THE UNIVERSITY OF BURDWAN

SYLLABUS OF TWO YEAR POSTGRADUATE PROGRAMME

IN

Mathematics

Under

Curriculum and Credit Framework for Postgraduate Programme (CCFPP), as per N.E.P. 2020

w.e.f. 2026 – 2027

2- year PG Programme

Semesterwise and Coursewise Distribution of Credit & Marks under CCFPP as per NEP, 2020

SEMESTER	Course Type	Code & Level	Name of the Course	Credit	L – T - P	Marks	Marks Dist. Th. – Pr. - IA
I	Major/Core Course	**PG2MATH1011 (400-499)**	Research Methodology, Indian Knowledge System & General Topology	6	5-1-0	75	60 –0 – 15
	Major/Core Course	**PG2MATH1012 (400-499)**	Integration Theory & Complex Analysis	6	5-1-0	75	60 –0 – 15
	Major/Core Course	**PG2MATH1013 (400-499)**	Classical Mechanics	6	5-1-0	75	60 –0 – 15
	Major/Core Course	**PG2MATH1014 (400-499)**	Operations Research, Integral Equations & Integral Transforms	6	5-1-0	75	60 –0 – 15
	Minor Course	**PG2MATH1021 (300-399)**	Introduction to Operations Research or course(s) from SWAYAM	4	3-1-0	75	60 –0 – 15
	Total			**28**		**375**	

II	Major/Core Course	**PG2MATH2011 (400-499)**	Numerical Analysis & Practical	6	3-1-2	75	40 –20 – 15
	Major/Core Course	**PG2MATH2012 (400-499)**	Geometry of Curves and surfaces in E^3	4	3-1-0	75	60 –0 – 15
	Major/Core Course	**PG2MATH2013 (400-499)**	Elements of Functional Analysis & Calculus of R^n	4	3-1-0	75	60 –0 – 15
	Major/Core Course	**PG2MATH2014 (400-499)**	Algebra	4	3-1-0	75	60 –0 – 15
	Minor Course	**PG2MATH2021 (300-399)**	Numerical Methods or course(s) from SWAYAM	4	3-1-0	75	60 –0 – 15
	Total			**22**		**375**	

SEMESTER – I

MAJOR COURSES

Course Code: PG2MATH1011
Course Name: Research Methodology, Indian Knowledge System & General Topology
(Credit: 6, Marks: 75)
Total Hours: Lecture -75, Tutorial – 15

Objectives

To introduce the rich intellectual traditions of India and their continuing relevance in the modern world as well as to establish a systematic approach to research in mathematics. The course also aims to present a complete course in topology at its basic level.

Learning outcomes

On completion of the course, the student should have the following learning outcomes defined in terms of knowledge, skills and general competence.

Knowledge: The students would gain knowledge about

i. various stages of research, from identifying a problem to publishing a research article.
ii. evolution of Indian Knowledge Systems.
iii. topological space, separation axioms, compact space and its different general forms, connected space and its variants.
iv. topological nature of real line, Euclidean plane, metric spaces in better way.
v. essence of generalization that helps to motivate into research.

Skills: The students would be able to

i. familiarize with various open-source research tools and mathematical software.
ii. cultivate skills for integrating indigenous insights with global knowledge systems for innovation and sustainable development.
iii. access and also generate different tricky examples and counter examples involving in topology
iv. simplify a mathematical problem in different field of science using concept of topology
v. motivate themselves for future research after getting the glimpse of gateway of classical analysis to modern analysis and relate these ideas in different field of science

General competence: The students would gain

i. idea of logical reasoning in pure mathematics, modeling aspects of applied mathematics.
ii. knowledge of engaging in interdisciplinary research and innovation.
iii. descriptive idea of various properties of topological spaces.
iv. knowledge of richness in classical analysis.
v. expertise in solving many tricky problems in topology and other branches classical analysis.

Research Methodology

Meaning of research, Objectives of research, Motivation in research, Types of research, Research approaches, Significance of research, Research methods versus methodology, Research and scientific method, Importance of knowing how research is done, Research process, Criteria of research, Concept of research problem, Selecting research problem, Necessity of defining the problem, Technique involved in defining a problem, Review of literature, Research report, Indexing and Classifications, Ethics in research, Plagiarism. [L-13H & T-2H]

Indian Knowledge System

Historical overview of Indian mathematics and its influence, Overview of numerals and the decimal system, Vedas and Sulbasutras, Overview of ancient Indian mathematics: Geometry, Arithmetic operations: Ekadhika Purva sutra, Nikhilam sutra and Urdhva-Tiryak sutra, Trigonometry and Algebraic methods.

Indian mathematicians (Aryabhata, Brahmagupta and others) and their contributions, Modern developments in Indian mathematics including Ramanujan's contributions to number theory. [L-12H & T-3H]

Reading References:

Text Books:

1. Research Methodology, Methods and Techniques-C.R. Kothari, New Age Publishers
2. The Crest of the Peacock: Non-European Roots of Mathematics -George Gheverghese Joseph, Princeton University Press (1991).
3. The mathematics of India: concepts, methods, connections, sources and studies in the history of mathematics and physical sciences- P.P. Divakaran, Hindustan Book Agency (2018).

Reference Books:

1. A Concise History of Mathematics in India -Bibhutibhushan Datta and Avadesh Narayan Singh, New Delhi: Motilal Banarsidass (1995).
2. Geometry in ancient India- Saraswati Amma, Motilal Banarsidass (1999, 2nd Ed.).
3. Methodology of Educational Research-Lokesh Koul, Vikas Publishing House, 1984.
4. Mathematics in India -Kim Plofker, Princeton University Press (2009).
5. Vedic Mathematics, Bharati Krisna Tritharaj Maharaja, Motilal Banarsidass Publishers Private Limited, Delhi, 1965 (Revised 1992).
6. Erik Gregersen, The Britannica Guide to The History of Mathematics, Britannica.
7. Eleanor Robson, Jacqueline Stedall, The Oxford Handbook of THE HISTORY OF MATHEMATICS, Oxford.

General Topology

Contents:

Topological Spaces: Definition, examples, open sets, closed sets, base and subbase for open sets and closed sets, local base, interior, closure, exterior, boundary of a set, derived set, neighbourhood, limit point, dense subset, topology from neighbourhood axioms, Kuratowski closure axioms and closed sets axioms - few applications. Coarser and finer topologies.

[L-10H&T-1H]

Convergence of a sequence, limit point of a sequence, continuous maps, open maps, closed maps, homeomorphisms – their properties and examples, product topology, projection maps. **[L-6H&T-2H]**

1st countable, 2nd countable, separable and Lindelöf spaces– their interrelations and properties, examples.

[L-6H&T-1H]

Separation axioms: $T_0, T_1,$ Hausdorff (T_2), regular, completely regular, normal, completely normal spaces, $T_i - spaces, i = 1, 2,3,4,5,$ and $T_{3\frac{1}{2}} - space,$ their connections, properties and examples, Urysohn's lemma, Tietze's extension theorem (statement only). **[L-10H&T-2H]**

Compact, sequentially compact, Fréchet compact and countably compact spaces, subspaces and their mutual relationship, Alexander subbase theorem (statement only), Tychonoff Product theorem, Locally compact spaces and their properties. **[L-10H&T-2H]**

Connected space, components, totally disconnected space, locally connected space, path connected, examples.

[L-8H&T-2H]

Reading References:

Text Books:

1. Introduction to General Topology- K. D. Joshi, 2nd edition, (New Age International, 2018).
2. Introduction to Topology and Modern Analysis- G. F. Simmons, 1st edition, (Tata McGraw-Hill, 2015).

Reference Books:

1. Topology- J. R. Munkres, 2nd edition (Pearson, 2015).
2. General Topology- S. Willard (Dover Publication, INC, 2004).
3. Topology- K. Janich, 1st edition, (Springer Verlag, 2006).

4. Encyclopedia of General Topology- P.K. Hart, J. Nagata, J.E. Vaughan, 1st edition (Elsevier, 2003).
5. Introduction to General Topology- S.T. Hu, 1st edition (Holden Day, 1966).
6. Foundation of Topology- C.W Patty, 2nd edition (Jones and Bartlett Publishers, Inc, 2008).
7. General Topology (Chapter 1-4)- N. Bourbaki, 1st edition (Springer, 1998).
8. Topology- J. Dugundji, 1stedition (Ubs Publishers Distributors Ltd, 1999).
9. Counter examples in topology- L.A. Steen, J.A. Seebach, (2nd edition, Dover Publication, Inc.,1995).
10. Introduction to General Topology- J.L. Kelly (Springer India, 1988).
11. General Topology- R. Engelking, (2nd edition, Helderman Verlag, 1989).

Course Code: PG2MATH1012

Course Name: Integration Theory & Complex Analysis
(Credit: 6, Marks: 75)
Total Hours: Lecture -75, Tutorial – 15

Objectives
To present the concepts of Riemann-Stieltjes integral, Lebesgue measure, Lebesgue integral and also to present a systematic introduction of the fundamental course on complex analysis.

Learning outcomes
On completion of the course, the student should have the following learning outcomes defined in terms of knowledge, skills and general competence.

Knowledge: The students would gain knowledge about
i. Riemann-Stieltjes integral as a generalization of Riemann integral.
ii. Lebesgue measure, measurable sets, measurable functions.
iii. Lebesgue integral and its relationship with Riemann integral.
iv. homotopy version of Cauchy's theorem.
v. the ideas on singularities with their classifications and its role on some important theorems like Rouche's theorem, Casorati-Weierstrass theorem etc.
vi. Mobius transformations, Riemann Mapping theorem and analytic continuation with its geometric interpretations.

Skills: The students would be able to
i. calculate Riemann-Stieltjes integral of various functions.
ii. find Lebesgue measure of various subsets of $\mathbb{R}$.
iii. determine functions which are Lebesgue measurable.
iv. calculate Lebesgue integral of measurable functions.
v. integrate a complex valued function having certain types of singularities.
vi. learn a geometrical study of Mobius transformations.

General competence: The students would gain
i. general idea of Riemann-Stieltjes integral, Lebesgue measure and Lebesgue integral.
ii. overall expertise in dealing with complex integration and computing residues.
iii. expertise in solving many applied problems using complex analysis.
iv. analytical and reasoning skills, which improve their thinking power.

Integration Theory

Contents:
Riemann-Stieltjes integral, necessary and sufficient condition for existence of Riemann-Stieltjes integral, integration by parts, change of variables in integral, integral of step functions, first mean value theorem and second mean value theorem for Riemann-Stieltjes integrals. **[L- 6 H & T- 1H]**

Lebesgue outer measure, properties satisfied by Lebesgue outer measure, measurable sets and their properties, Lebesgue measure. **[L- 8H & T – 2 H]**

Measurable functions, continuity and measurability, monotonicity and measurability, measurability of supremum and infimum, simple functions, sequence of measurable functions.
[L- 6H & T – 1H]

The Lebesgue Integral: Lebesgue integral of a nonnegative measurable function (bounded or unbounded), integrable functions and their simple properties, Lebesgue integral of functions of arbitrary sign, integral of pointwise limit of sequence of measurable functions, Lebesgue monotone convergence theorem and its consequences, Fatou's lemma, dominated convergence theorem, comparison of Lebesgue and Riemann integral, Lebesgue criterion of Riemann integrability.

[L- 17H & T- 4H]

Reading References:

Text Books:

1. Real Analysis- H. L. Royden, (3rd edition, Pearson, 1988).
2. Measure Theory and Integration- G. de. Barra (New Age International (P) Ltd, 2013).
3. Mathematical Analysis-T. M. Apostol (Narosa, 1985).

Reference Books:

1. Measure Theory- P. R. Halmos (Springer-Verlag, 1974).
2. Measure and Integration- S. K. Berberian (The Macmillan Co., 1965)
3. Real Analysis- B.K.Lahiri and K.C.Roy (World Press, 1988).
4. A second Course of Mathematical Analysis- J. C. Burkil & H. Burkil (CUP, 1980).
5. Real Analysis- R. R. Goldberg (Springer-Verlag, 1964).
6. Theory of Functions of a Real Variable- P. Natanson, (Vol. II, Fedrick Unger Publi. Co., 1961).
7. Principle of Mathematical Analysis. W. Rudin (Mc Graw Hill, 1964).
8. Measure, Integration and Function Spaces. Charles Swartz (World Scientific, 1994).
9. Theory of Functions.E. C. Titchmarsh (CUP, 1980).

Complex Analysis

Contents:

Homotopy version of Cauchy's fundamental theorem, simply connected region and primitives of analytic functions, Morera's theorem. [L- 5H & T- 1H]

Zeros of an analytic function, singularities and their classifications, Riemann's theorem, limit points of zeros and poles, Casorati-Weierstrass's theorem, behaviour of a function at the point at infinity, winding number, counting zeros, open mapping theorem. [L-11H & T- 2H]

Fundamental theorem of algebra, maximum modulus principle, Theory of residues, Cauchy's residue theorem and evaluation of improper integrals, Argument principle, Rouche's theorem and its applications, Laurent series and its examples, Schwarz's lemma and its consequences.

[L-14H & T- 3H]

Conformal mappings, Möbius transformations, Riemann mapping theorem (statement only), analytic continuation (definition, uniqueness and examples using power-series method).

[L- 8H & T- 1 H]

Reading References:

Text Books:

1. Functions of one Complex variable- J. B. Conway, (2nd edition, Narosa Publishing House, New Delhi, 1997).

Reference Books:

1. Theory of Complex functions- R. Remmmert (Springer-Verlag, New York, 1991).
2. Complex Analysis- L. V. Ahlfors, 3rd edition (McGraw-Hill, 1979).
3. Complex Variables and applications- R. V. Churchill and J. W. Brown (McGraw-Hill,1996).
4. Theory of Functions of a Complex Variable (Vol. I, II & III). A. I. Markushevich (Prentice-Hall (1965& 1967).
5. Introduction to the Theory of Function of a Complex Variable- E. T. Copson (Oxford University press, 1970).
6. Foundation of Complex Analysis- S Ponnuswamy, (2nd edition, Narosa Publishing House, 2018).
7. Introduction to complex analysis- Kunihiko Kodaira (Cambridge Studies in Advanced Mathematics, Series Number 107).
8. Complex Analysis- A. P. Baisnab and Mantu Saha, Levant Books, India (Sarat Book Distributors, Kolkata).

Course Code: PG2MATH1013
Course Name: Classical Mechanics
(Credit: 6, Marks: 75)
Total Hours: Lecture -75, Tutorial – 15

Objectives

To impart knowledge and understanding of fundamental concepts of dynamics of system of particles, motion of a rigid body, constrained motion, Lagrangian and Hamiltonian formalism, canonical transformations and brackets.

Learning outcomes

On completion of the course, the student should have the following learning outcomes defined in terms of knowledge, skills and general competence.

Knowledge: The students would gain knowledge about

i. mathematical formalisms of classical mechanics.
ii. conservation laws, symmetries, angular momentum and spin.
iii. canonical transformations, generating functions and brackets.
iv. functional, Euler-Lagrange equations.

Skills: The students would be able to

i. describe the motion of a mechanical system using Lagrangian and Hamiltonian formalism.
ii. describe motion of a rigid body.
iii. solve some physical systems moving under some constraints.
iv. use Euler-Lagrange equations to find stationary paths.
v. evaluate Lagrange and Poisson brackets.
vi. develop Hamilton-Jacobi method to solve equations of motion.

General competence: The students would gain

i. general idea of classical mechanics which will be useful for further studies in theoretical physics.
ii. understanding about fundamental mechanical processes in nature.
iii. experience to construct approximate mechanical modelsusing mathematical tools.

Contents:

Conservation of energy, linear momentum and angular momentum of a system of particles; Definition, classification and examples of constraints; Degrees of freedom; Generalised coordinates; Physical interpretation of the Newton's laws of motion; Limitations of the Newton's laws of motion.

[L-10H & T-2H]

Motion of a rigid body in two dimensions – laws of motion, conservation of angular momentum and energy, motion under finite and impulsive forces; Motion of a rigid body in three dimensions - Euler's dynamical equations and solution, invariable line and invariable plane, torque free motion, Euler angles, components of angular velocity in terms of Euler angles, motion of a top in a perfectly rough floor, stability of top motion.

[L-16H & T-3H]

Lagrange's equation of motion of the first kind; Gibbs-Appell's principle of least constraint; Lagrange's equations of motion of the second kind (holonomic and non-holonomic systems); Velocity dependent potential; Dissipative forces; Rayleigh's dissipation function; Generalised momenta and energy; Gauge function for Lagrangian; Cyclic coordinates; Routh process for ignorable coordinates; Noether's theorem; Symmetry and conservation laws.

[L-15H & T-3H]

Legendre dual transformation; Hamilton's canonical equations of motion; Principle of least action; Hamilton's principle; Derivation of Hamilton's equations of motion; Invariance of Hamilton's principle under coordinate transformation. **[L-13H & T-3H]**

Euler's theorem; Solution of Euler-Lagrange's equation; Sufficient condition for existence of extremals; Brachistochrone problem; Geodesic; Isoperimetric problem; Variational problems with moving boundaries.

[L-10H & T-2H]

Definition, examples and properties of canonical transformations; Generating functions; Lagrangian and Poisson

brackets (definition and properties); Poisson's theorems; Condition of canonicality in terms of Poisson bracket; Infinitesimal canonical transformations; Hamilton-Jacobi's equation.

[L-11H & T-2H]

Reading References:

Text Books:

1. Classical Mechanics- H. Goldstein (Narosa Publ. House, 1997)
2. Classical Mechanics- N. C. Rana & P.S. Jog (Tata McGrew Hill, 2001).

Reference Books:

1. Classical Mechanics with Introduction to Nonlinear Oscillation and Chaos- V. B. Bhatia (Narosa Publishing House, 1997).
2. A Treatise on the Analytical Dynamics of Particles and Rigid Bodies- E. T. Whittaker (Cambridge University Press, 1993).
3. Calculus of Variations- I. M. Gelfand and S.V. Fomin (Prentice Hall Inc., 2012).
4. Calculus of Variations with Applications- A. S. Gupta (Prentice–Hall of India, 1996).

Course Code: PG2MATH1014
Course Name: Operations Research, Integral Equations & Integral Transforms
(Credit: 6, Marks: 75)
Total Hours: Lecture -75, Tutorial – 15

Objectives

The course aims to provide a systematic and rigorous exposition of the theories and methods underlying operations research, supporting both conceptual understanding and practical problem-solving capabilities and to present the theories for studying integral equations and integral transforms in a systematic manner

Learning outcomes

On completion of the course, the student shall have the following learning outcomes defined in terms of knowledge, skills and general competence.

Knowledge: The students would gain knowledge about

i. key concepts in operations research, including the revised simplex method, post-optimality analysis, integer programming, classical optimization techniques, inventory models, queueing systems and integral equations and integral transforms.
ii. the mathematical foundations of integral transforms, including Laplace and Fourier transforms, their properties, and applications.

Skills: The students would be able to

i. learn about the revised simplex method, integer programming, inventory control and queueing theory.
ii. apply classical optimization techniques, including unconstrained and constrained optimization, Lagrange multipliers, and KKT conditions, to multivariable optimization problems.
iii. learn different techniques for evaluating integral equations
iv. know the mathematical foundations of integral equations.
v. gain broad competence in identifying when and how to use integral transforms

General competence: The students would gain

i. broad competence in identifying when and how to use operations research tools to model and solve scientific, engineering, and management problems.
ii. the ability to solve linear programming problems using the revised simplex method, analyze integer programming models, and address decision-making problems in inventory control and queueing theory.
iii. a foundational understanding of classical optimization techniques and their role in solving real-world optimization problems under various types of constraints.
iv. knowledge on different techniques for solving integral equations
v. general idea about the integral transforms

Operations Research

Contents:

Revised simplex method- standard forms I and II. **[L-5H & T-1H]**

Post Optimality Analysis: Changes in (i) objective function, (ii) requirement vector, (iii) coefficient matrix;

Addition and deletion of variables, Addition and deletion of constraints. **[L-10H & T-2H]**

Integer Programming: Gomory's cutting plane algorithm (All integer and mixed integer algorithms), Branch & Bound Method. **[L-6H & T-1H]**

Classical Optimization Techniques: Unconstrained optimization: Single variable optimization, multivariate optimization. Multivariable optimization with equality constraints: Lagrange's multiplier method, Interpretation of Lagrange multiplier, Multivariable optimization with inequality constraints: KKT conditions.

[L-8H & T-2H]

Inventory Control: Deterministic inventory models, economic order quantity and its extensions: without and with lead time. Finite replenishment rate Inventory models without and with planned shortages. Inventory models with partial backlogging and lost sales. Discrete Demand Model. Multi-item Inventory models with constraints. Quantity discounts: All units and incremental. Joint and Individual Ordering Policies.

[L-11H & T-2H]

Queueing Theory: Basic features of queueing systems, operating characteristics of a queueing system, arrival and departure (birth & death) distributions, inter-arrival and service times distributions, transient, steady state conditions in queueing process. Poisson queueing models- M/M/1, M/M/C for finite and infinite queue length.

[L-10H & T-2H]

Integral Equations & Integral Transforms

Contents:

Integral Equations: Linear integral equation of the first and second kind of Fredholm and Volterra type, Solutions with separable kernels. Characteristic numbers and eigenfunctions. Existence, Uniqueness and iterative solution of Fredholm and Volterra integral equations; Resolvent kernel. **[L-10H & T-2H]**

Integral Transforms: Laplace transform: Definition and its existence, Basic properties of Laplace transform, Laplace transform of derivatives and its asymptotic properties (initial value and final value theorems), Laplace transform of an integral, Convolution theorem. **[L-6H & T-1H]**

Fourier transform: Definition and basic properties, Fourier transform of some elementary functions, Fourier transform of derivatives, Inverse formula, Convolution theorem, Parseval's relation, Fourier sine and cosine transforms, Finite Fourier Transform. Solutions of Heat, Wave and Laplace equations by Fourier transform.

[L-9H & T-2H]

Reading References:

Text Books:

1. Operations Research – An Introduction- H. A. Taha (Prentice-Hall, 1997).
2. Advanced Optimization and Operations Research- A. K. Bhunia, L. Sahoo and A.A.Shaikh (Springer, 2020).
3. Operations Research: Theory and Applications- J. K. Sharma (Macmillan, 1997).
4. Linear Integral Equations- W. V. Lovitte (Dover Publications, 2005).
5. Linear Integral Equations- R. P. Kanwal (2ndedition,Birkhäuser, 1996).
6. The use of Integral Transforms- Ian N. Sneddon, (2nd edition, McGraw Hill,1972).
7. Fourier Transforms- Ian N. Sneddon, (2nd edition, Dover Publications, 2010).

Reference Books:

1. Operations Research: Theory. Methods and Applications- S. D. Sharma & H. Sharma(Kedar Nath Ram Nath, 1972).
2. Operations Research- K. Swarup, P. K. Gupta and M. Mohan(Sultan Chand & Sons, 1978).
3. Introduction to Operations Research- F. S. Hillier, G. J. Lieberman(McGraw-Hill, 2001).
4. Nonlinear Programming-Theory and Algorithms- M. S. Bazaraa, H. D. Sherali, C. M. Shetty (Wiley Interscience, 2006).
5. Introduction to Optimization Techniques: Fundamentals and Applications of Nonlinear Programming - M. Aokie (The Macmillan Company, 1971).
6. Linear Integral Equations- S.G. Mikhlin, 1stedition (Routledge, 1961).
7. Integral Equation- F. G. Tricomi (Dover Publications, 2012).
8. Integral Transforms and their applications- Loknath Debnath, (2nd edition, Chapman and Hall/CRC,2006).
9. Schaum's Outline of Laplace Transforms (Schaum's Outlines of Theory and Problems)- Murray Spiegel, 1st edition (McGraw-Hill Education, 1965).

MINOR COURSES

Course Code: PG2MATH1021
Course Name: Introduction to Operations Research
(Credit: 4, Marks: 75)
Total Hours: Lecture -45, Tutorial – 15

Objectives
To introduce the preliminary concepts of Operations Research for the students of other disciplines.
Learning outcomes
After completing the course, the student should have the following learning outcomes defined in terms of knowledge, skills and general competence:
Knowledge: The students would gain knowledge about

(i) the concept of F.S. and Concept of B.F.S.
(ii) the concept of Hyperplane, Convex set, Cone, extreme points, convex hull and convex polyhedron and their properties.
(iii) Simplex algorithm and duality theory.
(iv) Transportation and Assignment problem.
(v) The concept of Game theory
(vi) the concept of unconstrained and constrained optimization problems with equality constraints, Lagrange's multiplier method and its physical interpretation.

Skills: The students would be able to

(i) solve linear programming problem.
(ii) solve nonlinear unconstraint and equality constraint optimization problem.
(iii) solve different types game theory problem.

General competence: The students would gain

(i) general overview operations research and how to solve this type of problems.

Content
Definition of Linear Programming Problem (L.P.P.). Formation of L.P.P. from daily life involving in equations. Graphical solution of L.P.P. Basic solutions and Basic Feasible Solution (B.F.S) with reference to L.P.P. Matrix formulation of L.P.P. Degenerate and Non-degenerate B.F.S. Reduction of a Feasible Solution (F.S.) to a B.F.S. [L-6H &T-2H]

Hyperplane, Convex set, Extreme points, convex hull and convex polyhedron, Slack and surplus variables. Standard form of L.P.P. theory of simplex method, two phase method. [L-7H & T-3H]
Duality theory: The dual of dual is the primal. Relation between the objective values of dual and the primal problems. Relation between their optimal values. [L-6H & T-2H]
Transportation and Assignment problems. [L-6H & T-2H]
Concept of game theory. Rectangular games. Pure strategy and Mixed strategy. Saddle point and its existence. Optimal strategy and value of the game. Concept of Dominance. Fundamental Theorem of rectangular games. [L-7H& T-2H]
Unconstrained optimization [L-3H & T-1H]
Constrained optimization with equality constraints- Lagrange's multiplier [L-5H &T-1H]
Inventory control: Basic EOQ and EPQ models (with and without shortage) [L-5H &T-2H]

Text Books:
1. Operations Research – An Introduction. H. A. Taha (Prentice-Hall, 1997).
2. Advanced Optimization and Operations Research. A. K. Bhunia, L. Sahoo & A.A.Shaikh (Springer, 2020).
3. Operations Research: Theory and Applications. J. K. Sharma (Macmillan, 1997).
Reference Books:
1. Operations Research: Theory, Methods and Applications. S. D. Sharma & H. Sharma (Kedar Nath Ram Nath, 1972).
2. Operations Research. K. Swarup, P. K. Gupta, M. Mohan (Sultan Chand & Sons, 1978).
3. Introduction to Operations Research, F. S. Hillier, G. J. Lieberman (McGraw-Hill, 2001).
4. Linear Programming and Network Flows. Mokhtar S. Bazaraa, John J. Jarvis and Hanif D. Sherali (John Wiley and Sons, 2010).
5. Introduction to Operations Research. F.S. Hillier and G.J. Lieberman (Tata McGraw Hill, Singapore, 2009).
6. Operations Research: Applications and Algorithms: W. L. Winston, J.B. Goldberg (Thomson, 4th Edition, 2004)

SEMESTER – II

MAJOR COURSES

Course Code: PG2MATH2011
Course Name: Numerical Analysis & Practical
(Credit: 6, Marks: 75)
Total Hours: Lecture -45, Tutorial – 15, Practical – 60

Numerical Analysis

Objectives
To study numerical analysis to solve numerical problems that approximately emphasize error estimation.
Learning outcomes
On completion of the course, the student should have the following learning outcomes defined in terms of knowledge, skills and general competence.

Knowledge: The students would gain knowledge about
i. Solving systems of linear and nonlinear equations using various numerical methods.
ii. Performing numerical integration, solving both ordinary and partial differential equations numerically through different techniques.
iii. Conducting error analysis for these methods.

Skills: The students would be able to
i. Apply numerical solution techniques to a variety of physical problems.
ii. Conduct error analysis of numerical methods.

General competence: The students would gain
i. A broad understanding of computational techniques and algorithms for numerical methods.
ii. The ability to implement algorithms in a programming language.
iii. Skills for obtaining numerical solutions to physical/biological problems.

Contents:

Numerical solutions of non-linear equations: Modified Newton-Raphson method, Aitken δ^2 method, Newton and Quasi-Newton methods for nonlinear systems of equations.
Roots of polynomial equations: Bairstow method, Graeffe's root squaring process, and their convergences. **[L-5H & T-2H]**

Solution of linear systems: Partial pivoting, Complete pivoting, Operational counts, Triangular Factorization methods, Matrix Inversion method, Successive-Over Relaxation (SOR) iteration method, Convergence criteria, Concept of Ill Conditioning Systems.

[L-5H & T-2H]

Polynomial approximations: Existence and uniqueness of polynomial interpolation, Piecewise polynomial interpolation, Hermite interpolation, Error analysis, Cubic spline interpolation, Convergence properties, Least-square polynomial approximations, Approximations using orthogonal polynomials, Chebyshev polynomials. **[L-7H & T-2H]**

Numerical integration: Error in Newton-Cotes' formula, Gauss-Legendre and Gauss-Chebyshev quadrature formulae, Euler-Maclaurin summation formula, Richardson extrapolation, Romberg integration, Improper integrals, Estimation of errors.

[L-7H & T-2H]

Eigenvalues and Eigenvectors of a matrix: Power method for largest eigenvalue and corresponding eigenvector, Inverse power method, Jacobi's method, and their convergence.

[L-5H & T-2H]

Solutions of Initial Value Problems: Solution of first-order ordinary differential equation by multi-step predictor-corrector method, Milne's method, Adams-Bashforth method and Adams-Moulton method and Milne's method, Runge-Kutta-Fehlberg method; Error bounds, Convergence and Stability.

[L-5H & T-2H]

Solutions of Boundary Value Problems: Finite difference method, Shooting method for solving linear and non-linear equations, Introduction to finite element method.

[L-5H & T-1H]

Numerical solution of partial differential equations by finite difference method: Explicit and Implicit methods, Consistency, Convergence and stability, Lax theorem, Heat equation: Explicit and Implicit Crank-Nickolson methods, Wave equation: Explicit and Implicit finite difference method, Numerical stability analysis.

[L-6H & T-2H]

Reading References:

Text Books:

1. An Introduction to Numerical Analysis- K. E. Atkinson, (John Wiley & Sons, Singapore, 1989).
2. Elementary Numerical Analysis: An Algorithmic Approach- S.D. Conte and C. De Boor,(McGraw-Hill, New York, 1980).

Reference Books:

1. Introductory Methods of Numerical Analysis- S. S. Sastry, (PHI, New Delhi, 1999).
2. A First Course in Numerical Analysis- Ralston, (McGraw Hill, New York, 1965).
3. Numerical Methods for Scientific and Engineering Computation- M. K. Jain, S. R. K. Iyenger & P. K. Jain, (4^{th} edition, New Age International (P) Ltd., New Delhi, 2003).
4. Numerical Solution of Partial Differential Equations- G.D. Smith, (Oxford University Press, 1985).
5. Numerical Analysis and Algorithms- P. Niyogi, (McGraw Hill Education India Pvt Ltd, 1995).

Numerical Practical

Objectives

The main objectives of this course is to write C programming in order to solve different types of problems numerically with the help of computer.

Learning outcomes

On completion of the course, the student should have the following learning outcomes defined in terms of knowledge, skills and general competence.

Knowledge: The students would gain knowledge about

i. syntax in C programming language
ii. writing in C programs
iii. different numerical methods, algorithms and their programming

Skills: The students would be able to

i. write C programs
ii. solve different problems numerically with the help of computer programming
iii. apply different numerical methods by using C programming to handle various types of Research problem in future

General competence: The students would gain

i. the basic ideas about C programming
ii. the knowledge and understanding for different numerical techniques.

Contents:

Pre-requisite:

C Programming: Operators, Decision making (branching and looping), Array, User defined functions, Input and output files.

Problems:

Numerical Solution of transcendental and algebraic equations: Newton-Raphson method and Regula-Falsi method.

Numerical Solution of a System of Equations: Gaussian elimination method, Gauss-Seidel method, Matrix Inversion method.

Polynomial approximations: Lagrange Interpolation, Hermite interpolation.

Methods for Finding Eigen Pair of a Matrix: Power method for finding largest eigenvalue and its corresponding eigenvector.

Integration: Trapezoidal Rule, Simpson's one-third rule, Romberg's method.

Numerical Solution of ODE: Initial Value Problem: First-order ODE by Multistep Method - Milne's method, Numerical solutions of second-order ODE by fourth-order Runge-Kutta method.

Boundary Value Problem: Second order ODE by finite difference method, Shooting method.

Reading References:

Text Books:

1. C Language and Numerical Methods- C. Xavier, (New Age International, 2007).
2. Numerical Recipes in C: The Art of Scientific Computing- W. H. Press, S. A. Teukolsky, W. T. Vetterling, B. P. Flannery, (Cambridge University Press, 1992).

Reference Books:

1. Computer Fundamentals- G. C. Layek, A. Samad, S. Paramanik, (Fortran-77, C & Numerical Programs, Sarat Book Distributors, 2005).
2. Numerical Algorithms with C- G. Engeln-Müllges& F. Uhlig, 1st Ed., (Springer, 1996).
3. Numerical Methods in Science and Engineering- S.K. Pundir, (CBS, 2017).
4. Numerical Computation using C- R. Glassey, 1st Ed., (Elsevier, 1992).

Course Code: PG2MATH2012
Course Name: Geometry of Curves and surfaces in E^3
(Credit: 4, Marks: 75)
Total Hours: Lecture -45, Tutorial – 15

Objectives
To study the local and global properties of curves in the plane and space, intrinsic properties of surfaces and their classifications and applications.

Learning outcomes
On completion of the course, the student should have the following learning outcomes defined in terms of knowledge, skills and general competence:

Knowledge: The students would gain knowledge about

i. curves in the plane and space.
ii. local and global properties of curves.
iii. geometric quantities like curvature and torsion.
iv. nature of various surfaces.
v. curvature of surfaces.
vi. isometry of surfaces.
vii. fundamental forms of surfaces.
viii. geodesics on surfaces.
ix. classification of surfaces
x. Gauss Theorem of Egregium with application

Skills: The students would be able to

i. explain the fundamental concepts of the differential geometry of curves and surfaces.
ii. demonstrate accurate and effective use of fundamental techniques of differential geometry.
iii. determine curvature, torsion for a space curve using Serret-Frenet formulas.
iv. achieve the concepts of invariant quantities of surfaces.
v. acquire geometrical problem-solving and analysis skills which may be applied to diverse situations in mathematics, physics, and engineering.

General competence: The students would gain

i. general idea of geometry of curves and surfaces which will be useful for further studies.
ii. experience to learn geodesics of surfaces.
iii. concept of applications of Gauss Theorema of Egregium in cartography.

Contents:
Geometry of Curves: Definition of curves in E^3 with examples, arc-length, reparametrization, level curves vs. parametrized curves, curvature of plane curves and space curves, properties of plane curves, torsion of space curves, properties of space curves, Serret-Frenet formulae, simple closed curves with periods, isoperimetric inequality, four vertex theorem (statement only).

[L-12H & T-4H]

Geometry of Surfaces: Definition of surfaces with various examples, smooth surfaces with examples, tangent, normal and orientability of surfaces, quadric surfaces, applications of the inverse function theory, first fundamental form, length of curves on surfaces, isometries of surfaces, conformal mapping of surfaces, surface area, equiareal maps and theory of Archimedes.

[L-12H & T-4H]

Curvature of surfaces, second fundamental form, curvature of curves on a surface, normal and principal curvatures, Euler's theorem, geometric interpretation of principal curvatures. The Gaussian curvature and mean curvature, pseudosphere, flat surfaces, surfaces of constant mean curvature, Gaussian curvature of compact surfaces, Gauss map.

[L-12H & T-4H]

Geodesics and its basic properties, geodesic equations, geodesic on surfaces of revolution, geodesic as shortest

path, geodesic coordinates. Gauss's theorem egregium. CodazziMainardi equation, third fundamental form, compact surfaces of constant Gaussian curvatures.

[L-9H & T-3H]

Reading References:

Text Book:

1. Elementary Differential Geometry- A. Pressley, (Springer-Verlag, London, 2001 (Indian Reprint 2004)).

Reference Books:

1. Curves and Surfaces- S. Montel and A. Ros,2nd edition, (American Mathematical Society, 2009).
2. Differential Geometry of Curves and Surfaces- M. P. Do Carmo, (Prentice-hall, Inc., Englewood, Cliffs, New Jersey, 1976).
3. Elementary Differential Geometry- B. O' Neill, 2nd edition, (Academic Press Inc., 2006).
4. Differential Geometry of curves and surfaces- V. A. Toponogov, (Birkhäuser, 2006).
5. Differential Geometry- E. Kreyszig, (Dover Publications, Inc., New York, 1991).

Course Code: PG2MATH2013
Course Name: Elements of Functional Analysis & Calculus of $\mathbb{R}^n$
(Credit: 4, Marks: 75)
Total Hours: Lecture -45, Tutorial – 15

Elements of Functional Analysis

Objectives
To familiarize the students with a systematic foundation of the knowledge on the fundamental results of functional analysis so that the knowledge of these results could be applied to analytic problems of applied mathematics or mathematical physics.

Learning outcomes
On completion of the course, the student should have the following learning outcomes defined in terms of knowledge, skills and general competence.

Knowledge: The students would gain knowledge about

i. metric fixed point theory particularly on Banach Contraction Principle.
ii. some applications of Banach Contraction Principle
iii. the elementary theory on Banach spaces and Hilbert spaces together with
    a. their interrelations
    b. their geometrical study
    c. the criterion for dimensionality of spaces vis-a-vis compactness of a closed set
    d. convergence of series in Banach Spaces
    e. some important inequalities namely Minkowski inequality, HÖlder inequality, Cauchy-Schwartz Inequality, Bessel's inequality, Perseval's equality with their applications
    f. the applications of orthogonal and orthonormal vectors in Hilbert spaces
    g. square integrable functions and its study on its completeness property

Skills: The students would be able to be

i. habituated and motivated in working out various problems independently on the allied topics.
ii. influenced in searching for the close connection between the real analysis and topology up to a certain extent that enable them to solve the problems in different directions.

General competence: The students would gain

i. ability to read and to learn evaluate critically further topics in functional analysis
ii. ability in understanding the use of functional analysis in applied problems.

Contents:
Prerequisite on metric spaces including Banach contraction principle with its application to system of linear algebraic equations and Fredholm integral equation. **[L-3H & T- 1H]**

Normed linear spaces and their properties, equivalent norms and their properties, finite dimensional normed linear spaces and subspaces, Riesz lemma and its applications in Banach spaces, compactness in finite dimensional normed linear spaces, Banach spaces with examples like $\mathbb{R}^n, \mathbb{C}^n$, $C[a,b]$ (with sup norm and integral norm), c_0, l_p $(1 \leq p \leq \infty)$, quotient spaces. series in Banach spaces, convergence and absolute convergence of a series in Banach spaces, Minkowski inequality, Hölder inequality, $L_p[a,b]$, $1 \leq p < \infty$ and its completeness property. **[L-10H & T-3H]**

Inner product spaces and Hilbert spaces with examples and properties, continuity of inner product, Cauchy-Schwarz inequality, basic results on inner product spaces and Hilbert spaces, parallelogram law, Pythagorean law, polarization identity, orthogonal and orthonormal vectors, complete orthonormal sets, separable Hilbert spaces, Bessel's inequality, Persevals' equality, Fourier expansion, $L_2[a,b]$ and its properties.

[L-10H & T- 3H]

Reading References:

Text Books:

1. Introductory Functional Analysis with Applications- E. Kreyszig (Wiley, 2007).
2. Elements of Functional Analysis- B.K. Lahiri (The world Press Pvt. Ltd., 1994).
3. Functional Analysis, A First Course- S. Kumaresan and D. Sukumar, 1st edition (Narosa, 2020).

Reference Books:

1. A first course in Functional Analysis- D. Somasundaram (Narosa, 2015).
2. A Course in Functional Analysis- J.B. Conway (Springer, 2007).
3. Introduction to Functional Analysis- A.E. Taylor (John Wiley and Sons, 1958).
4. Functional Analysis- B.V. Limaye, (New Age International Publications, 2017).
5. Functional Analysis- G. Bachman and L. Narici (Academic Press, 1966).

Calculus of $\mathbb{R}^n$

Objectives

To present the concepts of limit, continuity and derivative of functions from $\mathbb{R}^n$to $\mathbb{R}^m$.

Learning outcomes

On completion of the course, the student should have the following learning outcomes defined in terms of knowledge, skills and general competence.

Knowledge: The students would gain knowledge about

i. topological properties of $\mathbb{R}^n$, concepts of limit and continuity of functions from $\mathbb{R}^n$to $\mathbb{R}^m$.
ii. derivative, directional derivative and partial derivative of functions from $\mathbb{R}^n$to $\mathbb{R}^m$.
iii. matrix representation of derivative of functions from $\mathbb{R}^n$to $\mathbb{R}^m$.
iv. implicit function theorem, inverse function theorem.

Skills: The students would be able to

i. determine limit, continuity, directional derivative, partial derivative and derivative of functions from $\mathbb{R}^n$to $\mathbb{R}^m$.
ii. determine inverse of a vector valued function under certain conditions.
iii. find explicit form of some variable from an implicit form under certain conditions.

General competence: The students would gain

i. general idea of limit, continuity and derivative of functions from $\mathbb{R}^n$ to $\mathbb{R}^m$, which will be useful for further studies in multivariate calculus, functional analysis.
ii. analytical and reasoning skills which improve their thinking power.

Contents:

Topology of $\mathbb{R}^n$, functions from $\mathbb{R}^n$ to $\mathbb{R}^m$, projection functions, component functions, limit and continuity. **[L-6H & T-3H]**

Derivative of functions from $\mathbb{R}^n$ to $\mathbb{R}^m$, directional derivatives and partial derivatives, partial derivatives of higher order, chain rule, matrix representation of derivative of functions, mean value theorem, continuously differentiable functions, C^∞-functions, real analytic functions. **[L-11H & T-4H]**

Implicit function theorem, inverse function theorem (local and global). **[L-5H & T-1H]**

Reading References:

Text Books:

1. Analysis on Manifolds- J. R. Munkres (Addison-Wesley Pub. Comp., 1991).
2. Calculus on Manifolds- M.Spivak (The Benjamin/Cummings Pub.comp.,1965).

Reference Books:

1. Introduction to Calculus and Analysis, Vol – II- R. Courant and F. John (Springer, 2004).
2. Basic Multivariate Calculus- J. E. Marsden, A.J. Tromba and A. Weinstein (Springer, 1993).
3. Calculus Vol. – II- T. M. Apostol (John Wiley Sons, 1969).

Course Code: PG2MATH2014
Course Name: Algebra
(Credit: 4, Marks: 75)
Total Hours: Lecture -45, Tutorial – 15

Objectives

To present a systematic development of advanced course in algebra.

Learning outcomes

On completion of the course, the student should have the following learning outcomes defined in terms of knowledge, skills and general competence.

Knowledge: The students would gain knowledge about

i. solvable group, free group Noetherian and Artinian rings and basic course on field extension.
ii. polynomial rings which is a rich source of counter examples.
iii. algebraic, transcendental, separable and normal extension, existence of algebraically closed field containing a field.
iv. basic introduction of module theory, a gateway of commutative algebra and algebraic geometry.

Skills: The students would be able to

i. access and also generate different tricky examples and counter examples involving in algebra.
ii. simplify a mathematical problem in different field of science using concept of algebra.
iii. motivate themselves for future research after getting the glimpse of gateway of classical algebra to modern algebra and relate these ideas in different field of science.

General competence: The students would gain

i. descriptive idea of various properties of different algebraic structure.
ii. broader view of basic algebra
iii. expertise in solving many tricky problems in advanced algebra.

Contents:

Group: p-groups, Normal series; subnormal series; solvable series, solvable groups, composition series; nilpotent group; Jordan-Holder Theorem; Ascending central series; descending central series; commutator subgroup; insolvability of $S_n, n \geq 5$.

[L-12H &T-4H]

Rings: Noetherian ring, Artinian ring – their properties, polynomial rings in arbitrary number of variables, Polynomial rings that are unique factorization domain, Gauss' lemma, Chinese remainder theorem in ring and its application to polynomial rings of one variable, Hilbert Basis Theorem.

[L-13H&T-5H]

Field: Field extension, degree of extensions, algebraic extensions, transcendental extensions, simple extensions, finite extensions, minimal polynomial of an algebraic element, Isomorphism extension theorem. splitting fields, normal extension: fundamental theorem of general algebra (Kronecker theorem), existence theorem, isomorphism theorem, algebraically closed field, Existence of algebraically closed field, Algebraic closures, Existence and uniqueness (up to isomorphism) of algebraic closures of a field, field of algebraic members. Separable Extension, Separable and inseparable polynomials, separable and inseparable extensions, perfect field, Artin's theorem. finite Field, the structure of finite field, existence of GF (p^n), construction of finite fields, field of order p^n.

[L-20H&T-6H]

Reading References:

Text Books:

1. Abstract Algebra- D.S. Dummit and R.M. Foote, 3rd edition (Wiley, 2016).
2. Abstract Algebra- P. B. Bhattacharya, S. K. Jain, S. R. Nagpaul, 2nd edition (Cambridge University Press, 2014).

Reference Books:

1. Fundamental of Abstract Algebra- D.S. Malik, J.N. Mordenson, M.K.Sen, 1st Edition (Mcgraw-Hill Book Company – Koga, 1997)
2. Algebra- T. W. Hungerford, 3rd Edition (Cengage Learning India Pvt Ltd,2012)
3. A First Course in Abstract Algebra- J.B. Fraleigh, 7th edition (Pearson Education (India) 2002)
4. Abstract Algebra- M. Artin, 2nd edition (Pearson Education, 2011)
5. Contemporary Abstract Algebra- J. A. Gallian, 4th Edition (Cengage Learning India Pvt Ltd 2019)
6. An Introduction to the Theory of Groups- J. Rotman,, 4th edition (Springer 1999).
7. Topics in Algebra- I.N. Herstein, 2nd Edition (John Wiley & Sons Inc (Sea) Pte Ltd, 2017).
8. Algebra- S. Lang, 3rd edition (Springer 2002).

MINOR COURSES

Course Code: PG2MATH2021
Course Name: Numerical Methods
(Credit: 4, Marks: 75)
Total Hours: Lecture -45, Tutorial – 15

Objectives
To study numerical methods for solving various physical/chemical/biological problems.

Learning outcomes
Upon completing the course, students are expected to achieve the following learning outcomes in terms of knowledge, skills, and general competence:

Knowledge: The students would gain knowledge about
i. Solving systems of linear and nonlinear equations using various numerical methods.
ii. Numerical integration is performed using different techniques

Skills: The students would be able to
i. Apply numerical solution techniques to a variety of physical/chemical/biological problems.
ii. Concept of errors in numerical methods.

General competence: The students would gain
i. A broad understanding of computational techniques and algorithms for numerical methods.
ii. The ability to implement algorithms in a programming language.
iii. Skills for obtaining numerical solutions to physical/chemical/biological problems.

Contents:
Errors: Relative, Absolute, Percentage, Round off, Truncation. **[L-1H & T-1H]**

Finding Roots of Transcendental and Polynomial Equations: Bisection method, Newton-Raphson method, Secant method, Regula-Falsi method, method of fixed-point iteration. Rate of convergence of these methods.

[L-10H & T-3H]

Solutions of the System of Linear Algebraic Equations: Direct methods: Gaussian Elimination and Gauss Jordan methods. Iterative methods: Gauss Jacobi method, Gauss-Seidel method.

[L-10H & T-3H]

Polynomial Interpolation: Finite difference operators, Polynomial interpolation theory, Lagrange and Newton's methods, bounds of Error. Numerical Differentiation: Methods based on interpolation.

[L-10H & T-3H]

Numerical Integration: Newton Cotes' formula, Trapezoidal rule, Simpson's 1/3rd rule, Weddle's rule, Composite Trapezoidal rule, Composite Simpson's 1/3rd rule.
[L-9H & T-2H]

Ordinary Differential Equations: Picard's successive approximations, Taylor series method, Euler's method, and Runge-Kutta schemes of orders two and four.
[L-5H & T-3H]

Reading References:

Text Books:

1. Numerical Methods for Scientific and Engineering-M.K. Jain, S.R.K. Iyengar and R.K. Jain, (2012).
2. Computation- 6th Ed., (New Age International Publisher, India, 2007).

Reference Books:

1. Applied Numerical Analysis- C.F. Gerald and P.O. Wheatley, (Pearson Education, India, 2008).
2. A First Course in Numerical Methods-Uri M. Ascher and Chen Greif, 7th Ed., (PHI Learning Private Limited, 2013).
3. Numerical Mathematical Analysis-Scarborough, James B., (Oxford and IBH publishing co, 1966).
4. An Introduction to Numerical Analysis- Atkinson, K. E., (John Wiley and Sons, 1978).