# Integral University, Lucknow
## Department of Mathematics & Statistics
## Study and Evaluation Scheme (w.e.f. 2020-21)

**M. Sc. (Mathematics)** **II$^{nd}$ year / III$^{rd}$ Semester**

| S. No. | Course code | Course Title | Type of Paper | Period Per hr/week/sem | | | Evaluation Scheme | | | | Sub. Total | Credit | Total Credits | Attributes | | | | | | | nited Nation Sustainable Development Goals (SDG s) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | L | T | P | CT | TA | Total | ESE | | | | Employability | Entrepreneurship | Skill Development | Gender Equality | Environment & Sustainability | Human Value | Professional Ethics | |
| **THEORIES** | | | | | | | | | | | | | | | | | | | | | |
| 1 | MT504 | Differential Geometry-II | **Core** | 03 | 01 | 00 | 40 | 20 | 60 | 40 | 100 | 3:1:0 | 4 | √ | | √ | | | | | 9 Industry, Innovation and Infrastructure |
| 2 | MT505 | Applied Functional Analysis | **Core** | 03 | 01 | 00 | 40 | 20 | 60 | 40 | 100 | 3:1:0 | 4 | √ | | √ | | | | | 9 Industry, Innovation and Infrastructure |
| 3 | MT506 | Integral Equations | **Core** | 03 | 01 | 00 | 40 | 20 | 60 | 40 | 100 | 3:1:0 | 4 | √ | | √ | | | | | 13 Climate Action |
| 4 | MT507 | Optimization Techniques | **Core** | 03 | 01 | 00 | 40 | 20 | 60 | 40 | 100 | 3:1:0 | 4 | √ | | √ | | | | | 12 Responsible Consumption and Production |
| 5 | MT508 | Fluid Dynamics | **Core** | 03 | 01 | 00 | 40 | 20 | 60 | 40 | 100 | 3:1:0 | 4 | √ | | √ | | | | | 13 Climate Action |
| 6 | MT509 | Special Function and Orthogonal Polynomials | **Core** | 03 | 01 | 00 | 40 | 20 | 60 | 40 | 100 | 3:1:0 | 4 | √ | | √ | | | | | 9 Industry, Innovation and Infrastructure |
| | | | **Total** | **18** | **06** | **00** | **240** | **120** | **360** | **240** | **600** | **24** | **24** | | | | | | | | |

**CT** = Class Test; **TA** = Teacher's Assessment,; **ESE** = End Semester Examination; **Sessional** = CT + TA; **Subject Total** = Sessional + ESE

# Integral University, Lucknow

| Effective from Session: 2015 - 16 | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Course Code** | MT504 | **Title of the Course** | Differential Geometry II | **L** | **T** | **P** | **C** |
| **Year** | **II** | **Semester** | III | **3** | **1** | **0** | **4** |
| **Pre-Requisite** | B. Sc. with Mathematics | **Co-requisite** | | | | | |
| **Course Objectives** | 1. This is an introductory course on Differentiable manifolds. The aim of this course is to introduce and develop basic theoretical concepts of almost contact manifolds and almost complex manifolds for n-dimensional spaces.<br>2. This course is aimed to provide an understanding of the affine connections, curvature tensors, linear connexion, Nijenhuis tensor, contravariant & covariant almost analytic vectors.<br>3. This course is aimed to provide the concept of semi-invariant and CR-sub manifolds of differentiable manifolds. | | | | | | |

| Course Outcomes | |
|---|---|
| **CO1** | Understand the concept of various kinds of almost contact manifolds with examples. |
| **CO2** | Able to define almost complex manifolds and calculate the curvature tensors, Nijenhuis tensor, contravariant & covariant almost analytic vectors. |
| **CO3** | Make logical arguments on Kahler & nearly Kahler manifolds and CR-submanifolds of Kahlerian manifolds. |
| **CO4** | Characterize Almost contact manifold to Sasakian manifold, quasi Sasakian manifold, k-contact Riemannian manifolds and find semi-invariant submanifolds of Sasakian manifolds. |
| **CO5** | Develop the understanding of the basic concepts of Almost Hermite manifolds, submanifolds of almost Hermite manifold, almost Grayan submanifold, F-structure manifolds. |

| Unit No. | Title of the Unit | Content of Unit | Contact Hrs. | Mapped CO |
|---|---|---|---|---|
| 1 | Tensor Analysis | Almost contact manifold, affinely almost co-symplectic manifold, contact metric structures, para-contact structures. | 8 | CO1 |
| 2 | Space curves | Almost complex manifold, Nijenhuis tensor, contravariant & covariant almost analytic vector, F-connection, linear connexion. | 8 | CO2 |
| 3 | Surface Theory | Kahler & nearly Kahler manifolds, affine connections, curvature tensors, CR-submanifolds of Kahlerian manifolds. | 8 | CO3 |
| 4 | Fundamental Equations | Sasakian manifold, quasi Sasakian manifold, k-contact Riemannian manifold, semi-invariant submanifolds of Sasakian manifold. | 8 | CO4 |
| 5 | Riemannian Manifolds | Almost Hermite manifolds, submanifolds of almost Hermite manifold, almost Grayan submanifold, F-structure manifolds. | 8 | CO5 |

**Reference Books:**


1. David E. Blair, Contact manifolds in Riemannian Geometry, Springer-Verlag. Structures of manifolds,
2. K. Yano & M. Kon, Structures of manifolds World Scientific Publishing Co. Pvt. Ltd.
3. S.I. Hussain. Lecture notes on differentiable manifolds
4. B.Y. Chen , Geometry of Submanifolds, Marcel Dekker, New York.


**e-Learning Source:**

1. https://www.youtube.com/watch?v=klks723on3k
2. https://www.youtube.com/watch?v=klks723on3k
3. https://www.youtube.com/watch?v=KwHfz5BegoU

**Course Articulation Matrix: (Mapping of COs with POs and PSOs)**

| PO-PSO / CO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PSO1 | PSO2 | PSO3 | PSO4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 3 | 1 | 1 | 1 | 2 | 1 | 1 | 3 | | | | |
| CO2 | 3 | 1 | 2 | 1 | 3 | 1 | 2 | 3 | | | | |
| CO3 | 3 | 1 | 2 | 1 | 3 | 1 | 1 | 2 | | | | |
| CO4 | 3 | 1 | 1 | 1 | 2 | 1 | 2 | 3 | | | | |
| CO5 | 3 | 1 | 1 | 1 | 2 | 1 | 1 | 2 | | | | |

**1- Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation**

| | |
|---|---|
| **Name & Sign of Program Coordinator** | **Sign & Seal of HoD** |

# Integral University, Lucknow

| Effective from Session: 2019 - 20 | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Course Code** | MT505 | **Title of the Course** | **Applied Functional Analysis** | **L** | **T** | **P** | **C** |
| **Year** | **II** | **Semester** | III | **3** | **1** | **0** | **4** |
| **Pre-Requisite** | B. Sc. with Mathematics | **Co-requisite** | | | | | |
| **Course Objectives** | The course gives an introduction to Applied functional analysis, which is a branch of analysis in which one develops analysis in infinite dimensional vector spaces. The central concepts which are studied are normed spaces with emphasis on Banach and Hilbert spaces, and continuous linear maps (often called operators) between such spaces. After successfully completion of course, the student will able to explore subject into their respective dimensions. | | | | | | |

| | **Course Outcomes** |
|---|---|
| **CO1** | Define and describe Metric spaces, examples of metric spaces, interior point, limit point, open set, closed set, neighborhood, convergence, Cauchy sequence, continuity, complete metric spaces, compact metric spaces. |
| **CO2** | Define and describe Normed linear Space, Banach spaces, incomplete normed spaces, finite dimensional normed spaces and subspaces, equivalent norms, compactness, Riesz's lemma, linear operators, bounded and continuous linear operators, continuity of linear operators, linear functional, linear operators and functional on finite dimensional spaces. |
| **CO3** | Define and describe Inner product spaces, Hilbert spaces, properties of Inner product spaces, polarization identity, orthogonal complements and direct sums, orthogonal sets and sequences, series related to orthogonal sequences and sets, representation of functional on Hilbert space. |
| **CO4** | Describe Zorn's lemma, Hahn–Banach theorem, Hahn Banach theorem for complex vector spaces and normed spaces, Application to bounded linear functionals on C[ a,b], uniform boundedness theorem, Open mappings, open mapping theorem, Closed linear operators, closed graph theorem. |
| **CO5** | Define and describe Contraction mappings, Picard's iterates, Banach fixed point theorem, Application of Banach theorem to linear equations, Application of Banach theorem to differential equations. |

| **Unit No.** | **Title of the Unit** | **Content of Unit** | **Contact Hrs.** | **Mapped CO** |
|---|---|---|---|---|
| 1 | Metric Spaces | Metric spaces, examples of metric spaces, interior point, limit point, open set, closed set, neighborhood, convergence, Cauchy sequence, continuity, complete metric spaces, compact metric spaces. | 7 | CO1 |
| 2 | Normed Spaces & Banach spaces | Normed linear Space, Banach spaces, incomplete normed spaces, finite dimensional normed spaces and subspaces, equivalent norms, compactness, Riesz's lemma, linear operators, bounded and continuous linear operators, continuity of linear operators, linear functional, linear operators and functional on finite dimensional spaces. | 8 | CO2 |
| 3 | Inner Product spaces & Hilbert Spaces | Inner product spaces, Hilbert spaces, properties of Inner product spaces, polarization identity, orthogonal complements and direct sums, orthogonal sets and sequences, series related to orthogonal sequences and sets, representation of functional on Hilbert space. | 8 | CO3 |
| 4 | Fundamental Theorems of Normed and Banach | Zorn's lemma, Hahn–Banach theorem, Hahn Banach theorem for complex vector spaces and normed spaces, Application to bounded linear functionals on C[ a,b], uniform boundedness theorem, Open mappings, open mapping theorem, Closed linear operators, closed graph theorem | 9 | CO4 |
| 5 | Banach fixed point theorem | Contraction mappings, Picard's iterates, Banach fixed point theorem, Application of Banach theorem to linear equations, Application of Banach theorem to differential equations | 8 | CO5 |

**Reference Books:**


1. Introductory Functional Analysis with Applications by Erwin Kreyszig(1989).
2. Introduction to Functional Analysis with Applications by A.H. Siddiqui, Khalil Ahmad and P. Manchanda, Real World Education Publishers, New Delhi(2015).
3. Applied Functional Analysis by A.H. Siddiqui, Real World Education Publishers, New Delhi (2015).
4. Elements of the Theory of Functions and Functional Analysis by W. Rudin.


**e-Learning Source:**

1. https://nptel.ac.in/courses/111105037/
2. https://www.youtube.com/watch?v=7IIw_U8rv4Q
3. https://freevideolectures.com/course/3145/functional-analysis

| | Course Articulation Matrix: (Mapping of COs with POs and PSOs) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **PO-PSO** / **CO** | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PSO1 | PSO2 | PSO3 | PSO4 |
| **CO 1** | **3** | **1** | **1** | **1** | **2** | **2** | **2** | **3** | 3 | 3 | 2 | 3 |
| **CO 2** | **3** | **1** | **1** | **1** | **2** | **1** | **2** | **3** | 3 | 3 | 2 | 3 |
| **CO 3** | **2** | **1** | **1** | **1** | **2** | **1** | **2** | **3** | 3 | 3 | 3 | 3 |
| **CO 4** | **3** | **1** | **2** | **1** | **1** | **1** | **2** | **3** | 3 | 2 | 2 | 3 |
| **CO 5** | **3** | **1** | **1** | **1** | **2** | **1** | **2** | **3** | 3 | 3 | 2 | 3 |

**1- Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation**

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|---|---|
| **Name & Sign of Program Coordinator** | **Sign & Seal of HoD** |

**Integral University, Lucknow**

| **Effective from Session:** 2015 - 16 | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Course Code** | MT506 | **Title of the Course** | Integral Equations | **L** | **T** | **P** | **C** |
| **Year** | **II** | **Semester** | III | **3** | **1** | **0** | **4** |
| **Pre-Requisite** | B. Sc. with Mathematics | **Co-requisite** | | | | | |
| **Course Objectives** | The course is aimed to develop the skills in mathematics for grooming them into successful science graduate. The topics introduced will serve as basic tools for specialized studies in science field. | | | | | | |

| **Course Outcomes** | |
|---|---|
| **CO1** | Familiar with the concepts of integral operator and functional. |
| **CO2** | Recognize difference between Volterra and Fredholm Integral Equations, First kind and Second kind, homogeneous and inhomogeneous etc. |
| **CO3** | Acquired sound knowledge of Green's functions, Fredholm and Volterra integral equations and of the calculus of variations. |
| **CO4** | Ordinary and partial differential equations using Green's functions. |
| **CO5** | They apply different methods to solve Integral Equations. |

| **Unit No.** | **Title of the Unit** | **Content of Unit** | **Contact Hrs.** | **Mapped CO** |
|---|---|---|---|---|
| 1 | Fredholm and Volterra integral equation | Regularity conditions, special kinds of kernels, Eigen values and Eigen functions, Convolution integral, reduction to a system ofalgebraic equations , Fredholm alternative, an approximate method , examples, iterative scheme, Volterra integral equation, Some results about the resolvent Kernel, Examples. | 9 | CO1 |
| 2 | Classical Fredholm Theory | The method of solution of Fredholm, Fredholm first theory, Examples. | 7 | CO2 |
| 3 | Applications to ordinary differential equations | Initial value problems, boundary value problems, Dirac delta Function, Green's Function approach, Green's function for nth orderordinary differential equations, Modified Green's function, Examples. | 8 | CO3 |
| 4 | Symmetric Kernels | Introduction, Fundamental properties of Eigen values and Eigen functions for symmetric Kernels, Expansion in Eigen functions and Bilinear forms, Hilbert-Schmidt theorem and some immediate consequences, solutions of a symmetric integral equation, Examples | 8 | CO4 |
| 5 | Singular Integral Equations and Integral Transform methods | Abel's Equations, Inversion formula for singular integral equations, Laplace transform, Application to Volterra integral and integral differential equations with convolution type Kernels, Abel's Integral equations, Fourier Transform, Solution by Fourier Transform Method. | 8 | CO5 |

**Reference Books:**


1. 1. Numerical Methods for Scientific and Engineering computation by M.K.
2. Jain, S.R.K. Iyengar, R.K. Jain, New Age Int. Ltd., New Delhi.
3. Numerical Methods by P. Kandasamy, S. Chand Publ. New Delhi.
4. Introduction to Numerical Analysis, by S.S. Sastry Prentice Hall Flied


**e-Learning Source:**

1. https://nptel.ac.in/content/storage2/nptel_data3/html/mhrd/ict/text/115104096/lec47.pdf
2. https://nptel.ac.in/content/storage2/nptel_data3/html/mhrd/ict/text/111107103/lec13.pdf
3. http://hitoshi.berkeley.edu/221A/delta.pdf

**Course Articulation Matrix: (Mapping of COs with POs and PSOs)**

| **PO-PSO / CO** | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PSO1 | PSO2 | PSO3 | PSO4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | **3** | **2** | **2** | **1** | **1** | **3** | **1** | **1** | 1 | 2 | 1 | 1 |
| **CO2** | **2** | **2** | **2** | **1** | **1** | **2** | **2** | **1** | 1 | 2 | 1 | 2 |
| **CO3** | **2** | **2** | **2** | **1** | **1** | **2** | **3** | **3** | 1 | 3 | 1 | 2 |
| **CO4** | **3** | **2** | **3** | **1** | **1** | **3** | **2** | **3** | 3 | 1 | 3 | 3 |
| **CO5** | **3** | **2** | **1** | **1** | **1** | **2** | **1** | **1** | 3 | 1 | 3 | 3 |

**1- Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation**

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|---|---|
| **Name & Sign of Program Coordinator** | **Sign & Seal of HoD** |

# Integral University, Lucknow

| Effective from Session: 2015 - 16 | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Course Code** | MT507 | **Title of the Course** | Optimization Techniques | **L** | **T** | **P** | **C** |
| **Year** | II | **Semester** | III | **3** | **1** | **0** | **4** |
| **Pre-Requisite** | B. Sc. with Mathematics | **Co-requisite** | | | | | |
| **Course Objectives** | Understand the definitions and Formulation of linear programming problem and different optimizationtechniques | | | | | | |

| **Course Outcomes** | |
|---|---|
| **CO1** | To understand the definitions and Formulation of linear programming problem (LPP) Graphical method, Simplex method, Big-M method, Two Phase method, Primal & Dual problem. |
| **CO2** | Able to explain the Various method of finding initial basic feasible solution of transportation problem, Optimality criterion in transportation problem. Solution of assignment problem using Hungarian method. |
| **CO3** | Able to understand the basic definitions, Two-person Zero-sum games, Pure and mixed strategy, Principle of Dominance, Graphical method, Solution of games by linear programming method. Decision Theory: Introduction, Elements of decision problem, Types of decision making environment, Decision tree. |
| **CO4** | Able to explain Sequencing: Basic assumptions, Processing of n-Jobs on 2-Machines, n-Jobs on 3- Machines and 2-Jobs on k-Machines. Replacement Problems: Replacement of items that deteriorate with time, Replacement of items that fails suddenly - Individual replacement policy andGroup replacement policy |
| **CO5** | Able to explain Inventory Models,Types of inventory models, Various inventory costs, Deterministic inventory models, Economic order quantity, Price breaks- one, two, n-price breaks, Single period probabilistic inventory models. |

| **Unit No.** | **Title of the Unit** | **Content of Unit** | **Contact Hrs.** | **Mapped CO** |
|---|---|---|---|---|
| 1 | Linear Programming | Linear programming problem (LPP), Formulation of linear programming problem, Graphical method, Simplex method, Big-M method, Two Phase method, Primal & Dual problem. | 8 | CO1 |
| 2 | Transportation and Assignment Problem | Various method of finding initial basic feasible solution of transportation problem, Optimality criterion in transportation problem, Variations in transportation problem, Solution of assignment problem using Hungarian method and Variations in assignment problem | 8 | CO2 |
| 3 | Game Theory & Decision Theory | Basic definitions, Two-person Zero-sum games, Pure and mixed strategy, Principle of Dominance, Graphical method, Solution of games by linear programming method.**:** Introduction, Elements of decision problem, Types of decision making environment, Decision tree. | 8 | CO3 |
| 4 | Sequencing & Replacement Problems | Basic assumptions, Processing of n-Jobs on 2-Machines, n-Jobs on 3-Machines and 2-Jobs on k-Machines. Replacement of items that deteriorate with time, Replacement of items that fails suddenly - Individual replacement policy and Group replacement policy. | 8 | CO4 |
| 5 | Inventory Models | Types of inventory models, Various inventory costs, Deterministic inventory models, Economic order quantity, Price breaks- one, two, n-price breaks, Single period probabilistic inventory models. | 8 | CO5 |

**Reference Books:**


**1** H.A. TAHA "Operations Research- An Introduction” Pearson.

2. K.Swarup, P.K.Gupta and A. Manmohan, "Operations Research", S. Chand.

3. Hiller And Liebarman, “Introduction to Operations Research", McGraw Hill Company.

4. J.K.Sharma, “Operations Research ", Pearson.


**e-Learning Source:**

1. https://www.youtube.com/watch?v=be9e-Q-jC-0
2. https://www.youtube.com/watch?v=bQ5_PPRPjG4
3. https://www.youtube.com/watch?v=jauhoR7w1YM

| | **Course Articulation Matrix: (Mapping of COs with POs and PSOs)** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **PO-PSO CO** | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PSO1 | PSO2 | PSO3 | PSO4 |
| **CO1** | **3** | **3** | **2** | **2** | **2** | **2** | **2** | **3** | 3 | 2 | 3 | 3 |
| **CO2** | **2** | **3** | **3** | **2** | **2** | **3** | **2** | **2** | 2 | 3 | 2 | 3 |
| **CO3** | **2** | **2** | **2** | **2** | **3** | **2** | **3** | **2** | 3 | 2 | 3 | 2 |
| **CO4** | **2** | **3** | **3** | **3** | **2** | **2** | **2** | **2** | 2 | 3 | 2 | 2 |
| **CO5** | **2** | **2** | **3** | **2** | **2** | **2** | **2** | **2** | 3 | 2 | 2 | 3 |

**1- Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation**

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|---|---|
| **Name & Sign of Program Coordinator** | **Sign & Seal of HoD** |

**Integral University, Lucknow**

| **Effective from Session:** 2015 - 16 | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Course Code** | MT508 | **Title of the Course** | Fluid Dynamics | **L** | **T** | **P** | **C** |
| **Year** | **II** | **Semester** | III | **3** | **1** | **0** | **4** |
| **Pre-Requisite** | B.Sc. with Mathematics | **Co-requisite** | | | | | |
| **Course Objectives** | Students will be able to learn the concepts and mathematical understanding of Fluid Dynamics. They will understand the physical and mathematical formulation of non viscous fluids and their solutions and can develop the idea of source, sink and doublet and obtain complex potentials. Also Understand, formulate and solve the equations of motion under different conditions. Students will be able to understand the similarity of the fluids, obtain and solve the differential equations of viscous incompressible fluid under specified boundary conditions | | | | | | |

| **Course Outcomes** | |
|---|---|
| **CO1** | Develop mathematical understanding of fluid Dynamics problems. |
| **CO2** | Understand the various concepts and relations of fluid and understand the physical and mathematicalformulation of non viscous fluids and their solutions. |
| **CO3** | Understand and develop the idea of source, sink and doublet and obtain complex potentials |
| **CO4** | Able to understand, derive and solve the two dimensional equations of fluid motion of circular, ellipticand coaxial cylinders. Derive and solve the equation of motion of viscous fluid and obtain the energy equation, vorticity and circulation. |
| **CO5** | Apply the dimensional analysis to obtain the dimensionless numbers to express the fluid motion independently. Obtain, solve and analyze Navier-Stoke equation of motion of viscous fluid betweenparallel plates and of concentric rotating cylinders to find the velocity and temperature distribution function of the fluid. |

| **Unit No.** | **Title of the Unit** | **Content of Unit** | **Contact Hrs.** | **Mapped CO** |
|---|---|---|---|---|
| 1 | Unit 1 | Equation of motion - Lagrange's and Euler's equation of motion-Bernoulli's theorem - Stream functions - Irrotational motion in two-dimensions-Complex velocity potential sources–Sinks, doublets and their images-Milne-Thompson Circle theorem. | 8 | CO1 |
| 2 | Unit 2 | Two dimensional irrotational motion produced by motion of Circular, Co-axial and elliptic cylinders in an infinite mass of liquid-Theorem of Blasius motion of a sphere through a liquid at rest at infinity-Liquid streaming past a fixed sphere. | 8 | CO2 |
| 3 | Unit 3 | Fundamental Equations of Motion of Viscous Fluid; Equation of State, Equation of Continuity, Navier–Stokes (NS) Equations (equation of Motion, Equation of Energy, Streamlines & Pathlines, Vorticity and Circulation (Kelvin'sCirculation Theorem). | 8 | CO3 |
| 4 | Unit 4 | Dynamical Similarity (Reynold's Law), Inspection Analysis-Dimensional Analysis, Buckingham–π-Theorem, and its Applications π–products and coefficients, Non-dimensional parameters and their physical importance. Exact Solutions of the N S Equations | 8 | CO4 |
| 5 | Unit 5 | Steady Motion between parallel plates: Velocity distribution & Temperature Distribution. Plane Couette flow, generalized plane Couette flow. Flow between two concentric Rotating Cylinders: Velocitydistribution & Temperature distribution. | 8 | CO5 |

**Reference Books:**


1. W.H. Besaint and A.S.Ramsay, A Treatise on Hydromechanics, Part-II. CBS Publishers,Delhi, 1988.
2. F. Chorlton, Text book of Fluid Dynamics, CBS Publishers, Delhi, 1985.
3. G.K. Batchelor, An Introduction to Fluid Dynamics, Cambridge University Press (1970).
4. C.S. Yih, Fluid Mechanics, McGraw-Hill Book, Company


**e-Learning Source:**

1. https://nptel.ac.in/courses/112105171/
2. http://www3.dicca.unige.it/rrepetto/linked-files/fluid-dynamics-lecture-notes.pdf
3. http://web.engr.uky.edu/~acfd/me330-lctrs.pdf

| | **Course Articulation Matrix: (Mapping of COs with POs and PSOs)** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **PO-PSO / CO** | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PSO1 | PSO2 | PSO3 | PSO4 |
| **CO1** | 3 | 2 | 2 | 1 | 1 | 1 | 2 | 2 | 3 | 3 | 2 | 1 |
| **CO2** | 3 | 2 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 2 | 1 |
| **CO3** | 3 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 2 | 1 |
| **CO4** | 3 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 2 | 1 |
| **CO5** | 3 | 2 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 2 | 1 |

**1- Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation**

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|---|---|
| **Name & Sign of Program Coordinator** | **Sign & Seal of HoD** |

# Integral University, Lucknow

| **Effective from Session:** 2019 - 20 | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Course Code** | MT509 | **Title of the Course** | Special Functions | **L** | **T** | **P** | **C** |
| **Year** | **II** | **Semester** | III | **3** | **1** | **0** | **4** |
| **Pre-Requisite** | B.Sc. with Mathematics | **Co-requisite** | | | | | |
| **Course Objectives** | The interplay between mathematical analysis and physical understanding. • To investigate and derive the properties of special functions, inter-relations between such functions and their representations in various forms. • Certain specific systems of orthogonal polynomials and their properties. | | | | | | |

| **Course Outcomes** | |
|---|---|
| **CO1** | Solve, expand and interpret solutions of many types of important differential equations by making use of special functions and orthogonal polynomials. |
| **CO2** | Derive the formulas and results of certain classical special functions and orthogonal polynomials by different methods. |
| **CO3** | Derive the generating relations involving special functions. |
| **CO4** | Understand purpose and functions of the gamma and beta functions, and Transformation. |
| **CO5** | Achieve the knowledge to analyse the problems using the methods of special functions and orthogonal polynomials, which helps in exploring the role of special functions and orthogonal polynomials in other areas of mathematics. |

| **Unit No.** | **Title of the Unit** | **Content of Unit** | **Contact Hrs.** | **Mapped CO** |
|---|---|---|---|---|
| 1 | Gamma and Beta functions | The Euler or Macheroni Constant, Gamma function, A series for gamma function, Difference equation Gamma(Z+1) = Z Gamma(Z), Euler's Integral for Gamma(z), Beta function, Value of Gamma(z)Gamma(1-z), Factorial function, Legender duplication formula, Gauss multiplication Theorem. | 8 | CO1 |
| 2 | Hypergemetric and Generalized hypergeometric function | Definition and integral representation of Gauss hypergeomteric function 2F1 (a,b;c;z). Contagious function relation, Hypergeometric differential equations and its solutions, F(a,b;c;z) as function of its parameters, Elementary series manipulation, Simple transformations and reduction formulas. | 8 | CO2 |
| 3 | Bessel and Legendre polynomials | Definition of Jn(Z), Bessel differentia equation, generating functions, recurrence relations and integral representation; Generating function Legendre polynomials, Rodrigue's formula, Recurrence relations and hypergeometric form of Legendre polynomials, First and second kind integral transforms, orthogonally. | 8 | CO3 |
| 4 | Hermite Polynomials | Definition of Hermite Polynomials Hn(x), Pure and recuerrence relations, Rodrigue's formula, other generating functions, Orthogonally, Expansion polynomials. | 8 | CO4 |
| 5 | Laguerre Polynomials | The Laguerre Polynomials Ln(x), generating function, pure and differential recurrence relations, Rodrigues formula, Orthogonally, Expansion of Polynomials | 8 | CO5 |

**Reference Books:**


1. E. D. Rainville: Special Functions, Chelsea Publishing Co., Bronx, New York, Reprint, 1971.
2. Saran, N., Sharma S.D., and Trivedi: Special functions with applications, Pragati Prakashan, 1986.
3. Lebdev, N.N: Special functions and Their Applications, Prentice Hall, Englewood Cliffs, New Jersey, USA, 1995


**e-Learning Source:**

1. https://meet.google.com/apj-ammk-bhp, https://web.mst.edu/~lmhall/SPFNS/spfns.pdf
2. https://meet.google.com/byc-ckzd-ghr, http://web.math.ku.dk/~henrikp/wosfa/book-of-abstracts.pdf
3. https://meet.google.com/apj-ammk-bhp

**Course Articulation Matrix: (Mapping of COs with POs and PSOs)**

| **PO-PSO / CO** | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PSO1 | PSO2 | PSO3 | PSO4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | **3** | **1** | **1** | | **1** | **1** | **1** | **3** | 3 | 2 | 2 | 3 |
| **CO2** | **3** | **1** | **2** | | **3** | **1** | **1** | **3** | 3 | 3 | 2 | 3 |
| **CO3** | **3** | **1** | **2** | | **3** | **1** | **1** | **3** | 3 | 3 | 3 | 2 |
| **CO4** | **3** | **1** | **1** | | **3** | **1** | **1** | **3** | 2 | 2 | 3 | 3 |
| **CO5** | **3** | **1** | **1** | | **2** | **2** | **1** | **3** | 2 | 3 | 2 | 3 |

**1- Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation**

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| **Name & Sign of Program Coordinator** | **Sign & Seal of HoD** |

# Integral University, Lucknow
## Department of Mathematics & Statistics
## Study and Evaluation Scheme (w.e.f. 2020-21)

**M. Sc. (Mathematics)** — **II$^{nd}$ year / IV$^{th}$ Semester**

| S. No. | Course code | Course Title | Type of Paper | Period Per hr/week/sem | | | Evaluation Scheme | | | | Sub. Total | Credit | Total Credits | Attributes | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | L | T | P | CT | TA | Total | ESE | | | | Employability | Entrepreneurship | Skill Development | Gender Equality | Environment & Sustainability | Human Value | Professional Ethics | |
| **THEORIES** | | | | | | | | | | | | | | | | | | | | | |
| 1 | MT510 | Mechanics | **Core** | 03 | 01 | 00 | 40 | 20 | 60 | 40 | 100 | 3:1:0 | 4 | √ | | √ | | | | | |
| 2 | MT511 | Advanced Functional Analysis | **Core** | 03 | 01 | 00 | 40 | 20 | 60 | 40 | 100 | 3:1:0 | 4 | √ | | √ | | | | | |
| 3 | MT512 | Topology | **Core** | 03 | 01 | 00 | 40 | 20 | 60 | 40 | 100 | 3:1:0 | 4 | √ | | √ | | | | | |
| 4 | MT513 | Magneto Hydrodynamics | **Elective** | 03 | 01 | 00 | 40 | 20 | 60 | 40 | 100 | 3:1:0 | 4 | √ | | √ | | | | | |
| | MT514 | Mathematical Modelling and Simulation | **Elective** | | | | | | | | | | | √ | | √ | | | | | |
| | MT515 | Calculus of Variations | **Elective** | | | | | | | | | | | √ | | √ | | | | | |
| **PROJECT** | | | | | | | | | | | | | | | | | | | | | |
| 5 | MT516 | *Project | **Core** | 06 | 00 | 00 | 00 | 00 | 00 | 200 | 200 | 06 | 06 | √ | | √ | | | | √ | |
| | | | **Total** | **18** | **04** | **00** | **160** | **80** | **240** | **360** | **600** | **22** | **22** | | | | | | | | |

**CT** = Class Test; **TA** = Teacher's Assessment,; **ESE** = End Semester Examination; **Sessional** = CT + TA; **Subject Total** = Sessional + ESE

**Total Credits = 24 + 22 + 24 + 22 = 92**

*** The Evaluation scheme for Project**

| | Course Code | Project Dissertation | Presentation | Viva-Voce | Total |
|---|---|---|---|---|---|
| Project | MT516 | 100 | 50 | 50 | 200 |

# Integral University, Lucknow

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|---|---|---|---|---|---|---|---|
| **Effective from Session:** 2015 - 16 | | | | | | | |
| **Course Code** | MT510 | **Title of the Course** | Mechanics | **L** | **T** | **P** | **C** |
| **Year** | **II** | **Semester** | IV | **3** | **1** | **0** | **4** |
| **Pre-Requisite** | B.Sc. with Maths | **Co-requisite** | | | | | |
| **Course Objectives** | The purpose of this postgraduate course is to impart basic and key knowledge of classical mechanics. By using the principal of applied mathematics to obtain quantitative relations which are very important for higher studies. After successfully completion of course, the student will able explore subject into their respective dimensions | | | | | | |

| **Course Outcomes** | |
|---|---|
| **CO1** | Find and interpret General force system, equipollent force system, equilibrium conditions, couples, moments, general motion of rigid body, moments and product of inertia and their properties, Kinetic energy of rigid body |
| **CO2** | Evaluate and Interpret Eulers's dynamical equations, motion of rigid body with a fix point, generalized co-ordinates, Lagrange's equation, applications of Lagaragian formulation and D' Alembert's Principle. |
| **CO3** | Describe the Euler's equations for functional containing first order derivatives and one independent variable. |
| **CO4** | Find and Interpret the functional dependent on one and two functions, Jacobian and Legendre conditions. |
| **CO5** | Describe Hamilton Principle, Canonical equation of Hamilton, Hamilton equation of variation principle |

| **Unit No.** | **Title of the Unit** | **Content of Unit** | **Contact Hrs.** | **Mapped CO** |
|---|---|---|---|---|
| 1 | Unit 1 | General force system, equipollent force system, equilibrium conditions, couples, moments, general motion of rigid body, moments and product | 8 | CO1 |
| 2 | Unit 1 | Eulers's dynamical equations motion of rigid body, generalized co-ordinates, Lagrange's equation and its applications and D' Alembert's Principle. | 8 | CO2 |
| 3 | Unit 1 | Euler's equations for functional containing first order derivatives and one independent variable, Externals and functional dependent on more than one independent variable, Variation problems in parametric forms, Functional dependent on higher order derivatives | 8 | CO3 |
| 4 | Unit 1 | Functional dependent on one and two functions, one sided variation, Second variations Jacobian and Legendre conditions, variation principle of least action | 8 | CO4 |
| 5 | Unit 1 | Hamilton Principle, Cyclic coordinates, Canonical equation of Hamilton, Hamilton equation of variation principle, Principle of least action | 8 | CO5 |
| **Reference Books:** | | | | |
| 1. J.L. Synge and B.A. Griffith: Principle of mechanics, McGraw-Hill Book Company | | | | |
| 2. H. Goldstein: Classical Mechanics: Second Edition, Narosa Publishing House (1980) | | | | |
| **e-Learning Source:** | | | | |
| 1. http://www.astro.caltech.edu/~golwala/ph106ab/ph106ab_notes.pdf | | | | |
| 2. https://www.youtube.com/watch?v=ApUFtLCrU90 | | | | |

**Course Articulation Matrix: (Mapping of COs with POs and PSOs)**

| **PO-PSO / CO** | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PSO1 | PSO2 | PSO3 | PSO4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | **3** | **2** | **3** | **1** | **2** | **1** | **1** | **3** | 3 | 2 | 2 | 1 |
| **CO2** | **3** | **2** | **1** | **1** | **2** | **1** | **2** | **3** | 3 | 3 | 2 | 2 |
| **CO3** | **2** | **2** | **1** | **1** | **2** | **1** | **1** | **2** | 2 | 3 | 2 | 1 |
| **CO4** | **3** | **2** | **2** | **1** | **1** | **1** | **1** | **3** | 3 | 3 | 3 | 2 |
| **CO5** | **2** | **2** | **1** | **1** | **2** | **1** | **2** | **2** | 3 | 2 | 2 | 1 |

**1- Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation**

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| **Name & Sign of Program Coordinator** | **Sign & Seal of HoD** |

# Integral University, Lucknow

| Effective from Session: 2015 - 16 | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Course Code** | MT511 | **Title of the Course** | ADVANCED FUNCTIONAL ANALYSIS | **L** | **T** | **P** | **C** |
| **Year** | **II** | **Semester** | IV | **3** | **1** | **0** | **4** |
| **Pre-Requisite** | B.Sc. | **Co-requisite** | | | | | |
| **Course Objectives** | The course gives an introduction to spectral theory, compact linear operators and approximation theory which is one of the main branches of modern functional analysis. After successfully completion of course, the student will able to explore subject into their respective dimensions. | | | | | | |

| **Course Outcomes** | |
|---|---|
| **CO1** | Define and describe Hilbert–Adjoint operator, self adjoint, unitary and normal operators, adjoint operator, dual spaces, reflexive spaces, strong and weak convergence, convergence of sequence of operators and functional. |
| **CO2** | Define and describe Spectral Theory in finite dimensional Normed Spaces, Basic Concepts, Spectral Properties of Bounded Linear Operators, Use of Complex Analysis in Spectral Theory, Banach Algebra. |
| **CO3** | Define and describe Compact Linear Operator on Normed Spaces, Properties of Compact Linear Operator, Spectral Properties of Compact Linear Operators on Normed Spaces, Operator Equations Involving Compact Linear Operators, Further Theorem of Fredholm Type. |
| **CO4** | Describe Spectral Properties of Bounded Self – Adjoint Linear Operators, Positive Operators, Square Roots of a Positive Operator, Projection Operators, Further Properties of Projections, Spectral Family of a Bounded Self – Adjoint Linear Operators, Spectral Representation of Bounded Self Adjoint Linear Operators. |
| **CO5** | Define and describe Strict convexity, uniform convexity, Approximation in Normed Spaces, Existence and Uniqueness, Uniform Approximation, Chebyshev polynomial, Best approximation, approximation in Hilbert space |

| **Unit No.** | **Title of the Unit** | **Content of Unit** | **Contact Hrs.** | **Mapped CO** |
|---|---|---|---|---|
| 1 | Operators and Reflexive spaces | Hilbert–Adjoint operator, self adjoint, Unitary and normal operators, adjoint operator, Dual spaces, reflexive spaces, strong and weak convergence, convergence of sequence of operators and functional. | 8 | CO1 |
| 2 | Spectral Theory of Linear Operators in Normed | Spectral Theory in Finite Dimensional Normed Spaces, Basic Concepts, Spectral Properties of Bounded Linear Operators, Use of Spaces Complex Analysis in Spectral Theory, Banach Algebra. | 8 | CO2 |
| 3 | Compact linear Operators on Normed spaces | Compact Linear Operator on Normed Spaces, Properties of Compact Linear Operator, Spectral Properties of Compact Linear Operator Their Spectrum on Normed Spaces, Operator Equations Involving Compact Linear Operators, Further Theorem of Fredholm Type. | 8 | CO3 |
| 4 | Spectral Theory of Bounded Self – Adjoint Linear | Spectral Properties of Bounded Self – Adjoint Linear Operators, Positive Operators, Square Roots of a Positive Operator, Projection Operator Operators, Further Properties of Projections, Spectral Family of a Bounded Self – Adjoint Linear Operators, Spectral Representation of Bounded Self Adjoint Linear Operators. | 8 | CO4 |
| 5 | Approximation Theory | Strict convexity, uniform convexity, Approximation in Normed Spaces, Existence and Uniqueness, Uniform Approximation, Chebyshev polynomial, Best approximation, approximation in Hilbert space. | 8 | CO5 |

**Reference Books:**


1. Introductory Functional Analysis with Applications by Erwin Kreyszig(1989).
2. Introduction to Functional Analysis with Applications by A.H. Siddiqui, Khalil Ahmad and P. Manchanda, Real World Education Publishers, New Delhi(2015).
3. Applied Functional Analysis by A.H. Siddiqui, Real World Education Publishers, New Delhi (2015).
4. Elements of the Theory of Functions and Functional Analysis by W. Rudin


**e-Learning Source:**

1. https://www.youtube.com/watch?v=ZCq9zynbY_Y
2. https://cosmolearning.org/video-lectures/spectral-theory
3. https://cosmolearning.org/video-lectures/approximation-theory/

| | **Course Articulation Matrix: (Mapping of COs with POs and PSOs)** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **PO-PSO / CO** | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PSO1 | PSO2 | PSO3 | PSO4 |
| **CO1** | **3** | **1** | **1** | **1** | **2** | **2** | **2** | **3** | 3 | 3 | 2 | 3 |
| **CO2** | **3** | **2** | **1** | **1** | **2** | **1** | **2** | **3** | 3 | 3 | 2 | 3 |
| **CO3** | **2** | **2** | **1** | **1** | **2** | **1** | **1** | **3** | 3 | 3 | 3 | 3 |
| **CO4** | **3** | **2** | **2** | **1** | **1** | **1** | **1** | **3** | 3 | 2 | 3 | 3 |
| **CO5** | **3** | **2** | **1** | **1** | **2** | **1** | **2** | **3** | 3 | 3 | 2 | 3 |

**1- Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation**

| **Name & Sign of Program Coordinator** | **Sign & Seal of HoD** |
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# Integral University, Lucknow

| Effective from Session: 2019 - 20 | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Course Code** | MT512 | **Title of the Course** | Topology | **L** | **T** | **P** | **C** |
| **Year** | **II** | **Semester** | IV | **3** | **1** | **0** | **4** |
| **Pre-Requisite** | M.Sc (Mathematics) First year | **Co-requisite** | | | | | |
| **Course Objectives** | The purpose of this course is an introduction to topological spaces. It deals with constructions like subspaces, product spaces, and quotient spaces, and properties like compactness and connectedness. The course concludes with an introduction to fundamental groups and covering spaces. | | | | | | |

| Course Outcomes | |
|---|---|
| **CO1** | Students will gain an understanding to how the topology on a space is determined by the collection of open sets, by the collection of closed sets, or by a basis of neighbourhoods at each point, and you know what it means for a function to be continuous. |
| **CO2** | Students will be able to Use continuous functions and homeomorphisms to understand structure of topological spaces. |
| **CO3** | Students will be able to know what it means for a metric space to be complete, and you can characterize compact metric spaces, compact spaces, and locally compact spaces. |
| **CO4** | Students will be able to know the definition and basic properties of connected spaces, path connected spaces and familiar with the Urysohn lemma and the Tietze extension theorem, and you can characterise metrizable spaces. |
| **CO5** | Students will gain an understanding of approaches to product Topology ( finite & infinite ), Tychonoff product topology in terms of standard sub base and its characterizations. |

| Unit No. | Title of the Unit | Content of Unit | Contact Hrs. | Mapped CO |
|---|---|---|---|---|
| 1 | Topological spaces | Definition and examples of Topological spaces, closed sets, closure, neighborhoods, interior, exterior, boundary and accumulation point of a set, derived sets, dense sets, bases and sub bases, relative topology, Subspaces, Finite intersection property. | 8 | CO1 |
| 2 | Homeomorphism and separation axioms | Eulers's dynamical equations motion of rigid body, generalized co-ordinates, Lagrange's equation and its applications and D' Alembert's Principle. | 8 | CO2 |
| 3 | Compactness | Compactness, Basic properties of compactness, compactness and finite intersection property, Bolzano-Weierstrass property, sequential compactness, local compactness and one point compactification, connected sets in the real line | 8 | CO3 |
| 4 | Connectedness | Connectedness, connected spaces and their properties, local connectedness, path connectedness, components, locally connected spaces Urysohn's lemma, Teitz extension theorem, Para compactness, characterizations of para compactness in regular spaces | 8 | CO4 |
| 5 | Product Topology | Product Topology ( finite & infinite ), Tychonoff product topology in terms of standard sub base and its characterizations, product topology and separation axioms, connectedness and compactness( including the Tychonoff's theorem), countability and product spaces. | 8 | CO5 |

**Reference Books:**


1. G. Bredon, Topology and Geometry, Springer-Verlag, 2005
2. J. Dugundji, Topology, Allyn and Bacon, 1970.
3. J. L. Kelly, General Topology, Springer-Verlag, 2005.
4. J. R. Munkers, Topology, Second Edition, Pearson Education, 2003.
5. S. Willard, General Topology, Dover Publications, N. Y. 2004.


**e-Learning Source:**

1. https://nptel.ac.in/courses/111/106/111106054/
2. https://www.youtube.com/watch?v=kOFtfmCpNg0
3. http://jde27.uk/tg/topsp02.html

**Course Articulation Matrix: (Mapping of COs with POs and PSOs)**

| PO-PSO / CO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PSO1 | PSO2 | PSO3 | PSO4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | **3** | **1** | **1** | | **2** | **1** | **1** | **3** | 2 | 2 | 3 | 1 |
| **CO2** | **3** | **1** | **2** | | **3** | **1** | **1** | **3** | 2 | 3 | 2 | 1 |
| **CO3** | **3** | **1** | **2** | | **3** | **1** | **1** | **3** | 3 | 2 | 2 | 2 |
| **CO4** | **3** | **1** | **1** | | **2** | **1** | **1** | **3** | 2 | 2 | 3 | 2 |
| **CO5** | **3** | **1** | **1** | | **2** | **1** | **1** | **3** | 3 | 2 | 2 | 2 |

**1- Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation**

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| **Name & Sign of Program Coordinator** | **Sign & Seal of HoD** |

# Integral University, Lucknow

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|---|---|---|---|---|---|---|---|
| **Effective from Session:** 2015 - 16 | | | | | | | |
| **Course Code** | MT515 | **Title of the Course** | Calculus of Variations | **L** | **T** | **P** | **C** |
| **Year** | **II** | **Semester** | IV | **3** | **1** | **0** | **4** |
| **Pre-Requisite** | Graduation with Mathematics | **Co-requisite** | | | | | |
| **Course Objectives** | The calculus of variations concerns problems in which one wishes to find the minima or extrema of some quantity over a system that has functional degrees of freedom. Many important problems arise in this way across pure and applied mathematics and physics. They range from the problem in geometry of finding the shape of a soap bubble, a surface that minimizes its surface area, to finding the configuration of a piece of elastic that minimizes its energy. Perhaps most importantly, the principle of least action is now the standard way to formulate the laws of mechanics and basic physics. In this course it is shown that such variational problems give rise to a system of differential equations, the Euler-Lagrange equations. Furthermore, the minimizing principle that underlies these equations leads to direct methods for analyzing the solutions to these equations. These methods have far reaching applications and will help develop student's technique. | | | | | | |

| **Course Outcomes** | |
|---|---|
| **CO1** | Can understand what functional, strong and weak variations are, and have some appreciation of their applications. |
| **CO2** | Can use the Euler-Lagrange equation or its first integral to find differential equations for stationary paths, |
| **CO3** | Develop an understanding of problem of Minimum surface of revolution , Minimum energy problem, Brachistochrone Problem , Variational Notation , Variational Problems involving several functions. |
| **CO4** | Determine the solution of differential equations with initial and boundary value problems. |
| **CO5** | Visualize and deal with problems consisting of Hamilton's Principle, Lagrange's Equation, Hamilton's Equation. Variational Problems with Movable boundaries. |

| Unit No. | Title of the Unit | Content of Unit | Contact Hrs. | Mapped CO |
|---|---|---|---|---|
| 1 | Unit 1 | Definitions of functional, Strong and weak variations, Derivations of Euler's Equation, Other forms of Euler's Equation, Special Cases, Examples, Fundamental Lemma of Calculus of Variations. | 8 | CO1 |
| 2 | Unit 2 | The problem of Minimum surface of revolution, Minimum energy problem, Brachistochrone Problem , Variational Notation , Variational Problems involving several functions | 8 | CO2 |
| 3 | Unit 3 | Isoperimetric problems, Examples, Euler's Equations in two independent Variables, Variational Problems in Parametric form, Functional dependent on Higher Order Derivatives, Euler Poisson Equation | 8 | CO3 |
| 4 | Unit 4 | Variation of functional, Euler-Lagranges equation, Necessary and sufficient conditions for extrema, Variational methods for boundary problems in ordinary and partial differential equations | 8 | CO4 |
| 5 | Unit 5 | Application of Calculus of Variation, Hamilton's Principle, Lagrange's Equation, Hamilton's Equation. Variational Problems with Movable boundaries, Simplest problem with movable boundaries, Examples, Problems with movable boundaries for functional of the form $\int (x, y, z, y', z')dx\,dy\,dz$ and $\int (x, y, y', y'')dxdydz$ , Examples | 8 | CO5 |

**Reference Books:**


1. L.Elsgolts: Differential Equation and Calculus Of Variation.

2. W.R.Runde: Integral equations and Applications.

3. Pathan, M.A, Benarji, P.K, Chauraisa, V.B.L, Goyal, M.C: Special Functions and Calculus of variations, Indus Valley Publications, Jaipur, New Delhi, 2004.


**e-Learning Source:**

1. https://www.youtube.com/watch?v=GiPOQC5nYMs
2. https://youtu.be/WPlBrzjI1KI?t=52

**Course Articulation Matrix: (Mapping of COs with POs and PSOs)**

| PO-PSO / CO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PSO1 | PSO2 | PSO3 | PSO4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | **3** | **2** | **1** | **1** | **2** | **2** | **3** | **3** | 3 | 2 | 3 | 3 |
| **CO2** | **3** | **2** | **1** | **1** | **2** | **1** | **3** | **3** | 3 | 2 | 1 | 3 |
| **CO3** | **2** | **2** | **1** | **1** | **2** | **1** | **3** | **3** | 2 | 2 | 3 | 3 |
| **CO4** | **3** | **2** | **2** | **1** | **1** | **1** | **3** | **3** | 3 | 3 | 2 | 3 |
| **CO5** | **3** | **2** | **1** | **1** | **2** | **1** | **3** | **3** | 2 | 3 | 2 | 3 |

**1- Low Correlation; 2- Moderate Correlation; 3- Substantial Correlation**

| | |
|---|---|
| **Name & Sign of Program Coordinator** | **Sign & Seal of HoD** |