion of an element from an Array, Finding the largest/smallest element in an array, Two Dimensional Arrays: Addition/Multiplication of two matrices, Transpose of a square Matrix, Null Terminated Strings as Array of Characters, Representation of Sparse Matrices.

Pointers - Address operators, Pointer type declaration, Pointer assignment, Pointer Initialization, Pointer arithmetic, Function and pointers, Arrays and pointers, Pointer Arrays.

CREDIT-III

Introduction to MATLAB, Basic features, Array and Array Operations: simple Array, Array construction and orientation, Array mathematics, Standard Arrays, manipulation and sorting, Multi Dimensional Arrays: Array construction, Array construction, Array mathematics and manipulation, Relational and Logical operations, Control flow, Functions: M-file function construction rules, I/O arguments, Function workspaces, Functions and the MATLAB search path.

CREDIT-IV

Matrix Algebra: sets of linear equations, matrix functions, special matrices, Data analysis and Statistical functions, Polynomials: roots, multiplications, addition, division, Derivatives and Integrals, evaluation, Fourier analysis: Discrete Fourier transform, Fourier series, Integration and Differentiation, Differential Equations: IVP Format, ODE suit solvers, basic use.

Books Recommended:

1. E.Balagurusamy, Programming in ANSI c.
2. The C Programming Language, Brian W. Kernighan, Dennis M. Ritchie.
3. S.G.Kochan, Programming in c.
4. Mastering MATLAB, Duane Hanselman, Bruce Little field.
5. MATLAB, A Practical approach, Stormy Attaway.

ADVANCED CALCULUS

Course No: **MM-EA-107**		Max. Marks:	50
Duration of Examination: 1:15 Hrs.		External Exam:	40
No. of Credits: **02**		Internal Assessment:	10

CREDIT-I

Functions of several variables in R^n, the directional derivative, directional derivative and continuity, total derivative, Matrix of a linear function. Jacobian matrix, chain rule, mean value theorem for differentiable functions.

CREDIT-II

Sufficient conditions for differentiability and for the equality of mixed partials, Taylor's theorem for functions from R^n and R. Inverse and Implicit function theorem in R^n. Extremum problems for functions on R^n. Lagrange's multiplier's, Multiple Riemann Integral and change of variable formula for multiple Riemann integrals.

Recommended Books:

1. Rudin, W. Principles of Mathematical Analysis.
2. T.M.Apostol : Mathematical Analysis.
3. S.M.Shah and Saxena : Real Analysis.

PROBABILITY THEORY

Course No: **MM-EA-108**	Max. Marks: 50
Duration of Examination: 1:15 Hrs.	External Exam: 40
No. of Credits: **02**	Internal Assessment: 10

CREDIT-I

The probability set functions, its properties, probability density function, the distribution function and its properties. Mathematical Expectations, some special mathematical expectations, Inequalities of Makov, Chebyshev and Jensen.

CREDIT-II

Conditional probability, independent events, Baye's theorem, Distribution of two and more random variables, Marginal and conditional distributions, conditional means and variances, Correlation coefficient, stochastic independence and its various criteria.

Recommended Books:

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

OPEN ELECTIVE

Course No: **MM-EO-109**	Max. Marks: 100
Duration of Examination: 2:30 Hrs.	External Exam: 80
No. of Credits: **04**	Internal Assessment: 20

SEMESTER-II

DISCRETE MATHEMATICS

Course No: **MM-CR-201**		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.

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

REAL ANALYSIS-II

Course No: **MM-CR-202**	Max. Marks:	100
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 ofLebesgue –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 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.

COMPLEX ANALYSIS-I

Course No: **MM-CR-203**		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 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 $w=\frac{1}{2}(z+\frac{1}{z})$.

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. Nehari Z, Conformal mappings.

THEORY OF NUMBERS-II

Course No: **MM-EA-204** 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 $x^d \equiv 1(\text{mod}\, p)$, 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. $a^{\lambda(m)} \equiv 1(\text{mod } m)$, 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 $n\geq 2$. 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. $\sqrt{5}$ 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.

OPERATIONS RESEARCH

Course No. **MM-EA-205**		Max. Marks:	100
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.

FOURIER ANALYSIS

Course No: **MM-EA-206**	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, 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.**

LINEAR ALGEBRA

Course No: **MM-EA-207**	Max. Marks: 50
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.

NUMERICAL ANALYSIS

Course No: **MM-EA-208**		Max. Marks:	50
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.

MATHEMATICAL MODELING

Course No: **MM-EA-209**	Max. Marks: 50
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.

INTEGRAL EQUATIONS

Course No: **MM-EA-210**	Max. Marks: 50
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.

OPEN ELECTIVE

Course No: **MM-EO-211**	Max. Marks: 100
Duration of Examination: 2:30 Hrs.	External Exam: 80
No. of Credits: **04**	Internal Assessment: 20

SEMESTER-III

ORDINARY DIFFERENTIAL EQUATIONS

Course No: **MM-CR-301**	Max. Marks:	100
Duration of Examination: 2:30 Hrs.	External Exam:	80
No. of Credits: **04**	Internal Assessment:	20

CREDIT-I

First order ODE, Singular solutions, p-discriminate and c-discriminate, Initial value problem of first order ODE, General theory of Homogeneous and Non-homogeneous linear ODE, simultaneous linear equations with constant coefficients. Normal form. Factorization of operators. Method of variation of parameters, Picard's theorem on the existence and uniqueness of solutions to an initial value problem.

CREDIT-II

Solution in Series: (i) Roots of an Indicial equation, un-equal and differing by a quantity not an integer. (ii) Roots of an Indicial equation, which are equal. (iii) Roots of an Indicial equation differing by an integer making a coefficient infinite. (iv) Roots of an Indicial equation differing by an integer making a coefficient indeterminate.

Simultaneous equation $dx/P = dy/Q = dz/R$ and its solutions by use of multipliers and a second integral found by the help of first. Total differential equations Pdx + Qdy +Rdz = 0. Necessary and sufficient condition that an equation may be integrable. Geometric interpretation of the Pdx + Qdy + Rdz =0.

CREDIT-III

Existence of Solutions, Initial value problem, Ascoli- lemma, Cauchy Piano existence theorem, Uniqueness of solutions with examples, Lipchitz condition and Gronwall inequality, Method of successive approximation, Picard-Lindlof theorem, Continuation of solutions, System of Differential equations, Dependence of solutions on initial conditions and parameters.

CREDIT-IV

Maximal and Minimal solutions of the system of Ordinary Differential equations, Cartheodary theorem, Linear differential equations, Linear Homogeneous equations, Linear system with constant coefficients, Linear systems with periodic coefficients, Fundamental matrix and its properties, Non-homogeneous linear systems, Variation of constant formula. Wronskian and its properties.

Recommended Books:

1. H.T.H. Piaggio, Differential Equations, CBS Publishers and Distributors, New Delhi.

2. P.Hartmen : Ordinary Differential Equations.

3. W.T.Reid : Ordinary Differential Equations.

4. E.A.Coddington and N.Levinson :Theory of Ordinary Differential Equations.

1. D. Somasundaram, Ordinary Differential Equations, Narosa Publishers, New Delhi.

COMPLEX ANALYSIS-II

Course No: **MM-CR-302**		Max. Marks:	100
Duration of Examination: 2:30 Hrs.		External Exam:	80
No. of Credits: **04**		Internal Assessment:	20

CREDIT-I

Calculus of Residues, Cauchy's residue theorem, Evaluation of integrals by the method of residues, Parseval's Identity, Branches of many-valued functions with special reference to arg(z), Log z and z^n , Blashke's theorem i.e., if f(z) is analytic and bounded by 1 in $|z| \leq 1$ and vanishes at z= $z_{n,\ n=1,2,\ldots\ldots,}$ $|z_n| \leq 1$, then $\sum(1-|z_n|)$ is convergent or else $f(z) \equiv 0$.

CREDIT-II

Poisson integral formula for circle and half plane, Poisson-Jensen formula, Estermann's uniqueness theorem, Carlemann's theorem and the uniqueness theorem associated with it, Hadamard's three circle theorem, Log M(r) and Log I_2 (r) as convex functions of log r, Theorem of Borel and Caratheodory.

CREDIT-III

Power series: Cauchy-Hadamard formula for the radius of convergence, Picad's theorem on power series: If $a_n > a_{n+1}$ and lim a_n=0, then the series $\sum a_n z^n$ has radius of convergence equal to 1 and the series converges for $|z|=1$except possibly at z =1, A power series represents an analytic function within the circle of convergence, Hadamard- Pringsheim theorem. The principle of analytic continuation, uniqueness of analytic continuation, Power series method of analytic continuation, functions with natural boundaries e.g., $\sum z^{n!}$, $\sum z^{2^n}$, Schwarz reflection principle.

CREDIT-IV

Functions with positive real part, Borel's theorem: If f(z) $=1+\sum a_n z^n$ is analytic and has a positive real part in $|z|<1$, then $|a_n|\leq 2$, Univalent functions, Area theorem, Bieberbach's conjecture (statement only) and Koebe's ¼ theorem.

Space of Analytic Functions, Bloch's Theorem, Schottky's theorem, a - points of an analytic function, Picard's theorem viz, an integral Function which is not a constant takes every value with one possible exception, Landau's theorem.

Recommended Books:

1. L.V. Ahlfors, Complex Analysis
2. E. C.Tichtmarsh, Theory of Functions
3. J. B. Conway, Functions of a Complex Variable-I
4. Richard Silverman, Complex Analysis
5. Z. Nehari, Conformal Mappings
6. A.I. Markushevish, Theory of Functions of a Complex Variable

FUNCTIONAL ANALYSIS-I

Course No: **MM-CR-303**	Max. Marks: 100
Duration of Examination: 2:30 Hrs.	External Exam: 80
No. of Credits: **04**	Internal Assessment: 20

BANACH SPACE:

CREDIT-I

Banach Spaces: Definition and examples, subspaces, quotient spaces, Continuous Linear Operators and their Characterization, Completeness of the space L(X,Y) of bounded linear operators (and its converse), incompleteness of C[a, b], under the integral norm, Finite dimensional Banach spaces, Equivalence of norms on finite dimensional space and its consequences, Dual of a normed linear space, Hahn Banach theorem (extension form) and its applications, Complemented subspaces, Duals of l_p^n, C_o , l_p $(p\geq1)$, C[a, b].

CREDIT-II

Uniform boundedness Principle and weak boundedness, Dimension of an ∞-dimensional Banach space, Conjugate of a continuous linear operator and its properties, Banach-Steinhauss theorem, open Mapping and closed graph theorems, counterexamples to Banach-Steinhauss, open mapping theorem and closed graph theorems for incomplete domain and range spaces, separable Banach spaces and the separability of some concrete Banach spaces (C_o, C[0,1], l_p, $p\geq1$), Reflexive Banach Spaces, closed subspace and the dual of a reflexive Banach space, Examples of reflexive and non-reflexive Banach spaces.

HILBERT SPACE:

CREDIT-III

Hilbert spaces: Definition and examples, Cauchy's Schwartz inequality, Parallogram law, orthonormal (o.n) systems, Bessel's inequality and Parseval's Identity for complete orthonormal systems, Riesz-Fischer theorem, Gram Schmidt process, o.n basis in separable Hilbert spaces.

CREDIT-IV

Projection theorem, Riesz Representation theorem. Counterexample to the Projection theorem and Riesz Representation theorem for incomplete spaces. Hilbert property of the dual of a Hilbert space and counter examples of incomplete inner product spaces, Reflexivity of Hilbert space, Adjoint of a Hilbert space operator, weak convergence and Bolzano-Weirstrass property in Hilbert Spaces. Normal and Unitary operators, Finite dimensional spectral theorem for normal operators.

Recommended Books:

1. B.V.Limaya: Functional Analysis.
2. C.Goffman G. Pedrick: A First Course in Functional Analysis.
3. L.A. Lusternick & V.J. Sobolov. : Elements of Functional Analysis.
4. J.B. Conway : A Course in Functional Analysis.

ABSTRACT MEASURE THEORY

Course No. **MM-EA-304**		Max. Marks:	100
Duration of Examination: 2:30 Hrs.		External Exam:	80
No. of Credits: **04**		Internal Assessment:	20

CREDIT-I

Semiring , algebra and σ - algebra of sets, Borel sets, measures on semirings, outer measure associated with a set function and basic properties, measurable sets associated with an outer measure as a σ - algebra , construction of the Lebesgue measure on R^n .

CREDIT-II

For f Є L_1 [a, b], $F^{/}$= f a.e. on [a, b]. If f is absolutely continuous on (a, b) with f(x)=0 a.e, then f = constant. Characterization of an absolutely continuous function as an indefinite Lebesgue integral. Non-Lebesgue integrability of f where f (x) = $x^2\sin(1/ x^2)$, f (0) =0 on [0, 1]. Fundamental theorem of calculus for the Lebesgue integral. A brief introduction to L_p spaces. Holder's and Minkowki's inequalities.

CREDIT-III

Improper Riemann integral as a Lebesgue integral, calculation of some improper Riemann integrable functions, space of Lebesgue integrable functions as completion of Riemann integrable functions on [a,b], change of variables formula and simple consequences, Riemann Lebesgue lemma.

CREDIT-IV

Product measures and iterated integrals, example of non-integrable functions whose iterated integrals exist (and are equal), Fubini theorem, expressing a double integral as an iterated integral, Tonelli-Hobson theorem as a converse to Fubini theorem, differentiation under the integral sign.

Recommended Books:

1.C.D.Aliprantis and O.Burkinshaw, Principles of Real Analysis
2.Goldberg , R. : Methods of Real Analysis
3.T.M.Apostol : Mathematical Analysis

Suggested Readings:

1.Royden, L: Real Analysis (PHI)
2.Chae, S.B. Lebesgue Integration(Springer Verlag).
3.Rudin, W. Principles of Mathematicals Analysis(McGraw Hill).
4.Barra ,De. G. : Measure theory and Integration (Narosa)
5.Rana ,I.K. : An Introduction to Measure and Integration, Narosa Publications.

ADVANACED GRAPH THEORY

Course No: **MM-EA-305**		Max. Marks:	100
Duration of Examination: 2:30 Hrs.		External Exam:	80
No. of Credits: **04**		Internal Assessment:	20

CREDIT-I

Colorings

Vertex coloring, chromatic number $\chi(G)$, bounds for $\chi(G)$, Brook's theorem, edge coloring, Vizing's theorem, map coloring, six color theorem, five color theorem, every graph is four colourable iff every cubic bridgeless plane map is 4-colorable, every planar graph is 4-colorable iff $\chi'(G) = 3$, Heawood map-coloring theorem, uniquely colorable graphs

CREDIT-II

Matchings

Matchings and 1-factors, Berge's theorem, Hall's theorem, 1-factor theorem of Tutte, antifactor sets, f-factor theorem, f-factor theorem implies1-factor theorem, Erdos- Gallai theorem follows from f-factor theorem, degree factors, k-factor theorem, factorization of K_n .

CREDIT-III

Edge graphs and eccentricity sequences

Edge graphs, Whitney's theorem on edge graphs, Beineke's theorem, edge graphs of trees, edge graphs and traversibility, total graphs, eccentricity sequences and sets, Lesniak theorem for trees, construction of trees, neighbourhoods, Lesniak theorem graphs.

CREDIT-IV

Groups in graphs and Graph networks

Automorphism groups of graphs, graph with a given group, Frucht's theorem, Cayley digraph, Transport networks, maximum flow cut and its capacity, Max-flow-Min-cut theorem, multiple sources and sinks, networks containing undirected edges, lower bounds on edge flows, topological sorting, critical path, graphs in game theory, kernel of a digraph

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

MATHEMATICAL BIOLOGY

Course No. **MM-EA-306**	Max. Marks: 100
Duration of Examination: 2:30 Hrs.	External Exam: 80
No. of Credits: **04**	Internal Assessment: 20

CREDIT-I

Diffusion in biology: Fick's law of diffusion, Fick's perfusion law, membrane transport, diffusion through a slab, convective transport, Trancapillary exchange; Heat transport in biological tissues, Oxygen transport through red cells, Gas exchange in lungs, the ideal gas law and solubility of gases, the equation of gas transport in one Alveolus.

CREDIT-II

Biofluid mechanics: Introduction, various types of fluid flows, viscosity, basic equation of fluid, mechanics, continuity equation, equation of motion, the circulatory system, systemic and pulmonary circulation, the circulation in heart, blood composition, arteries and arterioles, models in blood flow, Poiseulle's flow and its applications, the pulse wave.

CREDIT-III

Tracers in physiological systems: Compartment systems, the one compartment system, Discrete and continuous transfers, ecomatrix, the continuous infusion, the two compartment system, Bath-tub models, three-compartment system, the leaky compartment and the closed systems, elementary pharmacokinetics, parameter estimation in two compartment models, basic introduction to n-compartment systems.

CREDIT-IV

Biochemical reactions and Population Genetics: The law of mass action, enzyme kinetics, Michael's- Menten theory, Competitive inhibition, Allosteric inhibition, enzyme-substrate-inhibitor system, cooperative properties of enzymes, the cooperative dimer, haemoglobin. Haploid and Diploid genetics, spread of favourite allele, mutation-selection balance, heterosis, frequency dependent selection.

Books Recommended

1. J.D. Murray, Mathematical Biology, CRC Press
2. S.I. Rubinow, Introduction to Mathematical Biology, John Wiley and Sons
3. Guyton and Hall, Medical Physiology.
4. S.C. Hoppersteadt and C.S. Peskin, Mathematics in Medicine and Life Sciences, Springer-Verlag
5. J.R. Chesnov, Lecture notes in Mathematical Biology, Hong Kong Press
6. J. N. Kapur, Mathematical methods in Biology and Medicine, New Age Publishers
7. D. Ingram and R.F. Bloch, Mathematical methods in Medicine, John Wiley and Sons.

WAVELET THEORY

Course No: **MM-EA-307**	Max. Marks: 100
Duration of Examination: 2:30 Hrs.	External Exam: 80
No. of Credits: **04**	Internal Assessment: 20

CREDIT-I

Time Frequency Analysis and Wavelet Transforms

Gabor transforms basic properties of Gabor transforms, continuous and discrete wavelet transforms with examples, basic properties of wavelet transforms, examples of Haar wavelet, Mexican hat wavelet and their Fourier transforms, dyadic orthonormal wavelet bases for $L^2(\mathbb{R})$.

CREDIT-II

Multiresolution Analysis and Construction of Wavelets

Definition and examples of multiresolution analysis (MRA), properties of scaling functions and orthonormal wavelet bases, construction of orthonormal wavelets with special reference to Haar wavelet, Franklin wavelet and Battle-Lemarie wavelet, Spline wavelets, construction of compactly supported wavelets, Daubechie's wavelets and algorithms.

CREDIT-III

Other Wavelet Constructions and Characterizations

Introduction to basic equations, some applications of basic equations, characterization of MRA wavelets and scaling functions, construction of biorthogonal wavelets, wavelet packets, definition and examples of wavelets in higher dimensions.

CREDIT-IV

Further Extensions of Multiresolution Analysis

Periodic multiresolution analysis and the construction of periodic wavelets, multiresolution analysis associated with integer dilation factor (M-band wavelets), harmonic wavelets, properties of harmonic scaling functions.

Books Recommended

Text Book:

1. L. Debnath, Wavelet Transforms and their Applications, Birkhauser, 2002.
2. I. Daubechies, Ten Lectures on Wavelets, CBS-NSF Regional Conferences in Applied Mathematics, 61, SIAM, Philadelphia, PA, 1992.
3. K. Ahmad and F. A. Shah, Introduction to Wavelets with Applications, Real World Education Publishers, New Delhi, 2013.

Reference Books:

5. C. K. Chui, An Introduction to Wavelets, Academic Press, New York, 1992.
6. M. Pinsky, Introduction to Fourier Analysis and Wavelets, Brooks/Cole, 2002.
7. E. Hernandez and G. Weiss, A First Course on Wavelets, CRC Press, New York (1996).

OPEN ELECTIVE

Course No. **MM-EO-308**	Max. Marks: 100
Duration of Examination: 2:30 Hrs.	External Exam: 80
No. of Credits: **04**	Internal Assessment: 20

SEMESTER-IV

PARTIAL DIFFRENTIAL EQUATIONS

Course No: **MM-CR-401**	Max. Marks: 100
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

DIFFERENTIAL GEOMETRY

Course No: **MM-CR-402**		Max. Marks:	100
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

ADVANCED ABSTRACT ALGEBRA—II

Course No: **MM-CR-403**	Max. Marks: 100
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.

ANALYTIC THEORY OF POLYNOMIALS

Course No: **MM-EA-404**	Max. Marks: 100
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).

MATHEMATICAL STATISTICS

Course No: **MM-EA-405**	Max. Marks: 100
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.

FUNCTIONAL ANALYSIS-II

Course No. **MM-WA-406**		Max. Marks:	100
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).

NON LINEAR ANALYSIS

Course No: **MM-EA-407**		Max. Marks:	100
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.

ADVANCED TOPICS IN TOPOLOGY AND MODERN ANALYSIS

Course No. **MM-EA-408**	Max. Marks: 100
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.

PROJECT

Course No: **MM-EA-409**		Max. Marks:	100
Duration of Examination: 2:30 Hrs.		External Exam:	80
No. of Credits: **04**		Internal Assessment:	20

OPEN ELECTIVE

Course No: **MM-EO-410**	Max. Marks: 100
Duration of Examination: 2:30 Hrs.	External Exam: 80
No. of Credits: **04**	Internal Assessment: 20