SYLLABUS FOR B.Sc. MATHEMATICS DEGREE PROGRAM UNDER CBCS w.e.f. 2017-18

Discipline Specific Core (Mathematics) Papers for B.Sc.

Sl. No.	Paper Code	Semester	Title	No. Of Credits.
1	DSC 1A	I	Calculus and Numerical Methods	4+2
2.	DSC 1B	II	Matrices and Linear Algebra	4+2
3.	DSC 1C	III	Ordinary Differential Equations and Discrete Mathematics	4+2
4.	DSC 1D	IV	Analysis and Operations Research	4+2

Skilled Enhancement Courses

Sl. No.	Paper Code	Semester	Title	No. Of Credits.
1	SEC 1	III	Statistical Methods	3+1
2.	SEC 2	IV	Analytical Geometry	3+1

Generic Elective Courses for Non Mathematics Students

Sl. No.	Paper Code	Semester	Title	No. Of Credits.
1.	GE-1	I	Probability and statistics	3+1
2.	GE-2	II	Numerical Computations	3+1
3.	GE-3	III	Mathematics for Competitive Examination -I	4
4.	GE-4	IV	Mathematics for Competitive Examination -II	4

B.Sc. Mathematics: (CBCS)

Semester I : DSC IA : Calculus and Numerical Methods

Semester II : DSC IB : Matrices and Linear Algebra

SYLLABUS

Semester I: DSC IA : Calculus and Numerical Methods. **Credits: 4+2**

Course learning outcomes:

1) Students will have a thorough understanding of the real number system.
2) Students will relate calculus to real-world problems.
3. Students will prove basic results in calculus.
3) Students will learn various techniques from Numerical Methods

1. Real Number System: Algebra of real number system, Axioms of order structure in $\mathbb{R}$, Upper and Lower bounds of subsets of $\mathbb{R}$, lub of subsets of $\mathbb{R}$, Order completeness of $\mathbb{R}$,

Archimedean property, Intervals and their types, Nested interval Theorem, Absolute value and their properties. **[12 hours]**

2. Real Sequences: Real Sequence (Definition and examples), Range of a sequence, Bounded sequence, Convergence of a sequence (Definition and examples), Uniqueness of limit of sequence, Algebra of sequences, Sandwich Lemma, Monotonic sequences and their convergence, Subsequence of a sequence (Definition and examples), Properties of subsequences, Bolzano Weierstrass theorem. **[12 hours]**

3. Limits and Continuity: Neighbourhood of a point, Deleted neighbourhood of a point, Limit of a function at a point (Definition and examples) Uniqueness of a limit, Algebra of limits, Continuity of a function at a point (Definition and examples), Algebra of continuous of function, Left hand limit, Right hand limit, Types of discontinuities, Sequential continuity, Some more properties of continuous functions, Boundedness of continuous function on a closed interval, Intermediate value theorem for continuous functions, Image of the closed interval under a continuous function, Attaining maximum and minimum of a continuous function on closed interval, Fixed point of a function, Fixed point theorem for continuous function. **[12 hours]**

4. Derivatives and its Applications: Derivative of a function at a point (Definition and examples), Geometric interpretation of a derivative, Algebra of derivatives, Chain rule, Some more properties of the derivative, Darboux's theorem for differentiable functions, Intermediate value theorem for differentiable functions, Rolle's theorem and its geometric significance, Lagranges mean value theorem and its geometric significance, Cauchy's mean value theorem and its geometric significance, Monotonic functions (Definition and examples), Monotonic functions and derivatives, Higher order derivatives, Taylor's theorem, Mclaurin's theorem, Taylor's and Mclaurin's series expansions, Leibnitz rule for higher order derivative of product of functions, Stationary points and their classification, Local maxima and Local minima, Condition for a stationary point to be local maxima and minima,
Indeterminate forms of the type $\frac{0}{0}, \frac{\infty}{\infty}, \infty - \infty, 0.\infty, 0^0, 1^\infty, \infty^0$. **[15 hours].**

5. Numerical Methods:

Calculus of Finite differences: Operators Δ, ∇, & E . Difference Tables. Properties of Δ, ∇, & E. Fundamental Theorem of Difference Calculus. Expression of any value of a function in terms of leading term and leading differences of a difference table. Method of separation of symbols.

Interpolation and Extrapolation: Newton's forward and backward interpolation formulae. Lagrange's Interpolation formula . Newton's Divided Difference formula.
Examples based on the above formulae.

Numerical Differentiation and Integration: Differentiation formulae for equidistant arguments. Examples. General quadrature formula for equidistant ordinates (Newton –Cotes Formula Or Gauss Legendre quadrature formulae). Trapezoidal rule and its Geometrical interpretation. Simpson's one third rule, Simpson's three-eighth rule. Weddle's rule (Only Statements)

Solution of Algebraic and transcendental Equations: Method of Bisection, Regula-Falsi Method, Newton-Raphson Method and their Computation scheme. Special Cases of Newton-Raphson Method like finding q^{th} root of a positive real number'd' and finding reciprocal of a positive real number 'd' without using division. **[09 hours]**

List of Practical sessions: (4 hours each)

1. Basics of Programming, Programming Languages, Python syntax, If, Elif, Else and while loops, simple programs involving these loops.
2. Computing limits using $\varepsilon - \delta$ definition.

3. Checking if a function is continuous & identifying discontinuity.
4. Finding Taylors and Maclaurin series expansions.
5. Identifying and classifying stationary points and finding local maxima and minima of a function.
6. Using L'hospitals rule to compute limits.
7. Newton-Gregory Forward and Backward Interpolation Formulae.
8. Lagrange's Interpolation Formula for unequal intervals and Newton's Divided difference formula for unequal intervals
9. Numerical Differentiation: Using Differentiation formulae for equidistant arguments .
10. Numerical Integration: Trapezoidal rule, Simpson's one third rule and Weddle's rule.
11. Solution of Algebraic and transcendental equations by the Bisection method.
12. Solution of Algebraic and transcendental equations by the Regula Falsi method and the Newton–Raphson method.

Note: Practicals should be done by using free software like Python, C^{++}, etc.

Principal Texts:

1. A Basic Course in Real Analysis, Ajit Kumar & S. Kumaresan, CRC Press.
2. Introductory Methods of *Numerical Analysis* By S.S.Sastry. PHI

References:

1. Introduction to Real Analysis, Robert G. Bartle & Donald R. Sherbert, Wiley Student Edition.
2. Mathematical Analysis, Tom Apostol, Narosa Publishing House.
3. Calculus (Vol. 1), Tom Apostol , Wiley Student Edition.
4. Shaum's outline on Advaced Calculus, Robert Wrede & Murray R. Spiegel, Tata McGraw Hill.
5. Numerical methods: Problems & Solutions. M. K. Jain, Iyengar, Jain. Wiley Eastern.
6. Calculus of Finite difference & Numerical Analysis: Gupta & Malik, Krishna Prakashan Mandir , Meerut.

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Semester II: DSC IB Matrices and Linear Algebra. Credits: 4+2

Course outcome: On successfully completing the course the student will be able to:

1. define basic terms and concepts of vector spaces, basis and dimension.
2. Solve systems of linear equations using various methods including Gaussian and Gauss-
3. Prove basic results in linear algebra using appropriate proof-writing techniques such as linear independence of vectors.
4. Understand determinants and their properties.
5. Understand real vector spaces and subspaces and apply their properties.
6. Find basis and dimension of a vector space.
7. Find a basis for the row space, column space and null space of a matrix and find the rank and nullity of a matrix.
8. Compute linear transformations, kernel and range, and inverse linear transformations, and find matrices of general linear transformations.
9. Find the dimension of spaces such as those associated with matrices and linear transformations.
10. Find eigenvalues and eigenvectors and use them in applications.

11. Evaluate the norm, angle between vectors, and orthogonality of two vectors
12. Compute inner products on a real vector space.
13. To impart the ability of solving problems in matrix algebra using a programming language.

Syllabus

System of linear equations [Nicholson, Chapter 1]: Solutions & Elementary Operations: (Linear system of equations, solutions, equivalence of 2 systems, elementary operations on equations, elementary row operations). Gaussian Elimination: (Row /Row reduced echelon forms, Gaussian algorithm, Rank). Homogeneous Equations: (Sufficient condition for the existence of non-trivial solution). **[6 hours]**

Matrix Algebra[Nicholson, Chapter 2]: Matrix Addition, Scalar multiplication, Transposition: (Definition, properties, symmetric matrix). Matrix Multiplication:(Definition, properties, block multiplication). Matrix Inverses: (Definition, uniqueness, properties, Matrix inversion algorithm (row reduction)). Elementary Matrices:(Definition, Properties, theorems). **[3 hours]**

Determinants [Nicholson, Chapter 3]: The Laplace Expansion: (Determinant, properties, upper/ lower triangular matrices). Determinant & Matrix inverses (Product theorem & other related theorems, orthogonal matrices, minors, co-factors, adjoint formula for A^{-1} , Cramer's rule) **[3 hours]**

Vector Spaces: Definition and examples, Vector subspaces, Basis and Dimension of Vector Spaces. **[6 hours]**

Lines and Quotient Spaces: Definition of a line, Affine spaces, Quotient Spaces. **[6 hours]**

Linear Transformations: Linear Transformation, Representation of linear maps by matrices, Kernel and Image of a Linear Transformation, Linear Isomorphism, Geometric ideas and some loose ends, Some special Linear Transformations. **[9 hours]**

Inner Product Spaces: Inner Product Spaces, The Euclidean plane and the dot product, General Inner Product Spaces, Orthogonality, Some geometric applications, Orthogonal projection onto a line, Orthonormal basis, Orthogonal complements and projections, Linear Functionals and Hyperplanes, Orthogonal Transformations, Coordinates associated with an Orthonormal Basis, Reflections and Orthogonal Maps of the Plane. **[9 hours]**

Diagonalization: Rotation of axes of conic, Eigenvalues and eigenvectors, Cayley-Hamilton theorem, Diagonalisation of symmetric matrices. **[9 hours]**

Review Problems: Linear equations, Linear dependence, Basis and Dimension, Linear Transformations, Euclidean Spaces, Problems in Linear Geometry, Miscellaneous problems. **[9 hours]**

List of Practical sessions (4 hours each)

1. For loop, List comprehensions, Entering matrices as lists within a list. Addition, Scalar multiplication, Transpose.

2. Multiplication of matrices
3. Minors of a matrix
4. Determinant of a matrix.
5. Inverse of a matrix using Adjoint
6. Cramer's Rule.
7. Defining a function to multiply a row by a scalar
   Defining a function to interchange 2 rows
   Defining a function to replace row (i) by row(i) + z row(j).
8. Program to perform row reduction to Reduced row-echelon form
9. Program to generate nxn identity matrix.
10. Program to find inverse of a matrix using row reduction.
    Program to solve a system equations using Gaussian elimination.
11. Finding eigen vectors of a matrix (with real eigen values upto order 2x2).
12. Diagonalization of a Matrix (with distinct real eigen values upto order 2x2)

Note: Practicals should be done by using free software like Python, C^{++}, etc.

Principal Texts:

1. Linear algebra with applications by Keith Nicholson (3rd Edition, PWS publishing company).
2 Linear Algebra, A Geometric Approach, S. Kumaresan, PHI Learning Private Limited. (Chapter 6 omitted.)

References:

1. An Introduction to Linear Algebra, V Krishnamurthy, V P Mainra, J L Arora, Affiliated East-West Press Pvt. Ltd.
2. Theory and Problems of Linear Algebra, Seymour Lipschitz, Schaum's Outline Series, McGraw-Hill Book Company.
3. Linear Algebra, Kenneth Hoffman and Ray Kunze, EEE Publication.
4. Linear algebra and applications by Gilbert Strang (4th Edition, Cengage Learning)

Course Outcome

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Semester – III **Credits: 4+2**

DSC 1C: Differential Equations and Discrete Mathematics

Course outcome:

- Recognize ODEs and system of ODEs concepts that are encountered in the real world, understand and be able to communicate the underlying mathematics involved to help another person gain insight into the situation.
- Work with ODEs and systems of ODEs in various situations and use correct mathematical terminology, notation, and symbolic processes in order to engage in work, study, and conversation on topics involving ODEs and systems of ODEs with colleagues in the field of mathematics, science or engineering.
- Analyse real world scenarios to recognize when ordinary differential equations (ODEs) or systems of ODEs are appropriate, formulate problems about the scenarios, creatively model

these scenarios in order to solve the problems using multiple approaches, judge if the results are reasonable, and then interpret and clearly communicate the results.

- To understand and apply the fundamental concepts in graph theory for solving practical problems. Demonstrate different traversal methods for trees and graphs. Model real world problems using graph theory.

Syllabus:

1. FIRST ORDER ORDINARY DIFFERENTIAL EQUATIONS:-

Review of Basic concepts such as order, degree, formation, solution and their types of differential equations. First order first degree differential equation and initial value problem. Method of separation of variables. Homogeneous and Non - homogeneous differential equation. First order linear differential equations. Bernoulli"s differential equation. Exact and Non – exact differential equations. Condition for exactness. Integrating factors and rules to find integrating factors. Clairaut"s differential equation and differential equations reducible to Clairaut"s form. Ricatti"s differential equation. Applications of first order differential equations. Modeling with differential equations.

(8 Hours)

2. SECOND ORDER LINEAR DIFFERENTIAL EQUATIONS:-

General form of second order linear differential equation and its classification. Existence and Uniqueness theorem for solution of second order linear differential (Only statement). Second order homogeneous linear differential equation and its properties. Wronskian of solutions of homogeneous linear differential equation and its properties. Linear dependence and independence of solutions of homogeneous differential equation. Complementary function. Use of known solution to find second linearly independent solution of homogeneous differential equation. Homogeneous linear differential equations with constant coefficients and with variable coefficients. Method of undetermined coefficients. Method of variation of parameters. Applications of second order linear differential equations. **(10 Hours)**

3. D – OPERATORS:-

D – Operator method to solve n^{th} order homogeneous linear differential equation with constant coefficients. Properties of D – Operator. Inverse D – operator and it properties. Inverse D – operator method to solve n^{th} order Non - homogeneous linear differential equation with constant coefficients **f(D) = R(x)**, where **$R(x) = e^{ax}$, cosax, sin ax**, polynomial in „**x**" and their products. **(8 Hours)**

4. SYSTEM OF 1^{ST} ORDER DIFFERENTIAL EQUATIONS:-

Conversion of n^{th} order differential equation to first order system of differential equations. Existence and uniqueness of solution (statement only). " 2 ×2 " homogeneous linear first Order system of differential equations and their solution. Wronskian of " 2×2 "

homogeneous linear first order system of differential equations and its properties. Linear dependence and independence of solutions of " 2 ×2 " homogeneous linear first order system of differential equations. Matrix method to solve " 2×2 " homogeneous linear first order system of differential equations with constant coefficients. Method of solving " 2×2 " Non - homogeneous linear first order system of differential equations with constant coefficients. **(10 Hours)**

5. GRAPH THEORY:-

Introduction. Basic terminology. Types of Graphs. Multigraphs and Weighted graphs. Isomorphism of graphs. Paths and circuits. Shortest path in weighted graphs. Eulerian paths and circuits. Hamiltonian paths and circuits. Factors of graphs. planar graphs. **(12 Hours)**

6. TREES AND CUT-SETS:-

Trees. Rooted trees. Path lengths in rooted trees. Prefix codes. Binary search trees. Spanning trees and cut- sets. Minimum spanning tree. Kruskal"s algorithm. Prim"s algorithm. Transport network. **(12 Hours)**

List of practical sessions (4 hours each):

1. General solution of $\frac{dy}{} = \frac{a_1x + b_1y + c_1}{}$.

$$\frac{dx}{a_2x+b_2y+c_2}$$

2. General solution of M(x, y)dx + N(x, y)dy = 0.
3. Method of undetermined coefficients.
4. Method of variation of parameters.
5. Inverse D – operator method to solve f(D) = R(x).
6. Matrix method to solve " 2×2 " homogeneous linear first order system of differential equations.
7. Shortest path using Dijkstra"s algorithm for weighted graphs.
8. Eulerian paths and circuits in graphs.
9. Hamiltonian paths and circuits in graphs.
10. Prefix Codes in trees.
11. Minimum Spanning tree using Kruskal"s algorithm.
12. Minimum Spanning tree using Prim"s algorithm.

Principal texts:

1. Differential Equations and Their Applications: Martin Braun (Springer)
2. Elements of Discrete Mathematics: C. L. Liu and D. P. Mohapatra (Tata Mcgraw Hill)

References:

1. Differential Equations with Applications and with Historical Notes: G. F. Simmons (Tata Mcgraw Hill)
2. Ordinary Differential Equations: E. A. Coddington (PHI Learning Pvt. Ltd.)
3. Shaum"s Outline on Differential Equations: Richard Brownson (Tata Mcgraw Hill)
4. Discrete Mathematical Structures: Kolman, Busby and Ross (PHI Learning Pvt. Ltd.)
5. Discrete Mathematics and Applications: Kenneth Rosen (TMH).
6. Shaum"s Outline on Discrete Mathematics: Seymour Lipschutz and Marc Lipson (Tata Mcgraw Hill).

Semester – IV **Credits: 4+2**

DSC 1D: Analysis and Operations Research

Learning outcomes:

On successfully completing the course a student will be able to :

1. Apply the knowledge of convergence to problems and the various theorems on convergence, absolute convergence and conditional convergence
2. Understand partitions and their refinement
3. Understand Integrability and theorems on integrability
4. Acquire the idea about Riemann Integrability and Riemann Integration and Understand various theorems associated with Riemann Integration
5. Explain convergence of a series
6. Develop skill in checking the uniform convergence of series using various tests of convergence
7. Distinguish between Pointwise convergence and Uniform Convergence
8. Illustrate the effect of uniform convergence on the limit function with respect to continuity, differentiability, and integrability
9. Determine the limit point of a series of functions.
10. to provide solutions to real life or industry problems using operations research.

Syllabus:

1. Infinte Series [Ajit kumar, Chapter 5]:

Convergence of infnite series, absolute convergence, Conditional convergence, Geometric series, Cauchy criterion for convergence, Algebra of convergent series, Comparision test, Convergence of Harmonic P-series, D'Alembert ratio test,Cauchy nth root test,Leibniz test or alternating series test**.** **[10 hours]**

2. Riemann Integration [Ajit kumar, Chapter 6]:

Darboux Integrability, Criterion for integrability, Properties of integrabilities. First fundamental theorem of calculus, Second fundamental theorem of calculus, integration by parts, Mean value theorems for integrals, First mean value theorem for integrals, Second mean value theorem I, Second mean value theorem II, Riemann original definition**.**

[20 hours]

3. Sequences and Series of functions[Ajit kumar, chapter 7]:

Pointwise convergence of sequence of functions and examples, Uniform convergence of sequence of functions and examples, Mn-Test,Cauchy Criterion for uniform convergence, Consequences of Uniform convergence, Continuity of limit function, Series of functions, Absolute convergence, Cauchy Criterion for uniform convergence of a series, Weierstrass M-test, Weierstrass Approximation Theorem. **[10 hours]**

4. Operations Research

Fundamentals: Linear Programming problems, Convex sets ,Extreme points of Convex sets, Convex Polyhedron ,hyperplanes, Graphical Method, Simplex Method, Theorems on simplex method ,Big-M method, Two phase method, Unrestricted variables, Duality and solution using duality, Theorems on Duality, Dual Simplex method, Post Optimal Analysis (Discrete changes in cost and requirement vector) Transportation Problems, North west corner method, Vogel's approximation method, Modi Method, Assignment Problems, Hungrian Method, Basics of Inventory control, Inventory model with No shortages and Instantaneous production, Inventory model with Shortages allowed and Instantaneous production. Basics of Queueing theory, Queueing Model (M/M/1):(1/FIFO),
Queueing Model (M/M/1):(N/FIFO). **[20 hours]**

List of Practical sessions [4 hours each]

1. Basics of Linear Programming problems including Formulation.
2. Graphical Method
3. Simplex Method, Unbounded solution, Alternate solution
4. Big-M method, unrestricted variables.
5. Two phase method
6. Duality and solution using duality.
7. Dual Simplex method
8. Post Optimal Analysis (Discrete changes in cost and requirement vector)
9. Transportation Problems, existence of solution (North west corner method, Vogel's approximation method)
10. Transportation Problems (Modi Method,Problems to Minimize/Maximize objective function)
11. Assignment Problems (Hungrian Method)
12. Basics of inventory control, Inventory model with No shortages and Instantaneous

production.
13. Inventory model with Shortages allowed and Instantaneous production.
14. Queueing Model (M/M/1):(1/FIFO)
15. Queueing Model (M/M/1):(N/FIFO)

Principal texts:

1. A Basic Course in Real Analysis, Ajit Kumar and S.Kumaresan ; CRC Press.
2. Linear Programming by G. Hadley; Adddison.

References:

1. Mathematical Analysis I, R.D.Bhat, Vipul Prakashan,Mumbai.
2. Mathematical Analysis II, R.D.Bhat,Vipul Prakashan,Mumbai.
3. Introduction to Real analysis ,Robert G.Bartle, Donald R.Sherbert, Third edition, Wiley Publication.
4. Methods of Real analysis , Richard R.Goldberg, Oxford and IBH publishing Co.pvt.ltd.
5. Calculus Vol-I, Tom M.Apostol, Second edition, Wiley Publication.
6. Operations Research, Kanti Swarup and Gupta, S. Chand and company , Delhi.

Semester – III Credits: 4

SEC 1 : Statistical Methods

Course outcomes:

1. To know the meaning , importance and scope and limitations of statistics
2. To be able to find the correlation between two variables using Karl pearsons and rank correlation coefficient.
3. To find probability of an event using the different definitions of probability also to find inverse probability using Baye's theorem
4. To write the probability distribution and mathematical expectations of a discrete as well as continuous random variable.
5. To study the different theoretical distribution like binomial, poisson and normal distribution and find the probabilities and probability distribution from them.
6. To be able to find interval estimate, test the validity of a hypothesis for large samples as well as small samples using the various parametric and non parametric test.
7. For the practical component student should be able to find the statistical values and measures for different test and should be able to interpret the results

1. **Introduction- Meaning and Scope**: Definition of Statistics, Importance and scope of Statistics, Limitations of Statistics, Distrust of Statistics. **(2 hours)**
2. **Correlation and Regression Analysis**: Introduction. Karl Pearson‟s coefficient of Correlation, Rank correlation method. Regression Analysis. **(10 hours)**
3. **Theory of Probability**: Introduction, Mathematical probability, Statistical probability, Axiomatic probability, Addition theorem of probability.(Proof omitted), Multiplication theorem of probability. Pair wise and mutual independence, Inverse probability – Baye‟s theorem. **(6 hours)**
4. **Random Variables**: Probability Distributions and Mathematical Expectation: Random variable, Probability distribution of a Discrete Random Variable, Probability distribution of a Continuous Random Variable, Mathematical Expectations. **(3 hours)**
5. **Theoretical Distributions**: Binomial distribution, Poisson Distribution, Normal Distribution. **(5 hours)**
6. **Testing of Hypothesis**: Interval Estimation, Testing of Hypothesis. **(3 hours)**
7. **Large sample tests**: Introduction, Sampling of Attributes, Sampling of Variables. **(4 hours)**
8. **Parametric tests**: Student‟s „t‟ distribution, ANOVA, Post-hoc analysis. **(10 hours)**
9. **Non-Parametric tests**: Chi Square test, Mann-Whitney test, Kruskal walli‟s test. **(7hours)**

List of Practicals (Using ***R*** or similar softwares) **(10 hours)**

1. Finding measures of central tendency, namely, mean, median and mode.
2. Finding measures of dispersion, namely, range, quartile deviation, mean deviation and standard deviation.
3. Testing of hypothesis for single mean and difference of means using „t- test‟ and paired „t-test‟.
4. Testing of hypothesis for more than two means using ANOVA.
5. Testing of hypothesis regarding independence of attributes using Chi square test.
6. Testing the hypothesis stating that the k independent samples have been drawn from the populations which have identical distributions using Kruskal Walli‟s test.

References:

1. Fundamentals of Statistics, S.C Gupta, Himalaya Publishing House, Seventh Edition. (**Principal**

*Reference for purpose of conducting practicals only.

1) Fundamentals of Mathematical Statistics, S.C Gupta, V.K Kapoor, S.Chand Publications.
2) Mathematical Statistics, J.N Kapur, H.C Saxena, S.Chand Publications.
3) Probability, Statistics and Random Processes, T Veerarajan, McGraw Hill Education (India) Private Limited.
4) Probability Theory, B. R. Bhat, New Age International, 2007.

Semester – IV Credits: 4

SEC 2 : Analytical Geometry

Course outcome:

1) To review and discuss in detail various curves in R^2 and R^3
2) To visualize curves in R^2 with the help of softwares such as Geogebra, Python, etc.

Syllabus:

1. **Metric Properties on the Plane**. (3 hours)
2. **Straight Lines in the Plane**. (3 hours)
3. **Circles in Plane**. (3 hours)
4. **Conics in the Plane and its plane sections**. (12 hours)
5. **Classification of Conics**. (5 hours)
6. **Polar Co-ordinate System**. (3hours)
7. **Co-ordinates in 3-space**. (3 hours)
8. **Plane in 3-space**. (4 hours)
9. **Lines in 3-space**. (3 hours)
10. **Transformation of Co-ordinates**. (4 hours)
11. **Sphere**. (4 hours)
12. **Cones**. (4 hours)
13. **Cylinder**. (4 hours)
14. **The Conicoid**. (5 hours)

Reference:

1. Analytic Geometry: Two and Three Dimension, D. Chatterjee, Narosa Publishing House, 2009.
2. Analytic Geometry, Shanti Narayan and P. K. Mittal, S. Chand and Company Ltd, 2007.

Remark:

1. Tracing of general second degree conics/conicoids using the mathematical software GEOGEBRA, SAGE, MATH and PYTHON.
2. Properties of pair of lines, circles, parabola, Ellipse etc., may be verified using mathematical softwates lime GEOGEBRA/SAGEMATH.

Generic Courses for Non Mathematics Students

Semester – III Credits: 4

GE-3: Mathematics for Competitive Examination –I

Course outcome:

Will be able to attempt the mathematical and logical questions confidently in competitive examination.

Syllabus

Ratio and proportion; Indices; Logarithms; Linear, Quadratic and cubic equations; Inequalities; Simple & compound interest, annuity & loans

Problem sets on

Time & distance; Time & work; Percentages; Profit & Loss; Boats & Streams; Testing directional sense; Problems on age calculation; Pattern analysis; Data interpretation

Short cut techniques for

Multiplication; Finding squares, square roots; Cubes, cube roots; Magic squares; Digit sum method; Subtraction; solving Linear, Quadratic and cubic equations;

Refrences:

1. Quantitative Aptitude for Common Admission Test by Arun Sharma , Mc Graw Hill (6^{th} edition)
2. Common Proficiency test Quantitative Aptitude, published by The institute of chartered accountants of India

Semester – IV Credits: 4

GE-4: Mathematics for Competitive Examination –II

Course outcome:

Will be able to attempt the mathematical and logical questions confidently in competitive examination.

Syllabus:

Permutation and combinations; Sequences & Series (Arithmetic progression/Geometric progression); Number systems; Sets, relations and functions

Problem sets on

Partnerships; Age; LCM/GCD; simplification of decimal fractions; unitary method; Mensuration (2D/3D); conics; trigonometry; alphabet & number series; Coding & Decoding; Number ranking; stocks & shares; blood relations; surds

Short cut techniques for

Analytical conics; Division; Factorization; Partial fractions

Refrences:

1. Quantitative Aptitude for Common Admission Test by Arun Sharma , Mc Graw Hill (6^{th} edition)

2. Common Proficiency test Quantitative Aptitude, published by The institute of chartered accountants of India.

Programme: B.Sc. Mathematics Sem V
Course Code: MTC105 : **Title of the Course: Algebra**
Number of Credits: 06
Effective from: June, 2019.
Course outcome: Students will learn concepts of Group and Ring and apply to solve problems.

Prerequisites	Knowledge of Set theory, Number system, algebraic operations and their properties.	
Objectives	This course helps in understanding basic concepts of Groups and Rings.	
Contents	1. Groups definition and elementary properties; Finite group and subgroups; Examples; Cyclic groups; Properties of cyclic groups; Classification of subgroups of cyclic groups.	18 hours
	2. Permutation groups; Cycle notation; Properties of permutations. Isomorphisms: Definitions and examples; Cayley's Theorem; Properties of isomorphisms; Automorphism.	20 hours
	3. Cosets; Properties of cosets; Lagrange's Theorem and consequences; An application of cosets to permutation group.	05 hours
	4. Definition and examples of external direct product; Properties of external direct product; The group of units modulo n as an external direct product.	04 hours
	5. Normal subgroups and factor groups; Application of factor groups; Internal direct product. Definition and examples of group homomorphisms; Properties of homomorphisms; First Isomorphism Theorem.	12 hours
	6. Fundamental Theorem of Finite Abelian Groups; Isomorphism classes of Abelian groups; Proof of Fundamental Theorem.	08 hours
	7. Rings; Properties of rings; Subrings; Integral domains; Examples of integral domains; Fields; Charecteristic of a ring.	08 hours
	8. Ideals and Factor rings; Prime ideals; maximal ideals; Ring homomorphisms; Properties of ring homomorphisms; Field of quotients.	12 hours
	9. Polynomial rings; The Division Algorithm and consequences.	03 hours

Pedagogy	Lectures/ tutorials/assignments/self-study
References	**PRINCIPAL TEXT**: Joseph A. Gallian, *Contemporary Abstract Algebra*, (8^{th} ed), Cengage Learning. **References** (1) John B. Fraleigh, *A First Course in Abstract Algebra*, (7^{th} ed), Pearson Education Inc. (2) I. N. Herstein, *Topics in Algebra*, Second Edition, Wiely Student Edition, 2006. (3) G. Birkhoff and S. Mac Lane : *A survey of Modern Algebra* . Routledge; [Recommended for Teachers. Teachers Manual is available.] (4) E.B. Vinberg *A graduate course in Algebra* American Mathematical society Publications.

Programme: B.Sc. Mathematics Sem V
Course Code: MTC 106 **Title of the Course: Analysis II**
Number of Credits: 06
Effective from: June, 2019.
Course outcomes: Students will learn to evaluate improper integrals, compute beta , gamma functions and Fourier series.

Prerequisites	Knowledge of basic course in Analysis and Calculus of one variable.	
Objectives	This course helps in understanding advance concepts of applied analysis.	
Contents	**1. Improper Integrals:** Improper Integrals of type I; Cauchy's general principle of convergence for Improper integrals of type I; Comparison test for improper integrals of type I; Comparison test in limit form for improper integrals of type I; p - test for improper integrals of type I; Improper Integrals of type II; Cauchy's general principle of convergence for Improper integrals of type II; Comparison test for improper integrals of type II; Comparison test in limit form for improper integrals of type II; p - test for improper integrals of type II; Improper Integrals of type III.	20 hours
	2. Beta and Gamma Functions: Definitions of Beta and Gamma Functions and their convergence. Properties of Beta and Gamma functions. Relation between beta and Gamma functions. Legendre's duplication formula.	15 hours
	3. Power series in IR: Definition and examples. Radius and interval of convergence, Uniform convergence and absolute convergence, Term by term differentiation and integration of power series in IR. Power series definitions of Exponential, Logarithmic and trigonometric functions, their properties. Weierstrass' polynomial approximation theorem. [Statement only and explanation]	15 hours
	4. Inner product spaces: Square integrable functions. Usual integral inner product on C[a, b] and its properties. Norm induced by usual integral inner product. Orthogonal and orthonormal sequences of functions in C[a, b] with usual integral inner product. Complete orthogonal and orthonormal set in C[a, b] with respect to usual integral inner product. Bessel's inequality and Parsevel's identity set in C[a, b] with respect to usual integral inner product.	20 hours
	5. Fourier series: Fourier series of real functions on $(-\pi, \pi)$ and $(0, \pi)$. Fourier coefficients; properties of Fourier coefficients; the Fourier series of a function relative to an orthonormal system. Bessel's inequality. Trigonometric Fourier series, Fourier series of odd & even function. Integration & differentiation of Fourier series at a point. Fourier theorem. Fourier Series of real functions on (c, c+2l). Riemann-Lebesgue Lemma. Parsevel's identity.	20 hours

Pedagogy	Lectures/ tutorials/assignments/self-study
References	**Principal Texts** : 1. S. C. Malik : Principles of Mathematical Analysis 2. R.D.Bhat : Mathematical analysis II 3. B.S.Grewal: Higher Engineering Mathematics **Reference**s: 1. Tom Apostal **, Calculus Vol. I** , Second Edition, Wiley Students Edition , India, 2012 2. R. Goldberg : Methods of Real analysis, Oxford and IBH Publishers. 3. E. Kreyszig: Advanced Engineering Mathematics

Programme: B.Sc. Mathematics Sem V

Course Code: MTC107 **Title of the Course: Calculus of 2 and 3 variables**

Number of Credits: 06

Effective from: June, 2019.

Course Outcomes: Students will learn to find extreme values of functions of several variables, evaluate multiple integrals and apply the concepts to solve some problems of Physics.

Prerequisites	Knowledge of Real Analysis, Linear Algebra, Vector Algebra and Calculus of one variable.	
Objectives	This course helps in understanding basic concepts multivariable calculus.	
Contents	**Differential Calculus.** Review of vectors in Plane and space. Vector products and their properties. n- dimensional Euclidean space. Curves in the plane and space.	05 hours
	Functions from IR^n to R (scalar fields) and functions from IR^2 to IR^3 (vector fields), limits and continuity of functions, basic results on limits and continuity of sum, difference, scalar multiples of vector fields, continuity and components of a vector field. Partial derivatives and continuity. Differentiability. Derivative Matrix and tangent planes. The Chain rule. Gradients and directional derivatives. Implicit differentiation.	15 hours
	Higher order partial derivatives. Equality of mixed derivatives. Taylors theorem. Critical points and extrema. . Second derivative test. Constrained extrema and Lagrange's multipliers.	15 hours
	Applications. Acceleration. Arc length. Vector fields. Divergence and Curl .	10 hours
	Integral Calculus Volume and Cavalier's Principle. Double integral over a Rectangle, over a region. Triple integrals. Change of variables. Cylindrical and spherical coordinates. Applications. Average value. Center of mass. Moments of inertia.	20 hours
	Integrals over curves and surfaces. Line integrals. parameterized surfaces. Area of a surface. Surface integrals. Green's theorem. Stokes' Theorem, Gauss' theorem. Path independence. Fundamental theorem of Calculus.	25 hours
Pedagogy	Lectures/ tutorials/assignments/self-study	
References	**Principle Text:** Basic multivariable Calculus by J.E. Marsden, A.J. Tromba and A. Weinstein, Springer Verlag. Indian print. II edition 2005. [Teacher's manual available]	

	References: 1. T. Apostol: Calculus, Vol. 2, John Wiley & Sons. 2. J. Stewart, Calculus,Brooke/Cole Publishing Co. 3. D. Zill & W.S. Wright: Multivariable Calculus

Programme: B.Sc. Mathematics Sem V
Course Code: MTE101 **Title of the Course: Foundations of Mathematics**
Number of Credits: 04
Effective from: June, 2019.
Course outcome: Students will learn to present mathematics logically.

Prerequisites	Knowledge of Set theory, Number system, algebraic operations and their properties.	
Objectives	This course helps in developing basic Logic required for study of Mathematics.	
Contents	**1. Statements and Logic**: Statements; Statements with quantifiers; Compound statements; Implications; Proofs in Mathematics.	05 hours
	2. Sets: Sets; Operations on sets; Family of sets; Power sets; Cartesian product of sets.	05 hours
	3. Functions: Basic definitions; one-one, onto functions and bijections; Composition of functions; Inverse of a function; Image of subsets under functions; Inverse image of subsets under functions.	15 hours
	4. Relations: Relation on sets; Types of relations; Equivalence relations; Equivalence classes and partitions of sets.	08 hours
	5. Induction Principles: The induction Principle; The Strong Induction Principle; The Well-Ordering Principle; Equivalence of the three principles.	10 hours
	6. Countability of sets: Sets with same cardinality; Finite sets; Countable sets; Comparing cardinality.	10 hours
	7. Order Relation: Partial and total orders; Chains, bounds and maximal elements; Axiom of choice and its equivalents.	07 hours
Pedagogy	Lectures/ tutorials/assignments/self-study	
References	PRINCIPAL TEXT: 1. Kumar, S. Kumaresan and B.K. Sarma, *A Foundation Course in Mathematics*, Narosa Publisher, 2018 References: 1. Paul Halmos : Set Theory, SpringerVerlag, 1960. 2. Set Theory: Read it, Absorb it and Forget it by Vipul Kakkar	

Programme: B.Sc. Mathematics Sem V
Course Code: MTE102 **Title of the Course: Combinatorics**
Number of Credits: 04
Effective from: June, 2019.
Course outcome: Students will learn various counting techniques and applying them to problems.

Prerequisites	Knowledge of Set theory, Number system, algebraic operations and their properties	
Objectives	This course will help student to learn various enumeration techniques.	
Contents	**1. Basic Methods:** Basic Pigeon-hole principle, generalized Pigeon-hole principle, methods of mathematical induction – weak induction and strong induction..	08 hours
	2. Elementary Counting Problems: Permutations, Strings over finite alphabet, Choice problems.	08 hours
	3. The Binomial Theorem: Binomial theorem, Multinomial theorem(,When exponent is a positive integer.)	08 hours
	4. Partitions: Compositions, Set partitions, Integer partitions.	08 hours
	5. Cycles in Permutations: Cycles in permutations, Permutations with restricted cycle structure.	08 hours
	6. The Sieve: Enumerating the elements of intersecting sets, applications of the sieve formula.	08 hours
	7. Generating Functions: Ordinary generating functions – Recurrence relations and generating functions, Products of generating functions, Compositions of generating functions. Exponential generating functions – Recurrence relations and exponential generating functions, Products of exponential generating functions, Compositions of exponential generating functions.	12 hours
Pedagogy	Lectures/ tutorials/assignments/self-study.	
References	**PRINCIPAL TEXT:** A Walk Through Combinatorics – An Introduction to Enumeration and Graph Theory by Miklos Bona, Second Edition, World Scientific Publications.	

	Refrences: 1. Applied Combinatorics by Alan Tucker, Third Edition, John Wiley and sons, New York. 2. Combinatorial Theory and Applications by V. Krishnamurthy, East-West Press, New Delhi.

Programme: B.Sc. Mathematics Sem VI
Course Code: MTC108 **Title of the Course: Differential Equations-II**
Number of Credits: 06
Effective from: June, 2019.
Course outcome: Students will learn to solve differential equations by different methods.

Prerequisites	Knowledge of Real Analysis, Linear Algebra, Differential equations, Several variable calculus.	
Objectives	This course helps in understanding basic concepts of Differential Equations. It develops the ability to solve differential equations by standard methods.	
Contents	**1**. **Review of First and Second order ordinary differential equations:** Basic concepts. First order ordinary differential equations with constant coefficients. Homogeneous and non homogeneous equations. Exact and non exact differential equations. Integrating factors. Second order differential equations with constant coefficients. Complementary function and particular solution. Use of known solution to find linearly independent second solution. Method of variation of parameters. Equations with variable coefficients. Method of undetermined coefficients.	20 hours
	2. Power Series Solutions of Some Linear Equations: Homogeneous equations with analytic coefficients. Legendre equation, Justification of power series method, Introduction to linear equations with Regular singular points, Euler equation, example and general case of second order equations with regular singular points, A convergence proof, Exceptional cases, Bessel equation, Regular singular points at infinity. Properties of Legendre Polynomials and Bessel's function. Generating function.	35 hours
	3. Laplace Transforms: Laplace transforms of various functions, General properties of Laplace transforms, Inverse Laplace transforms, Convolution theorem, Application of Laplace transforms to solve differential equations.	15 hours
	4. Numerical Methods of Solving Differential Equations: Picard's method, Euler's method, Modified Euler's method, Runge-Kutta method, Milne's method, Adams-Bashforth-Moulton method.	20 hours
Pedagogy	Lectures/ tutorials/assignments/self-study.	
References	**PRINCIPAL TEXTS:** 1) An Introduction to Ordinary Differential Equations by Earl A.	

	Coddington, Prentice-Hall of India Private Limited, New Delhi. 2) A text book of Differential Equations by S.G.Deo, V Raghavendra and V. Lakshmikantham. TMH edition. 3) Numerical methods by M.KJain, S.R.K.Iyenger, R. K..Jain **Refrences:** 1. Differential Equations with historical notes by G. Simmons , TMH. 2. Mathematical Methods by Iyengar, Gandhi and others, S. Chand Publication. 3. Ordinary Differential Equations by G. Birkoff and G.C. Rota .

Programme: B.Sc. Mathematics Sem VI
Course Code: MTC109 **Title of the Course: Complex Analysis**
Number of Credits: 06
Effective from: June, 2019.
Course Outcomes: Students will learn basic concepts of complex analysis and apply them.

Prerequisites	Knowledge of Real Analysis and Calculus of one and two variables.	
Objectives	This course helps in understanding basic concepts of Complex analysis. .	
Contents	**1. Complex Numbers:** Sums and products, Algebraic properties, Vectors and moduli, Complex conjugates, Exponential form, Arguments of products and quotients, Roots of complex numbers, Regions in the complex plane.	08 hours
	2. Analytic Functions: Functions of complex variable, Limits, Theorems on limits, Continuity, Derivatives, Differentiation formulas, Cauchy-Riemann equations, Sufficient condition for Differentiability, Polar coordinates, Analytic functions, Harmonic functions.	12 hours
	3. Elementary Functions: Exponential function, Logarithmic function, Branches and Derivatives of Logarithms, Identities involving logarithms, Complex exponents, Trigonometric functions, Hyperbolic functions, Inverse trigonometric and hyperbolic functions.	10 hours
	4. Integrals: Derivatives of functions, Definite integrals of functions, Contours, Contour integrals, Contour integrals of functions with branch cuts, Upper bounds for moduli of contour integrals, Antiderivatives, Cauchy-Goursat theorem (without proof), Simply and Multiply connected domains, Cauchy integral formula and extension of Cauchy integral formula, Liouville's theorem, Fundamental theorem of algebra, Maximum modulus principle.	18 hours
	5. Series: Convergence of sequences and series, Taylor series, Taylor's theorem, Laurent series, Laurent's theorem.[statements only and applications]	12 hours
	6. Residues and Poles: Isolated singular points, Residues, Cauchy Residue theorem, Residue at infinity, The three types of Isolated singular points, Residues at poles, Zeros of analytic functions, Zeros and Poles.	18 hours

	7. <u>Mappings by Elementary functions:</u> Fractional Linear transformations, Transformation w=1/z, Mappings by 1/z, Mobius transformation.	12 hours
Pedagogy	Lectures/ tutorials/assignments/self-study	
References	**<u>PRINCIPAL TEXT:</u>** Complex Variables and Applications by James Brown and Ruel Churchill, Eighth Edition, McGraw-Hill International Edition. (With omission of sections 13, 14,27,28,47,63,64,65,66,67,80,81,82,83,84,85,88,89 of the principal text.) **<u>Refrences:</u>** 1) Foundations of Complex Analysis by S. Ponnusamy, Second Edition, Narosa Publishing House. 2) Functions of One Complex Variable by John B. Conway, Second Edition, Springer International Student Edition. 3) Basic Complex analysis by J.E.Marsden and M.J.Hoffman W H Freeman & Co.	

Programme: B.Sc. Mathematics Sem VI
Course Code: MTC110 **Title of the Course: Metric Spaces**
Number of Credits: 06
Effective from: June, 2019.

Course Outcome: Students will learn basic concepts of metric spaces.

Prerequisites	Course on Foundations of Mathematics and basic Analysis.	
Objectives	This course helps in understanding basic concepts of Metric spaces.	
Contents	**1. INTRODUCTORY CONCEPTS IN METRIC SPACES:-** Definition and Examples of Metric Spaces, Open Balls and Closed Balls, Hausdorff Property, Interior Point and Interior of a Set, Open Sets and their properties, Closed Sets and their properties, Limit Points and Isolated Points, Derived Set and its properties, Closure of a Set and its properties, Boundary Points, Distance between Sets, Diameter of a Set, Subspace of Metric Space and its properties, Boundedness in a Metric Space.	20 hours
	2. COMPLETENESS IN METRIC SPACES:- Sequence in a metric Space, Convergence of a Sequence in a Metric Space, Cauchy Sequence in a Metric Space, Complete Metric Spaces, Cantor's Intersection Theorem, Dense Sets.	10 hours
	3. CONTINUOUS FUNCTIONS ON METRIC SPACES:- Sequential Continuity, Continuity of Functions using Open Sets and Closed Sets, Continuity of Functions using Closure of a Set, Contraction map and its properties, Fixed Points, Picard's Fixed Point Theorem, Picard's Existence and Uniqueness Theorem for First Order Initial Value Problem.	20 hours
	4. COMPACTNESS IN METRIC SPACES:- Compact Metric Spaces and Compact Sets, Examples of Compact Metric Spaces and Compact Sets, Properties of Compact Metric Spaces and Compact Sets, Sequential Compactness, Bolzano – Weierstrass Property, Heine – Borel Theorem, Totally Boundedness, Equivalence of Compactness and Sequential Compactness, Lebesgue Covering Lemma, Compactness and Finite Intersection Property, Continuous Functions and Compactness.	20 hours
	5. CONNECTEDNESS IN METRIC SPACES:- Separated Sets, Connected Metric Spaces and Connected Sets, Properties of Connected Metric Spaces and Connected Sets, Connected Subsets of IR, Connectedness and Continuous Functions, Intermediate value Theorem.	20 hours
Pedagogy	Lectures/ tutorials/assignments/self-study.	
References	**Principal text:**	

	Mathematical Analysis-I (Metric Spaces) : J.N.Sharma **References:** 1. Metric Spaces: E. T. Copson (Cambridge University Press). 2. Topology of Metric Spaces: S. Kumaresan (Narosa Publishing House). 3. A First Course in Metric Spaces: B. K. Tyagi (Foundation Books). 4. Metric Spaces : P. K. Jain and Khalil Ahmed (Narosa Publishing House).

Programme: B.Sc. Mathematics Sem VI

Course Code: MTE103 **Title of the Course: Number Theory**

Number of Credits: 04

Effective from: June, 2019.

Course Outcome: Students will learn basic concepts of Number theory and will be ready for advanced course on Number theory.

Prerequisites	Course on Foundations of Mathematics and Basic Algebra.	
Objectives	This course helps in understanding basic concepts of Number theory.	
Contents	**1. DIVISIBILITY THEORY IN INTEGERS:-** Divisibility in $\mathbf{Z}$ and its properties, Proper and Improper Divisors, Division Algorithm, Greatest Common Divisor(gcd) and its properties, Least Common Multiple(lcm) and its properties, Euclidean Algorithm to find gcd of two integers, Prime integers, Composite integers and Relatively Prime or Co-prime integers, Euclid's Lemma, The Linear Diophantine equation **ax + by = c**, The Fundamental Theorem of Arithmetic, The Sieve of Eratosthenes.	20 hours
	2. THE THEORY OF CONGRUENCES:- Congruence Modulo 'n' Relation and its properties, Linear Congruence in one variable and its solution in $\mathbf{Z}$, Congruent and Incongruent solutions of Linear Congruence. System of Linear Congruence in one variable and Chinese Remainder Theorem, System of Linear Congruence in two variables, Fermat's Theorem and Wilson's Theorem.	15 hours
	3. NUMBER – THEORETIC FUNCTIONS:- The Functions τ and σ and their properties, Multiplicative Functions. The M o bius Function μ and its Properties, Multiplicative property of M o bius Function , μ . The M o bius Inversion Formula, The Greatest Integer Function and its properties, Euler's Phi – Function and its properties. Euler's Theorem.	15 hours
	4. SOME NON-LINEAR DIOPHANTINE EQUATIONS:- Pythagorean triple**,** Primitive Pythagorean triple, Non- Linear Diophantine Equation $\mathbf{x^2 + y^2 = z^2}$, Fermat's Last Theorem.	10 hours
Pedagogy	Lectures/ tutorials/assignments/self-study	
References	**Principal text:** 1. Elementary Number Theory: David M. Burton (Tata Mcgrow Hill).	

	References: 1. An Introduction to the Theory of Numbers: I. Niven, H. S. Zuckerman and H. L. Montgomery (Wiley – India). 2. Elementary Number Theory with Applications: Thomas Koshy. (Elsevier India Pvt. Ltd.).

Programme: B.Sc. Mathematics Sem VI
Course Code: MTE104 : **Title of the Course: Operations Research II**
Number of Credits: 04
Effective from: June, 2019.

Course Outcome: Students will learn basic concepts in decision making.

Prerequisites	Knowledge of basics of operations research, probability theory and Linear algebra.	
Objectives	This course helps in understanding basic concepts of operations research in decision making.	
Contents	1. **Project Management** Planning, Scheduling and controlling of a project. Techniques of analysing. Methods of planning and programming. Development of bar charts. Shortcomings and remedial measures. Milestone Charts.	10 hours
	2. **Elements of Network** Event, activity, dummy. Rules of Network, Numbering of events, Cycles. Planning for network construction. Work breakdown structures.	6 hours
	3. **Project Evaluation & Review Technique (PERT)** PERT time estimates T_E, $T_{L.}$ Network analysis. Probability of meeting schedule time.	6 hours
	4. **Critical Path Method (CPM)** CPM process and network. Time estimates, Float. Critical activities and path. Project crashing	6 hours
	5. **Dynamic Programming** Dynamic Programming: Recursive nature of dynamic programming Forward and Backward Recursion	12 hours
	6. Integer Linear Programming (ILP) Algorithms: Branch and Bound; Cutting Plane; Heuristic. Examples. Computational considerations in ILP. Travelling salesman problem.	10 hours

	7. Game theory Some basic terminologies, Optimal solution of two person zero sum game, Solution of mixed strategy games, graphical solution of games, linear programming solution of games. Two person Zero sum games. Solving simple games.	10 hours
Pedagogy	Lectures/ tutorials/assignments/self-study	
References	**PRINCIPAL TEXTS**: 1. Kanti Swarup, Man Mohan and Gupta, *Operations Research*, S. Chand and company, New Delhi. 2. H.A.Taha, Operations Research, An Introduction, Pearson, India. **References** (1) S.C. Gupta, Operations Research, S. Chand and Co. New Delhi. (2) Richard Bronson, Theory and Problems of Operations Research, TMH. (3) *A. M. Natarajan, P, Balasubramani* and *A. Tamilarasi* Operations Research; Pearsons India (4) P. RamaMurthy Operations Research II edition New age International (P) Ltd	