Courses Based on Labor Market Driven Policy (LMDP)

for

M.A./ M.Sc. Program in Mathematics

Submitted to

Faculty Board
Institute of Science and Technology
Tribhuvan University

Prepared by
Central Department of Mathematics
Mathematics Subject Committee
Date: - 2082/10/14

S.N	Course Code	Course Name
1	Math 0501	Topology
2	Math 0503	Complex Analysis
3	Math 0504	Algebra
4	Math 0512	Differential Equations
5	Math 0529	Graph Theory and Algorithms
6	Math 0540	Fuzzy Mathematics
7	Math 0542	Mathematical Statistics
8	Math 0502	Measure Theory
9	Math 0511	Functional Analysis
10	Math 0513	Advanced Complex Analysis
11	Math 0514	Differential Geometry
12	Math 0515	Mathematical Programming
13	Math 0516	Functions of Several Variables
14	Math 0520	Linear Algebra
15	Math 0543	Plane Algebraic Curves
16	Math 0545	Fractal Geometry
17	Math 0586	Mathematics for AI

Tribhuvan University

Institute of Science and Technology

1. Profile of the Course:

Course Title: Topology
Course Code: Math 0501
Level: M. A./ M. Sc. (Mathematics)
Nature of the Course: Theory + Tutorial

Credit Value: 5 Credit Hour
Full Marks: 50
Pass Marks: 25
Teaching Hours: 6 Hours / Week

2. Introduction and Rationale of the Course:

Topology is a fundamental branch of mathematics that provides a rigorous framework for understanding the structure of space. It establishes the language for core concepts such as continuity and convergence upon set-theoretic foundations, moving beyond the limitations of distance and measurement. This shifts the study of space from rigid geometry to the abstract relationships between points, such as how they are connected or clustered.

Topology investigates the properties that are invariant under continuous transformations such as bending, stretching, shrinking and twisting but not tearing. It focuses on geometric characteristics that depend on the intrinsic structure of figures rather than its length, size or magnitude. This course introduces the fundamental ideas of general topology including topological spaces, convergence, continuity, separability, compactness, connectedness and their related applications. This course develops students' abstract reasoning and rigorous proof skills, and provides a foundation for algebraic topology. Understanding topology is essential for advanced studies in mathematics and has applications in physics, computer science, and data analysis.
This course is aimed to

- Develop a rigorous understanding of topological structures and methods,
- Develop proof writing and abstract reasoning skills,
- Support students for advanced courses and research in pure and applied mathematics.

This course serves mainly as the interplay between algebra, geometry, and analysis, so it will be a foundation for many advanced mathematics such as Functional Analysis, Differential Equations, Optimization and Machine Learning etc.

3. Assessment Methods and Types:

A. Internal Examination

I. Internal Assessment

- First Terminal Examination

- Second Terminal Examination

II. Class Participation and Discussion

- Attendance
- Viva Voce

III. Individual Assignments

- Homework with Presentation

The internal examination of 20 marks will be conducted by the department of mathematics of related campus and the marks will be submitted to Dean Office, Examination Section IOST, Tribhuvan University, Balkhu, Kathmandu.

A candidate must pass the internal and the final examinations separately.

Marks allocation for the internal examination under the homework category

- Attendance: 2
- First Terminal Examination: 5
- Second Terminal Examination: 5
- Homework with Presentation: 5
- Viva Voce: 3

Marks allocation for the internal examination under the no homework category

- Attendance: 2
- First Terminal Examination: 6
- Second Terminal Examination: 6
- Presentation: 3
- Viva Voce: 3

B. External Assessment /Examination

There will be a final examination of 30 marks for the period of two hours organized by IOST, Dean's Office, Tribhuvan University

4. Unit-Wise Content Details:

Unit	Contents	Allocated Hours
1.	**Topological Spaces and Subspaces:** Topology on a set, Basis and subbasis for a topology, The order topology, The subspace topology	13
2	**Continuous Maps and Product Topology:** Closed sets and limit points, T0, *T*1 and Hausdorff space, Continuous functions, Topological properties, Box and product topology	16
3	**Metric and Quotient Topology:** Metric topology, Continuous maps in metric topology, Quotient maps and quotient topology, Construction of spaces using quotients, Properties preserved under quotient mappings	16
4	**Connectedness and Compactness:** Connected and disconnected spaces, Components and path-connectedness, Compact spaces and open covers, Finite intersection property, Compactness under continuous maps, Limit point and sequential compactness.	16

5	**Countability and Separation Axioms:** First and second countability axioms, Lindelöf spaces, Regular and normal spaces, Urysohn lemma, Tietze extension theorem	14

5. Text/Reference Books:

1. Frederick H. Croom, *Principles of Topology*, Dover Publications, New York, 2016.

2. James Dugundji, *Topology*, Allyn and Bacon, Boston, 1966.

3. John L. Kelley, *General Topology*, Springer-Verlag, New York, 1975.

4. James R. Munkres, *Topology* (2nd ed.), Pearson, Boston, 2017.

Tribhuvan University

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1. Profile of the Course:

Course Title: Measure Theory
Course No: Math 0502
Level: M. A./ M. Sc. (Mathematics)
Nature of the Course: Theory + Tutorials

Credit Value: 5 Credit Hour
Full Marks: 50
Pass Marks: 25
Teaching Hours: 6 Hours / Week

2. Introduction and Rationale of the Course:

Measure Theory is a core area of modern mathematics that extends the classical ideas of length, area, and volume to more general and complex sets. It provides a rigorous foundation for integration, allowing us to define and compute integrals for a wider class of functions than classical Riemann integration permits. This theory is essential in understanding measurable sets and functions, formulating probability spaces, and analyzing Lp spaces in functional analysis. This theory provides a solid foundation for understanding advanced concepts in analysis, probability, and applied mathematics.

This course is aimed to

- Develop a rigorous understanding of measure and its structures and methods,
- Develop proof writing and abstract reasoning skills, and
- Support students for advanced courses and research in pure and applied mathematics.

This course on Measure Theory serves as a bridge between set theory, integration, and functional analysis, providing a basic framework for advanced topics such as Probability Theory, Functional Analysis, Partial Differential Equations, and Machine Learning.

3. Assessment Methods and Types:

A. Internal Examination

I. Internal Assessment
- First Terminal Examination
- Second Terminal Examination

II. Class Participation and Discussion
- Attendance
- Viva Voce

III. Individual Assignments
- Homework with Presentation

The internal examination of 20 marks will be conducted by the department of mathematics of related campus and the marks will be submitted to Dean Office, Examination Section IOST, Tribhuvan University, Balkhu.

A candidate must pass the internal and the final examinations separately.

Marks allocation for the internal examination under the homework category:

- Attendance: 2
- First Terminal Examination: 5
- Second Terminal Examination: 5
- Homework with Presentation: 5
- Viva Voce: 3

Marks allocation for the internal examination under the no homework category:

- Attendance: 2
- First Terminal Examination: 6
- Second Terminal Examination: 6
- Presentation: 3
- Viva Voce: 3

B. External Assessment /Examination

There will be a final examination of 30 marks for the period of two hours organized by IOST, Dean's Office, Tribhuvan University.

4. Unit-Wise Content Details:

Unit	Contents	Allocated Hours
1.	**Algebras and Lebesgue Outer Measure:** Motivation: limitations of Riemann integration, Algebras and σ-algebras of sets, Measures, Measure spaces and examples, Construction of measures, Lebesgue Outer Measure and its properties	12
2	**Measurable sets and Lebesgue Measure:** Measurable sets, Lebesgue measure, Outer and inner approximations of Lebesgue measurable sets, Countable additivity, continuity and Borel- Cantelli Lemma, Non- measurable sets, Cantor set.	13
3	**Lebesgue Measurable Functions:** Measurable functions and examples, Sequential Pointwise Limits and Simple Approximations, Simple and characteristic function, Approximations by simple function, Littlewood's Three Principles, Egoroff's Theorem and Lusin's Theorem.	12
4	**Lebesgue Integration and Convergence Theorem:** Simple functions and Lebesgue integral, Riemann integral versus Lebesgue integral, Properties of the Lebesgue integral, Lebesgue integral of a bounded and non-negative measurable function over a set of finite measure, Lebesgue Dominated	20

	Convergence Theorem, The General Lebesgue Integral, Countable Additivity and Continuity of Integration, The Vitali Convergence Theorem.	
5	**L_p Spaces and Probability Measures:** Norm and Measurable functions in L_p space, Basic properties, Convergence and completeness, Hölder's and Minkowski's inequalities, Probability measures, Probability spaces.	18

5. Text/Reference Books:

1. H. L. Royden, P. Fitzpatrick: Real Analysis, 4th Edition. Pearson, 2010.
2. C. D. Aliprantis, O. Burkinshaw: Principles of Real Analysis, Academic Press, 1998.
3. Walter Rudin: Real and Complex Analysis, Third Edition, McGraw Hill international.
4. C. Swartz: Measure, Integration and Function Spaces, World Scientific, 1994.
5. P. Billingsley: Probability and Measure, 3rd Edition, Wiley, 1995.
6. R. Durrett: Probability: Theory and Examples, 5th Edition, Cambridge University Press, 2019.

Tribhuvan University

Institute of Science and Technology

1. Profile of the Course:

Course Title: Complex Analysis
Course Code: Math 0503
Level: M. A./ M. Sc. (Mathematics)
Nature of the Course: Theory + Tutorial

Credit Value: 5 Credit Hour
Full Marks: 50
Pass Marks: 25
Teaching Hours: 6 Hours / Week

2. Introduction and Rationale of the Course:

Complex analysis is a core subject in pure and applied mathematics, as well as the physical and engineering sciences with surprising practical applications. Complex Analysis, traditionally known as the theory of functions of a complex variable, is the branch of mathematical analysis that investigates functions of complex numbers and its calculus, which enables to describe geometric, algebraic and analytical insights. Central topics-such as analyticity, contour integration, power series, and residues and conformal mappings-reveal deep connections between differentiation and integration, allowing powerful techniques that are not available in real-variable contexts. The subject itself is profounded by beautiful unexpected results such as the Cauchy-Goursat Theorem, Cauchy Integral Theorem, the Maximum Modulus Principle, and the Residue Theorem-which provide conceptual clarity and computational efficiency. These theorems possess many advanced applications, from solving real integrals to modeling fluid flow, electromagnetic fields, and quantum systems. It is helpful in many branches of Mathematics, including Algebraic Geometry, Number Theory, Special Functions, Analytic Combinatorics, and Applied Mathematics, as well as in Physics, including the branches of Hydrodynamics, Thermodynamics, Quantum Mechanics, Astrophysics, and Twistor Theory. By extension, use of Complex Analysis also has applications in Engineering fields such as Nuclear, Aerospace, Mechanical and Electrical Engineering.

This course is aimed to

- Strengthen mathematical foundations by a deep and rigorous understanding of complex functions and their applications,
- Develop powerful computational tools by contour integration, Laurent series and residue calculus,
- Support applications in Physics, Engineering and Pure & Applied Mathematics.

This course serves mainly as the interplay between algebra, geometry, and analysis, so it will be a foundation for many advanced mathematics such as Functional Analysis, Differential Geometry, applications of Fourier and Laplace Transforms, Number Theory and Complex Dynamics.

3. Assessment Methods and Types:

A. Internal Examination

I. Internal Assessment

- First Terminal Examination
- Second Terminal Examination

II. Class Participation and Discussion

- Attendance
- Viva Voce

III. Individual Assignments

- Homework with Presentation

The internal examination of 20 marks will be conducted by the department of mathematics of related campus and the marks will be submitted to Dean Office, Examination Section IOST, Tribhuvan University, Balkhu, Kathmandu.

A candidate must pass the internal and the final examinations separately.

Marks allocation for the internal examination under the homework category

- Attendance: 2
- First Terminal Examination: 5
- Second Terminal Examination: 5
- Homework with Presentation: 5
- Viva Voce: 3

Marks allocation for the internal examination under the no homework category

- Attendance: 2
- First Terminal Examination: 6
- Second Terminal Examination: 6
- Presentation: 3
- Viva Voce: 3

B. External Assessment /Examination

There will be a final examination of 30 marks for the period of two hours organized by IOST, Dean's Office, Tribhuvan University.

4. Unit-Wise Content Details:

Unit	Contents	Allocated Hours
1.	**Elementary Functions in the Complex Plane C:** Linear function, Inversion function, Bilinear function (Implicit form, Mapping of upper half plane), Exponential and logarithmic functions, Trigonometric functions, Hyperbolic functions, Exponent functions, Inverse trigonometric and hyperbolic functions.	10
2	**Integral Calculus in the Complex Plane C:** Contour and contour integrals, Antiderivatives, Cauchy-Goursat theorem, Principle of deformation of contours, Cauchy integral formula and its consequences (Liouville's theorem, Fundamental theorem of algebra, Maximum modulus of functions, Poisson integral formula, Schwartz integral Formula).	18
3	**Sequences and Series in the Complex Plane C:** Convergence sequence and series, Power series, Taylor series, Laurent series, Absolute and uniform convergence of power series, Analytic continuation, Zeros and singular points, Condition under which $f(z) = 0$, Behavior of function near removable and essential singular points.	18

4	**Residue Theory and Applications:** Residues and residue theorem**,** Residue at poles, Applications of residues (Evaluation of improper integrals, Improper integrals involving Sine and Cosine, Definite integrals involving Sine and Cosine, Indented paths, Integration along branch cut), Argument principle and Rouche's theorem, Inverse Laplace transforms.	18
5	**Compactness and Convergence in the Complex Plane C:** Spaces of analytic functions, Spaces of meromorphic functions, The Riemann mapping theorem, The Weierstrass factorization theorem, Factorization of the Sine function, The gamma function, The Riemann zeta function.	11

5. Text/Reference Books:

1. James Watt Brown and Ruel V. Churchill: Complex Variables and Applications, McGraw-Hill Inc, 1996.
2. Eberhard Freitag, Rolf Busam: Complex Analysis, Springer-Verlag, Berlin, Heidelberg, 2005.
3. Serge Lang: Complex Analysis (Fourth Edition), Springer Science Business Media, Inc. 1999.
4. Endre Pap: Complex Analysis through Examples and Exercises, Kluwer Academic Publishers, 1999.
5. John B. Conway: Functions of One Complex Variable (Second Edition), Springer International Student Edition, 2002.

Tribhuvan University

Institute of Science and Technology

1. Profile of the Course:

Course Title: Algebra
Course Code.: Math 0504
Level: M.A./ M.Sc.(Mathematics)
Nature of the Course: Theory + Tutorial

Credit Hours: 5
Full Marks: 50
Pass Mark: 25
Teaching Hours: 6 hours/week

2. Introduction and Rationale of the Course:

Studying abstract algebra is necessary as it develops abstract reasoning and advanced problem-solving skills, provides a rigorous foundation for mathematical research, and reveals the underlying structures common to diverse fields such as computer science, cryptography, and theoretical physics. The subject facilitates the systematic study of general algebraic structures—such as groups, rings, and fields—that unify different mathematical systems and explain fundamental concepts including symmetry and invariance. Through its emphasis on abstraction and logical rigor, abstract algebra strengthens mathematical maturity, enhances proof-writing skills, and serves as a powerful framework for solving both theoretical and applied problems. This course is designed as a one-semester compulsory subject, typically offered in the first or second semester of the M.A./M.Sc. program in Mathematics. Its primary objectives are to equip students with in-depth theoretical knowledge and a strong conceptual foundation necessary for advanced study and research in mathematics, to foster sustained interest and appreciation for algebra and its applications across various mathematical disciplines, to prepare students for teaching mathematics with solid subject expertise, and to provide essential preparation for further study in areas such as number theory and algebraic geometry.

This course is aimed at

- Developing a strong theoretical understanding of fundamental algebraic structures, including groups, rings, and modules.
- Enhancing students' ability to construct, analyze, and present rigorous mathematical proofs.
- Preparing students for advanced study, teaching, and research in mathematics, with an emphasis on both theoretical foundations and computational applications of algebra.

3. Assessment Methods and Types:

A. Internal Examination

I. Internal Assessment

- First Terminal Examination
- Second Terminal Examination

II. Class Participation and Discussion

- Attendance
- Viva Voce

III. Individual Assignments

Homework with Presentation

The internal examination of 20 marks will be conducted by the Department of Mathematics of the related campus, and the marks will be submitted to Dean Office, Examination Section IOST, Tribhuvan University, Balkhu.

A candidate must pass the internal and the final examinations separately.

Marks allocation for the internal examination under the homework category

- Attendance: 2
- First Terminal Examination: 5
- Second Terminal Examination: 5
- Homework with Presentation: 5
- Viva Voce: 3

Marks allocation for the internal examination under the no homework category

- Attendance: 2
- First Terminal Examination: 6
- Second Terminal Examination: 6
- Presentation: 3
- Viva Voce: 3

B. External Assessment /Examination:

There will be a final examination of 30 marks for the period of two hours organized by IOST, Dean's Office, Tribhuvan University.

4. Unit-Wise Content:

Unit	Contents	Allocated Hours
1	**Groups:** Review of general concepts in classical algebraic systems, Generator of an arbitrary group; General Linear Group GLn, Special Linear group SLn, Quaternion group, Klein's four group, Dihedral group, Commutator group.	13
2	**Group Actions:** Group actions, orbits and stabilizers, Orbit-stabilizer Theorem, Conjugacy classes, the class equation, Automorphism, Cauchy's theorem, Sylow's p-subgroups, Sylow's theorems and applications.	16
3	**The Structure of Groups:** Free group, Free abelian group, finitely generated abelian group, finitely presented groups, Fundamental theorem of finitely generated abelian groups.	14

4	**Rings:** Basic recollections of rings, ideals, Polynomial ring, finitely generated ideal, Primitive polynomial, Gauss lemma, Eisenstein criterion, Polynomial rings over commutative rings, Power series ring, Local ring, Rings of quotient and localization, Chinese remainder theorem.	16
5	**Modules:** Modules, Basic concepts, Submodules, Quotient modules, Module homomorphism, finitely generated modules, Exact sequence, Short exact sequence, The Short five lemma, Snake Lemma, Split exact sequence, Localization of modules, Tensor product of modules. Modules over PID.	16

5. Text/Reference Books:

1. D.S. Dummit and R.M. Foote: Abstract Algebra, 3rd Edition, John Wiley & Sons, 2011.
2. Thomas W. Hungerford: Algebra, Springer-Verlag, New York, 1981.
3. I.N. Herstein: Topics in Algebra, 2nd Edition, Wiley, New Delhi, 2006.
4. J.A. Gallian: Contemporary Abstract Algebra, 10th Edition, Cengage, 2021.
5. P.M. Cohn: Basic Algebra, Springer, 2005.
6. Serge Lang: Algebra, Graduate Texts in Mathematics, Springer, 2002.
7. Joseph Rotman: Advanced Modern Algebra, 1st Edition, Prentice Hall, 2002.

Tribhuvan University

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1. Profile of the Course:

Course Title: Functional Analysis
Course Code: Math 0511
Level: M. A./ M. Sc. (Mathematics)
Nature of the Course: Theory + Tutorial

Credit Value: 5 Credit Hour
Full Marks: 50
Pass Marks: 25
Teaching Hours: 6 Hours / Week

2. Introduction and Rationale of the Course:

Functional Analysis is a core subject in pure and applied mathematics, as well as in the physical and engineering sciences, with profound theoretical importance and wide-ranging applications. Functional Analysis, traditionally understood as the study of vector spaces of functions and linear operators acting on them, is a branch of mathematical analysis that investigates infinite-dimensional spaces and the structures that arise from norms, inner products, and topologies. It provides a unifying framework to analyze problems from geometry, algebra, and analysis in both abstract and applied settings.

Central topics-such as normed and Banach spaces, Hilbert spaces, bounded and unbounded linear operators, dual spaces, and spectral theory-reveal deep connections between algebraic structure and analytical behavior. These concepts allow powerful techniques for studying convergence, continuity, and stability, which are not accessible through finite-dimensional analysis alone. The subject is enriched by fundamental results such as the Hahn–Banach Theorem, the Open Mapping Theorem, the Closed Graph Theorem, and the Uniform Boundedness Principle, which provide both conceptual clarity and strong analytical tools.

This course is offered in the first semester of the M.A./M.Sc. mathematics program as a compulsory subject. It aims to provide students with a strong theoretical foundation in Functional Analysis introducing current developments in the field. The subject has wide applications in differential and integral equations, optimization, and control theory, and plays a central role in areas such as Partial Differential Equations, Operator Theory, Probability, and Harmonic Analysis, with significant relevance to Physics and Engineering.

This course is aimed to

- Strengthen mathematical foundations through a rigorous understanding of abstract spaces and linear operators.
- Develop powerful analytical tools for studying infinite-dimensional problems.
- Support applications in Physics, Engineering, and Applied Mathematics.

This course primarily emphasizes the interplay between algebra, geometry, and analysis, serving as a foundational subject for advanced studies such as Operator Theory, Spectral Theory, Partial

Differential Equations, Optimization Theory, Applications of Fourier and Laplace Transforms, and Mathematical Physics.

3. Assessment Methods and Types:

A. Internal Examination

I. Internal Assessment

- First Terminal Examination
- Second Terminal Examination

II. Class Participation and Discussion

- Attendance
- Viva Voce

III. Individual Assignments

- Homework with Presentation

The internal examination of 20 marks will be conducted by the department of mathematics of related campus and the marks will be submitted to Dean Office, Examination Section IOST, Tribhuvan University, Balkhu, Kathmandu.

A candidate must pass the internal and the final examinations separately.

Marks allocation for the internal examination under the homework category

- Attendance: 2
- First Terminal Examination: 5
- Second Terminal Examination: 5
- Homework with Presentation: 5
- Viva Voce: 3

Marks allocation for the internal examination under the no homework category

- Attendance: 2
- First Terminal Examination: 6
- Second Terminal Examination: 6
- Presentation: 3
- Viva Voce: 3

B. External Assessment /Examination

There will be a final examination of 30 marks for the period of two hours organized by IOST, Dean's Office, Tribhuvan University.

4. Unit-Wise Content Details:

Unit	Contents	Allocated Hours
1.	**Metric Spaces and Normed Spaces:** Special classes of sequence and function spaces, Complete and non-complete metric spaces, Normed spaces and properties, Finite dimensional normed spaces and subspaces, Compactness and finite dimension, Related applications.	15
2.	**Linear Operators and Functionals:** Linear operators, Bounded and continuous linear operators, Linear functionals, Linear operators and functionals on finite dimensional spaces, Normed spaces of operators, Dual spaces, Related applications	18

3.	**Inner Product Spaces and Hilbert Spaces:** Inner product spaces, Hilbert spaces and related properties, Orthogonal complements and direct sums, Orthonormal sets and sequences. Related applications	15
4.	**Representation of functional on Hilbert spaces:** Riesz theorem for functional and operators, Hilbert adjoint operator, Self-adjoint operator, Unitary and normal operators, Related applications	15
5.	**Fundamental Theorems:** Zorn's lemma, Hahn-Banach theorem (HBT) in real and complex forms, Banach fixed point theorem, Biare's Category theorems, Related applications	12

5. Text/Reference Books:

1. E. Kreyszig: Introductory Functional Analysis with Applications, John Wiley & Sons, New York, 1978.
2. Walter Rudin: Functional Analysis, McGraw-Hill, New York, 1991.
3. John B. Conway: A Course in Functional Analysis, Springer-Verlag, New York, 1990.
4. C. Goffman and G. Pedrick: First Course in Functional Analysis, Prentice Hall of India, New Delhi, 1987.
5. A. E. Taylor and D. C. Lay: Introduction to Functional Analysis, John Wiley & Sons, New York, 1980.
6. G. Bachman and L. Narici: Functional Analysis, Dover Publications, New York, 2000.
7. F. Riesz and B. Sz. Nagy: Functional Analysis, Dover Publications, New York, 1990.

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1. Profile of the Course:

Course Title: Differential Equations
Course Code: Math 0512
Level: M. A./ M. Sc. (Mathematics)
Nature of the Course: Theory + Tutorial

Credit Value: 5 Credit Hour
Full Marks: 50
Pass Marks: 25
Teaching Hours: 6 Hours / Week

2. Introduction and Rationale of the Course:

Differential equation is one of the fundamental subjects in the field of pure mathematics as well as applied mathematics. It includes both calculus and analysis to describe the natural phenomenon. This subject incorporates the topics like series solution, system of equations, uniqueness and existence theorem, nonlinear theory and boundary value problems. It has many applications such direction field, stability, existence and uniqueness theorem for the real world problem, engineering and modeling of different diseases, population dynamics and other health issues.

This course is aimed to

- Strengthen mathematical foundations by a deep and rigorous understanding of differential equations and their applications in real world,
- Develop different methods of solving differential equations and
- Discuss the nonlinearity and stability
- Discuss and use the existence and uniqueness theorem
- Discuss the boundary value problem

This course serves mainly as the interplay between calculus, geometry, and analysis, so it will be a foundation for many advanced mathematics such as modeling of real world problem and application of theory of analytical subjects in the other field.

3. Assessment Methods and Types:

A. Internal Examination

I. Internal Assessment
- First Terminal Examination
- Second Terminal Examination

II. Class Participation and Discussion
- Attendance
- Viva Voce

III. Individual Assignments
- Homework with Presentation

The internal examination of 20 marks will be conducted by the department of mathematics of related campus and the marks will be submitted to Dean Office, Examination Section IOST, Tribhuvan University, Balkhu.
A candidate must pass the internal and the final examinations separately.
Marks allocation for the internal examination under the homework category

- Attendance: 2
- First Terminal Examination: 5
- Second Terminal Examination: 5
- Homework with Presentation: 5
- Viva Voce: 3

Marks allocation for the internal examination under the no homework category

- Attendance: 2
- First Terminal Examination: 6
- Second Terminal Examination: 6
- Presentation: 3
- Viva Voce: 3

B. External Assessment /Examination
There will be a final examination of 30 marks for the period of two hours organized by IOST, Dean's Office, Tribhuvan University.

4. Unit-Wise Content Details:

Unit	Contents	Allocated Hours
1	**Series Solutions of Second Order Linear Differential Equations:** Review of power series, Series solution near an ordinary point, Regular and singular points, Series solutions near a regular singular point, Gauss hypergeometric equations, Bessel's equation.	15
2	**System of First Order Linear Equations:** Introductory remarks, Linear systems, Homogeneous linear systems with constant coefficients, Solution of systems with matrices and exponentials.	15
3	**The Nonlinear Theory:** Nature of a nonlinear problem, Critical points and stability, Liapunov's direct method, Nonlinear systems, Nonlinear mechanics, Liapunov's second method, Periodic solutions and limit cycles.	15
4	**Boundary Value Problems:** Occurrence of two-point boundary value problems, Strum- Liouville boundary value problems, Non-homogeneous boundary value problem, Singular Strum- Liouville's problems.	15
5	**Existence and Uniqueness Theory:** Introduction, Successive approximations, Picard's existence and uniqueness theorem, Existence of solutions of linear equations, Continuous dependence of solutions.	15

5. Text / Reference Books:

1. William E. Boyce and Richard C. DiPrima: Elementary Differential Equations and Boundary Value Problems, Wiley Student Edition, 2015.
2. George F. Simmons and Seven G. Krantz: Differential Equations Theory, Techniques, and Practice, McGraw Hill Education (India) Private Limited, New Delhi, 2007.
3. R. Kent Nagle, Edward B. Saff and Arther David Snider: Fundamentals of Differential Equations and Boundary Value Problems, Pearson Education, 2012.

Tribhuvan University

Institute of Science and Technology

1. Profile of the Course:

Course Title: Advanced Complex Analysis
Course Code: Math 0513
Level: M. A./ M. Sc. (Mathematics)
Nature of the Course: Theory + Tutorial

Credit Value: 5 Credit Hour
Full Marks: 50
Pass Marks: 25
Periods: 6 Hours / Week

2. Introduction and Rationale of the Course:

Advanced Complex Analysis provides a rigorous and modern continuation of the theory of holomorphic and meromorphic functions begun in a first graduate course: Complex Analysis (Math 0512). The course develops the geometric, algebraic, analytic, and topological structures underlying complex function theory, emphasizing topics such as conformal mappings, normal families, potential theory, analytic continuation, Riemann surfaces, the theory of entire and meromorphic functions and theory of elliptic functions. These themes form the foundation of many areas of contemporary mathematics, from complex geometry and several complex variables to dynamical systems and analytic number theory. The course aims to equip students with both a deeper conceptual understanding of complex analytic phenomena and the technical tools required for advanced research in analysis, algebra and geometry.

Complex analysis occupies a central position in modern mathematics because of its unusually rich interplay between algebra, geometry, analysis, and topology. Many core results, such as the Riemann mapping theorem, the classification of entire functions, and the principles of analytic continuation, elliptic functions and normal families serve as paradigms for techniques used across pure and applied mathematics. At the senior graduate level, students must go beyond basic contour integration and series expansions to understand the structural aspects of holomorphic functions, including normal family theory, harmonic and potential-theoretic methods, the language of Riemann surfaces and profoundness of elliptic function theory.

This course is designed to provide complex analysis knowledge in deeper perspective. It prepares students for research in several complex variables, differential geometry, algebraic geometry, and dynamical systems, while also offering powerful tools relevant to PDE, mathematical physics, and analytic number theory. By emphasizing general principles and modern techniques, the course builds a conceptual toolkit that supports both theoretical exploration and broad mathematical applications.

3. Assessment Methods and Types:

A. Internal Examination

I. Internal Assessment

- First Terminal Examination
- Second Terminal Examination

II. Class Participation and Discussion

- Attendance
- Viva Voce

III. Individual Assignments

- Homework with Presentation

The internal examination of 20 marks will be conducted by the department of mathematics of related campus and the marks will be submitted to Dean Office, Examination Section IOST, Tribhuvan University Balkhu.

A candidate must pass the internal and the final examinations separately.

Marks allocation for the internal examination under the homework category

- Attendance: 2
- First Terminal Examination: 5
- Second Terminal Examination: 5
- Homework with Presentation: 5
- Viva Voce: 3

Marks allocation for the internal examination under the no homework category

- Attendance: 2
- First Terminal Examination: 6
- Second Terminal Examination: 6
- Presentation: 3
- Viva Voce: 3

B. External Assessment /Examination

There will be a final examination of 30 marks for the period of two hours organized by IOST, Dean's Office, Tribhuvan University.

4. Unit-Wise Content Details:

Unit	Contents	Allocated Hours
1	**Conformal Mappings and Geometric Function Theory:** Preservation of angles, Schwartz-Christoffel's transformations, Schwarz lemma, Analytic automorphism of the disc, The upper half plane, Schwarz reflection and its applications, Riemann mapping theorem. Hyperbolic Geometry.	15
2	**Entire and Meromorphic Functions:** Order and type, Jensen's formula, Canonical products & Hadamard factorization, Runge's theorem, Mittag-Leffler's theorem, Infinite product, Blaschke products, Nevanlinna theory (first and second main theorems).	15

3	**Normal Families and Montel Theorem:** Equicontinuity and normal families, Arzela's theorem, Theorems of Montel and Picard, Marty's theorem, Zalcman's lemma, Univalent functions, Iteration of holomorphic functions, Fatou set, Julia set, and Mandelbrot set basics.	15
4	**Harmonic Functions and Potential Theory:** Harmonic functions, Subharmonic functions**,** Order and type of subharmonic functions in the plane C, Green functions and harmonic measure, Introduction to potential theory. Capacity theory and applications.	15
5	**Elliptic Functions:** Elementary properties, Weierstrass $\wp$-function, Weierstrass ς and σ $-$functions, Jacobi elliptic functions, Theta functions, Modular functions, The field of elliptic functions, The addition theorem, Abel's theorem, The elliptic modular group, The ring of theta functions.	15

5. Text/Reference Books:

1. Lars V. Ahlfors: Complex Analysis, McGraw-Hill, Inc. 1979.
2. Theodore W. Gamelin: Complex Analysis, Springer-Verlag, New York Inc. 2001.
3. Serg Lang: Complex Analysis (Fourth Edition), Springer, New York, 1999.
4. Elias M. Stein and Rami Shakarchi: Complex Analysis, Princeton University Press, USA, 2003.
5. John B. Conway: Functions of One Complex Variable (Second Edition), Springer International Student Edition, 2002.
6. Stanford L. Segal: Nine Introductions in Complex Analysis, Elsevier, 2008.
7. E. B. Freitag and Rolf Busam: Complex Analysis, Springer-Verlag, Berlin, 2005.
8. L. Carleson and T. W. Gamelin: Complex Dynamics, Springer-Verlag Inc., New York, Berlin, Tokyo, 1992.

Tribhuvan University

Institute of Science and Technology

1. Profile of the Course:

Course Title: Differential Geometry
Course Code: Math 0514
Level: M. A./ M. Sc. (Mathematics)
Nature of course: Theory + Tutorial

Credit Value: 5 Credit Hour
Full Marks: 50
Pass Marks: 25
Periods: 6 Hours / Week

2. Introduction and Rationale of the Course:

Differential geometry is the core subject which deals with the combination of calculus and geometry.
It deals basically with the space curves, fundamental triads, fundamental forms, geodesics and surface theory. By going through these topics, a student can learn about the relation between the calculus with classical geometry. It has many applications in real world problem and theoretical concepts can be visualized with the help of software.
This course is aimed to

- Strengthen mathematical foundations by a deep and rigorous understanding of differential geometry and their applications in real world,
- Develop different approaches to get idea of curves and surfaces and
- Discuss the surface theory and geodesics

This course serves mainly as the interplay between calculus, geometry, and analysis, so it will be a foundation for many advanced mathematics such as modeling of real-world problem and application of theory of analytical subjects in the other field.

3. Assessment Methods and Types:

A. Internal Examination

I. Internal Assessment

- First Terminal Examination
- Second Terminal Examination

II. Class Participation and Discussion

- Attendance
- Viva Voce

III. Individual Assignments

- Homework with Presentation

The internal examination of 20 marks will be conducted by the department of mathematics of related campus and the marks will be submitted to Dean Office, Examination Section IOST, Tribhuvan University, Balkhu.
A candidate must pass the internal and the final examinations separately.

Marks allocation for the internal examination under the homework category:

- Attendance: 2
- First Terminal Examination: 5
- Second Terminal Examination: 5
- Homework with Presentation: 5
- Viva Voce: 3

Marks allocation for the internal examination under the no homework category:

- Attendance: 2
- First Terminal Examination: 6
- Second Terminal Examination: 6
- Presentation: 3
- Viva Voce: 3

B. External Assessment /Examination

There will be a final examination of 30 marks for the period of two hours organized by IOST, Dean's Office, Tribhuvan University.

4. Unit-Wise Content Details:

Unit	Contents	Allocated Hours
1	**Theory of Space Curves:** Arc length, tangent, normal and binormal, curvature and torsion of the general curve, curvature and torsion of the general curve given as the intersection of two surfaces, involutes and evolutes, fundamental existence theorem for the space curves, helices, Bertrand curves.	20
2	**Local Intrinsic and Non-intrinsic Property of a Surface:** Surface, curves on surface and surface of revolution, family of curves and direction coefficients, isometric correspondence, intrinsic property, metric and property, second fundamental forms, relation between the fundamental forms, principal curvatures and lines of curvature.	15
3	**Geodesics:** Geodesics, canonical geodesic equations, normal property of geodesics, existence theorem, geodesic parallels, geodesic curvature, Gauss Bonnet theorem, Gaussian curvature, conformal mappings.	20
4	**Envelopes and Developable:** Developable, developable associated with a space curve, developable associated with a space curve on a surface, minimal surface, ruled surface.	10
5	**Fundamental Equation of Surface Theory** Fundamental equations of surface theory, parallel surface, fundamental existence theorem for surfaces.	10

5. Text / Reference Books:

1. Weather Bern, CE: Differential Geometry (ELBS), Cambridge, 1955.
2. Mantredo P. do Carmo: Differential Geometry of Curves and Surfaces, Prentice Hall, 1976.
3. T. J. Willmore: An Introduction to Differential Geometry, Oxford University Pres, 1959.

Tribhuvan University

Institute of Science and Technology

1. Profile of the Course:

Course Title: Mathematical Programming
Course Code: Math 0515
Level: M. A./ M. Sc.(Mathematics)
Nature of the Course: Theory and Computation

Credit Value: 5 Credit Hour
Full Marks: 50
Pass Marks: 25
Working Hours: 6 Hours/Week

2. Introduction and Rationale of the Course:

Mathematical Programming (Math 0515) has been designed as a graduate course in optional category which introduces the modeling of mathematical programming problems, as well as the theory and methodology for solving constrained and unconstrained convex and nonlinear programming problems. Some of their computational results are also obtained.
This course is aimed to

- Understand and connect the skillful real-life problems as optimization problems.
- Formulate mathematical programming problems.
- Solve unconstrained and constrained convex and non-linear programming problems.
- Understand and implement algorithms related to mathematical programming.
- Apply the idea of mathematical optimization in other subject areas programming problems.

The course enhances knowledge, proof design skill of theorems, modeling skill, problem-solving skill, algorithm design skill and computational skill. This will enrich the competencies in the pertaining area.

3. Assessment Methods and Types:

A. Internal Examination

IV. Internal Assessment

- First Terminal Examination
- Second Terminal Examination

V. Class Participation and Discussion

- Attendance
- Viva Voce

VI. Individual Assignments

- Homework with Presentation

The internal examination of 20 marks will be conducted by the department of mathematics of related campus and the marks will be submitted to Dean Office, Examination Section IOST, Tribhuvan University, Balkhu, Kathmandu.

A candidate must pass the internal and the final examinations separately.
Marks allocation for the internal examination under the homework category:

- Attendance: 2
- First Terminal Examination: 5
- Second Terminal Examination: 5
- Homework with Presentation: 3
- Viva Voce: 3

Marks allocation for the internal examination under the no homework category:

- Attendance: 2
- First Terminal Examination: 6
- Second Terminal Examination: 6
- Presentation: 3
- Viva Voce: 3

B. External Assessment /Examination

There will be a final examination of 30 marks for the period of two hours organized by IOST, Dean's Office, Tribhuvan University

4. Unit-Wise Content Details:

Unit	Contents	Allocated Hours
1	**Modeling and Polyhedral Geometry:** Ingredients and formulation techniques for real-life optimization problems, Classification of optimization problems, Characterization and existence of extreme points and extreme directions, Representation theory in polyhedral geometry Feasibility and complementary slackness conditions in duality, Computational frameworks of related examples.	15
2	**Convex Programming:** Basics on convex programming, Minima and maxima of convex functions, modeling convex problems using real-life examples, Design and analysis of algorithms.	15
3	**The Fritz John and Karush-Kuhn-Tucker Optimality Conditions:** Unconstrained problems, Problems with inequality constraints, Problems with inequality and equality constraints, Selected numerical methods	15
4	**Lagrangian duality, Saddle point optimality conditions:** Lagrangian dual problem, Duality theorems and saddle point optimality conditions, Properties of the dual function, Formulating and solving the dual problem, Getting the primal solution, Analysis of algorithms.	15
5.	**Algorithmic Optimization and Implementation:** Complexity results of simplex, dual simplex methods, Selected algorithms to solve the convex, unconstrained and constrained nonlinear programming problems, Algorithms in solving real-life problems	15

5. Text/Reference Books:

1. Bazaraa, M. S., Sherali, H. D. and Shetty, C. M., *Nonlinear Programming: Theory and Algorithms*, John Wiley & Sons, New York, 2010.
2. Luenberger, D. G. and Ye, Y., *Linear and Nonlinear Programming*, Springer, New York, 2008.
3. Nocedal, J. and Wright, S. J., *Numerical Optimization*, Springer, New York, 2006.

Tribhuvan University

Institute of Science and Technology

1. Profile of the Course:

Course Title: Functions of Several Variables
Course Code: Math 0516
Level: M. A./ M. Sc. (Mathematics)
Nature of the Course: Theory + Tutorials

Credit Value: 5 Credit Hour
Full Marks: 50
Pass Marks: 25
Teaching Hours: 6 Hours / Week

2. Introduction and Rationale of the Course:

The study of functions of several variables is fundamental to modern mathematics and its applications. This course provides a rigorous treatment of differential and integral calculus in multiple dimensions, emphasizing both theoretical foundations and practical applications. Topics range from topology of Euclidean spaces and continuity to differentiation, integration, differential forms, and optimization methods.

This course is essential for students pursuing advanced studies in mathematics, physics, engineering, and data science. It develops the analytical skills needed to model multivariate phenomena in fields such as thermodynamics, fluid dynamics, economics, and machine learning. The rigorous approach, following Spivak's *Calculus on Manifolds*, prepares students for research in analysis, geometry, and applied mathematics.

This course is aimed to

- Strengthen mathematical foundations through rigorous understanding of multivariate calculus,
- Develop computational tools for optimization, integration on manifolds, and machine learning applications, and
- Support applications in physics, engineering, data science, and applied mathematics.

This course serves as a bridge between classical analysis and modern geometry, providing a foundation for advanced mathematics such as Differential Geometry, Functional Analysis, PDEs, and applications in Machine Learning and Optimization**.**

3. Assessment Methods and Types:

A. Internal Examination

I. Internal Assessment
- First Terminal Examination
- Second Terminal Examination

II. Class Participation and Discussion:
- Attendance
- Viva Voce

III. Individual Assignments:

- Homework with Presentation

The internal examination of 20 marks will be conducted by the department of mathematics of related campus and the marks will be submitted to Dean Office, Examination Section IOST, Tribhuvan University, Balkhu.

A candidate must pass the internal and the final examinations separately.

Marks allocation for the internal examination under the homework category:

- Attendance: 2
- First Terminal Examination: 5
- Second Terminal Examination: 5
- Homework with Presentation: 5
- Viva Voce: 3

Marks allocation for the internal examination under the no homework category:

- Attendance: 2
- First Terminal Examination: 6
- Second Terminal Examination: 6
- Presentation: 3
- Viva Voce: 3

B. External Assessment /Examination

There will be a final examination of 30 marks for the period of two hours organized by IOST, Dean's Office, Tribhuvan University.

4. Unit-Wise Content Details:

Unit	Contents	Allocated Hours
1.	**Function of Several Variables:** Definition of function of several variables, domain and range of function of several variables, its uses in Population Dynamics, Newton's Law of Cooling, Orthogonal Trajectories, Economics, Optimization; review of Euclidean n-space, norm, inner product, Cauchy-Schwarz inequality, functions from $\mathbb{R}^n$ to $\mathbb{R}^m$, limits, continuity; oscillation of the function, differentiation, inverse and implicit function theorems. Jacobian matrix, constant rank theorem**.**	10
2	**Integration:** Integration on rectangles, lower/upper sums. Measure zero, Fubini's Theorem, partitions of unity. Change of Variables Theorem, Sard's Theorem. Applications to polar/spherical coordinates**.**	15
3	**Differential Forms and Integration**: Tensors, alternating tensors, wedge product. Differential forms on $\mathbb{R}^n$, exterior derivative. Integration on chains, Stokes' Theorem on chains. Classical theorems as special cases (Green, Gauss, Stokes).	15
4	**Manifolds and Integration on Manifolds:** Smooth manifolds in $\mathbb{R}^n$ (definitions, examples). Tangent space, derivative map between manifolds. Differential forms on manifolds, integration on manifolds. Orientability and Volume Forms, Stokes' Theorem on manifolds (statement and applications).	20

5	**Applications of Functions of Several Variables in Optimization and Machine Learning:** Foundations and Unconstrained Optimization, Advanced Unconstrained Methods, Constrained Optimization - Theory, Linear and Quadratic Programming, Penalty and Barrier Methods, Applications in Machine Learning (Neural networks, Kernel methods, Manifold learning).	15

5. Text/Reference Books:

1. Spivak, M., *Calculus on Manifolds*, Benjamin/Cummings, New York, 1965.
2. Folland, G. B., *Advanced Calculus*, Prentice Hall, Upper Saddle River, NJ, 2002.
3. Deisenroth, M. P., *Mathematics for Machine Learning*, Cambridge University Press, Cambridge, 2020.
4. Nocedal, J. and Wright, S. J., *Numerical Optimization*, 2nd Edition, Springer, New York, 2006.
5. Lee, J. M., *Introduction to Smooth Manifolds*, 2nd Edition, Springer, New York, 2003.

Tribhuvan University

Institute of Science and Technology

1. Profile of the Course:

Course Title: Linear Algebra	Credit Hours: 5
Course No.: Math 0520	Full Marks: 50
Level: M.A./ M.Sc.(Mathematics)	Pass Mark: 25
Nature of the Course: Theory + Tutorial	Teaching Hours: 6 Hours/week

2. Introduction and Rationale of the Course:

Studying linear algebra is necessary because it provides the foundational tools for many advanced fields, such as machine learning, computer graphics, and physics, and is a core requirement for most technical disciplines. It allows for the efficient modeling and solving of complex systems, even those that are nonlinear, by using linear approximations. A strong understanding of its principles is also essential for critical thinking, problem-solving, and developing logical reasoning skills. It is useful in technical and scientific fields like approximating complex problems, machine learning, physics, engineering, and computer science. It is the foundation for other mathematics and logic. It develops critical skills, and in a broader sense, it is the problem-solving toolkit. This course is designed for the first year, first semester of the M.A./M.Sc program as an optional subject in mathematics. The main objectives of this course are to enable the students to develop in-depth knowledge and a good theoretical background in linear algebra to take up higher studies, to sustain interest and enjoyment of linear algebra and its applications in various branches of mathematics, to get associated with teaching mathematics with strong content, and to be familiar with recent trends in the field of linear algebra.

The course is aimed at enabling students to

- Develop a strong theoretical foundation in advanced Linear Algebra, focusing on abstract structures like dual spaces and quotient spaces.
- Understand the structure of linear transformations and vector spaces through canonical forms and decomposition theorems, including the link between Jordan forms and modules over a PID.
- Apply Linear Algebra concepts to other branches of mathematics, such as using the Spectral Theorem in geometry and the JCF in differential equations.
- Use Linear Algebra as a problem-solving toolkit in applied fields, including data science and machine learning (via PCA).
- Gain familiarity with modern topics and trends such as Singular Value Decomposition (SVD), Moore–Penrose inverse, and best low-rank matrix approximations.

- Develop proficiency in proof-based reasoning and formal mathematical communication to prepare for independent research or advanced teaching

3. Assessment Methods and Types:

A. Internal Examination:

I. Internal Assessment:
- First Terminal Examination
- Second Terminal Examination

II. Class Participation and Discussion:
- Attendance
- Viva Voce

III. Individual Assignments:

Homework with Presentation

The internal examination of 20 marks will be conducted by the Department of Mathematics of the related campus, and the marks will be submitted to the Dean examination section, IOST, Tribhuvan University, Balkhu. A candidate must pass the internal and the final examinations separately.

Marks allocation for the internal examination under the homework category:
- Attendance: 2
- First Terminal Examination: 5
- Second Terminal Examination: 5
- Homework with Presentation: 5
- Viva Voce: 3

Marks allocation for the internal examination under the no homework category:
- Attendance: 2
- First Terminal Examination: 6
- Second Terminal Examination: 6
- Presentation: 3
- Viva Voce: 3

B. External Assessment /Examination:

There will be a final examination of 30 marks for the period of two hours, organized by IOST, dean office, Tribhuvan University.

4. Unit-Wise Content Details:

Unit	Contents	Allocated Hours
1	**Linear Transformations and Matrices:** Review of vector spaces, Direct sum, Similarity, Linear transformations and matrices; Dual spaces, Annihilation, Quotient vector spaces, Isomorphism theorems, Rank-nulity theorem.	12

2	**Diagonalization:** Eigenvalues and eigenvectors, multiplicity, Linear Operator, Nilpotent operator, Diagonalization, T-invariant subspaces, T-cyclic subspaces, Minimal polynomial, Cayley-Hamilton theorem.	15
3	**Bilinear and Quadratic Forms:** Inner product spaces. Bilinear forms, Quadratic forms, Tensor product, Unitary and orthogonal operators, Sylvester's law, Symmetric form, Eigenvectors of symmetric linear operators, The spectral theorem. Conics and quadrics.	18
4	**Canonical Forms:** Jordan canonical form (JCF) I and II, Rational canonical form, Application of JCF $x' = Ax$, Smith normal form.	15
5	**SVD and its Applications:** Singular values, SVD Theorem, Moore–Penrose inverse, the Polar decomposition, PCA, and Best low-rank matrix approximation.	15

5. Text/Reference Books:

1. Friedberg, S. H., Insel, A. J. and Spence, L. E., *Linear Algebra*, 4th Edition, PHI Learning, New Delhi, 2013.
2. Artin, M., *Algebra*, Pearson Prentice Hall, New Jersey, 2011.
3. Strang, G., *Linear Algebra and Learning from Data*, Wellesley–Cambridge Press, Wellesley, 2019.
4. Boehm, J., *Computer Algebra*, Lecture Notes, 2020.
5. Axler, S., *Linear Algebra Done Right*, Springer-Verlag, New York, 2015.
6. Kowalski, E., *Linear Algebra*, Lecture Notes, ETH Zurich, 2024.
7. Lang, S., *Linear Algebra*, Addison-Wesley Publishing Company, Reading, 1987.

Tribhuvan University

Institute of Science and Technology

1. Profile of the Course:

Course Title: Graph Theory and Algorithms
Course Code: Math 0529
Level: M. A./ M. Sc.(Mathematics)
Nature of the Course: Theory and Computation

Credit Value: 5 Credit Hour
Full Marks: 50
Pass Marks: 25
Working Hours: 6 Hours/Week

2. Introduction and Rationale of the Course:

Graph Theory and Algorithms (Math 0529) has been designed as a graduate course in optional category which introduces the fundamental concepts of graph theory, some algorithms based on graph theory and their performance, combinatorial and optimization problems which can be described as applications of graph theory.

This course is aimed to

- Understand the basic notions of undirected and directed graphs relevant to combinatorial optimization.
- Understand algorithmic complexity NP-hardness, and principles of algorithm design.
- Understand and implement algorithms related to distances in digraphs and optimization problems.
- Apply graph-theoretic concepts to network flow partitioning, and assignment problems.
- Develop skills in designing and implementing graph algorithms for real-life combinatorial optimization applications.

The course enhances knowledge, proof design skill of theorems, modeling skill, problem-solving skill, algorithm design skill and computational skill. This will enrich the competencies in the pertaining area.

3. Assessment Methods and Types:

A. Internal Examination

VII. Internal Assessment

- First Terminal Examination
- Second Terminal Examination

VIII. Class Participation and Discussion

- Attendance
- Viva Voce

IX. Individual Assignments:

- Homework with Presentation

The internal examination of 20 marks will be conducted by the department of mathematics of related campus and the marks will be submitted to Dean Office, Examination Section IOST, Tribhuvan University, Balkhu, Kathmandu.

A candidate must pass the internal and the final examinations separately.

Marks allocation for the internal examination under the homework category

- Attendance: 2
- First Terminal Examination: 5
- Second Terminal Examination: 5
- Homework with Presentation: 5
- Viva Voce: 3

Marks allocation for the internal examination under the no homework category

- Attendance: 2
- First Terminal Examination: 6
- Second Terminal Examination: 6
- Presentation: 3
- Viva Voce: 3

B. External Assessment /Examination

There will be a final examination of 30 marks for the period of two hours organized by IOST, Dean's Office, Tribhuvan University

4. Unit-Wise Content Details:

Unit	Contents	Allocated Hours
1	**Fundamentals of Directed and Undirected Graphs:** Directed and undirected graphs, Paths, cycles, trees, Connectedness, Euler tours and Hamilton cycles, Graph applications in combinatorial optimization, Algorithm for graph representation	13
2	**Algorithms and Complexity:** Space and time complexity, Representations of graphs, Problem reduction techniques, Graph decision problems, Developing polynomial-time algorithms, Approximation and heuristic methods, Design of search algorithms.	14
3	**Combinatorial Optimization Problems and Algorithms Related to Graphs:** Shortest path problem - label-setting algorithm and label-correcting algorithm, Maximum flow problem - flow augmenting, labeling and polynomial algorithms, Design and analysis of algorithms	16
4	**Coloring and Matching:** Coloring problems, Coloring algorithms, Matching problems, Matching algorithms, Weighted matching, Computing the bipartite matching.	16

5.	**Graph Computing and Implementation:** Design of selected polynomial time graph algorithms and relevant graph applications, Analysis of selected polynomial time graph algorithms and relevant graph applications	16

5. Text/Reference Books:

1. Papadimitriou, C. H. and Steiglitz, K., *Combinatorial Optimization: Algorithms and Complexity*, Prentice Hall of India, New Delhi, 1997.
2. Ahuja, R. K., Magnanti, T. L. and Orlin, J. B., *Network Flows: Theory, Algorithms, and Applications*, Prentice Hall, New Jersey, 2013.
3. Jungnickel, D., *Graphs, Networks and Algorithms*, Springer-Verlag, Berlin, 2013.

Tribhuvan University

Institute of Science and Technology

1. Profile of the Course:

Course Title: Fuzzy Mathematics
Course Code: Math 0540
Level: M. A./ M. Sc. (Mathematics)
Nature of the Course: Theory + Tutorials

Credit Value: 5 Credit Hour
Full Marks: 50
Pass Marks: 25
Teaching Hours: 6 Hours / Week

2. Introduction and Rationale of the Course:

Studying fuzzy mathematics is necessary because it provides tools for modeling uncertainty, vagueness, and imprecision in real-world systems. It extends classical set theory and logic to handle incomplete or ambiguous information, with applications in artificial intelligence, control systems, decision analysis, data science, and engineering. A strong understanding of fuzzy mathematics is essential for developing intelligent systems, optimizing processes under uncertainty, and enhancing logical reasoning in complex environments.

This course is designed as an elective subject for the M.A./M.Sc. program. The main objectives are to enable students to develop in-depth knowledge of fuzzy set theory, fuzzy logic, fuzzy analysis, fuzzy topology, and their applications; to foster analytical and computational skills; and to prepare students for research, teaching, or industry roles involving fuzzy systems.

This course is aimed to:

- Strengthen mathematical foundations through rigorous understanding of fuzzy mathematics,
- Develop computational tools for uncertainty modeling, decision analysis, and artificial intelligence applications, and
- Support applications in control systems, engineering, data science, and applied mathematics.

This course serves as a bridge between classical mathematics and modern uncertainty modeling, providing a foundation for advanced topics such as Soft Computing, Artificial Intelligence, Decision Theory, and applications in Machine Learning and Control Systems.

3. Assessment Methods and Types:

A. Internal Examination

I. Internal Assessment

- First Terminal Examination
- Second Terminal Examination

II. Class Participation and Discussion

- Attendance
- Viva Voce

III. Individual Assignments:

- Homework with Presentation

The internal examination of 20 marks will be conducted by the department of mathematics of related campus and the marks will be submitted to Dean Office, Examination Section IOST, Tribhuvan University, Balkhu.

A candidate must pass the internal and the final examinations separately.

Marks allocation for the internal examination under the homework category:

- Attendance: 2
- First Terminal Examination: 5
- Second Terminal Examination: 5
- Homework with Presentation: 5
- Viva Voce: 3

Marks allocation for the internal examination under the no homework category:

- Attendance: 2
- First Terminal Examination: 6
- Second Terminal Examination: 6
- Presentation: 3
- Viva Voce: 3

B. External Assessment /Examination

There will be a final examination of 30 marks for the period of two hours organized by IOST, Dean's Office, Tribhuvan University.

4. Unit-Wise Content Details:

Unit	Contents	Allocated Hours
1.	**Foundations of Fuzzy Sets and Numbers:** Classical set review, fuzzy sets, membership functions, operations (t-norms, t-conorms). Extension principle. Fuzzy numbers: Types (triangular, trapezoidal), arithmetic, and equations.	15
2	**Fuzzy Relations, Logic, and Reasoning:** Composition, properties (equivalence, ordering). Fuzzy logic: Linguistic variables, connectives, inference methods (Mamdani, T-S), and approximate reasoning**.**	15
3	**Fuzzy Analysis and Calculus:** Metric spaces of fuzzy sets. Fuzzy functions: Continuity, differentiation (Hukuhara and gH-derivative), Fuzzy integrals: Sugeno integral, Introduction to fuzzy differential equations**.**	20
4	**Fuzzy Topology and Advanced Structures:** Fuzzy points and Q-neighborhoods. Fuzzy topological spaces (Chang's definition), interior, closure, continuity. Compactness and connectedness. Brief overview of separation axioms and applications in digital topology**.**	15

5	**Synthesis and Applications:** Defuzzification methods. Fuzzy control systems (design and stability). Fuzzy decision-making and pattern recognition. Case studies integrating analysis (FDEs) and topology (spatial reasoning).	10

5. Text/Reference Books:

1. Lir, G. J., & Yuan, B. (2013). *Fuzzy Sets and Fuzzy Logic: Theory and Applications*. Prentice Hall.
2. Zimmermann, H. J. (1996). *Fuzzy Set Theory and Its Applications*. Allied Publishers.
3. Diamond, P., & Kloeden, P. (1994). *Metric Spaces of Fuzzy Sets: Theory and Applications*. World Scientific.
4. Chang, C. L. (1968). *Fuzzy Topological Spaces*. Journal of Mathematical Analysis and Applications.
5. Lee, H. K. (2005). *First Course on Fuzzy Theory and Applications*. Springer.

Tribhuvan University

Institute of Science and Technology

Profile of the Course:

Course Title: Mathematical Statistics
Course Code: Math 0542
Level: M.A/ M.Sc. (Mathematics)
Nature of the Course: Theory + Tutorials

Credit Value: (5 Credit)
Full Marks: 50
Pass Marks: 50
Teaching Hours: 6 Hours/Week

2. Introduction and Rationale of the Course:

Mathematical Statistics is a fundamental course designed to equip Master's students with the rigorous probabilistic foundation and theoretical tools necessary for modern statistical inference. The course covers the construction and analysis of probabilistic models, the properties of sampling distributions, and the core methodologies for point estimation, confidence interval construction, and hypothesis testing, including a measure-theoretic approach to probability.

3. Assessment Methods and Types:

A. Internal Assessment

- First Terminal Examination
- Second Terminal Examination

- **Class Participation and Discussion**
  - Attendance
  - Viva Voce
- **Individual Assignments**
  - Homework with Presentation

The internal examination of 20 marks will be conducted by the department of mathematics of related campus and the marks will be submitted to Dean Office, Examination Section IOST, Tribhuvan University, Balkhu.
A candidate must pass the internal and the final examinations separately.
Marks allocation for the internal examination under the homework category:

- Attendance: 2
- First Terminal Examination: 5
- Second Terminal Examination: 5
- Homework with Presentation: 5
- Viva Voce: 3

Marks allocation for the internal examination under the no homework category:

- Attendance: 2
- First Terminal Examination: 6
- Second Terminal Examination: 6
- Presentation: 3
- Viva Voce: 3

B. External Assessment /Examination

There will be a final examination of 30 marks for the period of two hours organized by IOST, Dean's Office, Tribhuvan University.

4. Unit-Wise Content Details:

Unit	Contents	Allocated Hours
1	**Basic Concepts from Probability Theory:** Conditional probability and independence, random variables, density/mass functions, expected values, moments and moment generating functions, probabilistic models in statistical inference, random variable functions in risk analysis and insurance modeling.	10
2	**Common families of Distributions:** Discrete and continuous distributions, exponential families, Probability inequalities and identities, modeling real-world data, application of probability inequalities in concentration results and bounding estimation error.	12
3	**Properties of random sample:** Sums of random variables, sampling from normal distributions, convergence concepts (in probability, almost sure, in distributions), central limit theorem, law of the large numbers and their applications, approximation of sampling distributions for confidence intervals and hypothesis testing, generating a random sample.	16
4	**Statistical Inference (Estimation & Testing):** Point estimation (method of moments, MLE), properties of estimators (unbiasedness, consistency, efficiency, asymptotic properties), confidence intervals, Type I/II errors, power, Neyman–Pearson lemma, likelihood ratio tests, tests based on normal, χ^2 , t, and F distributions.	22
5	**Probability measure and integration:** Probability spaces, probability measures, outer measure and Carathéodory extension, construction of probability measures on $\mathbb{R}$ random variables and measurability, integration with respect to a probability measure, important Integration Theorems, use of integration for computing moments/covariance/correlation, derivation of probability inequalities (Markov, Chebyshev, Jensen, Hölder).	15

5. Text/Reference Books:

1. Casella, G. and Berger, R. L., *Statistical Inference*, 2nd Edition, Cengage Learning, Belmont, CA, 2002.
2. Ross, S. M., *A First Course in Probability*, 10th Edition, Pearson, Harlow, 2019.
3. Billingsley, P., *Probability and Measure*, 3rd Edition, John Wiley & Sons, New York, 1995.

Tribhuvan University

Institute of Science and Technology

1. Profile of the Course:

Course Title: Plane Algebraic Curves
Course Code: Math 0543
Level: M. A./ M. Sc (Mathematics)
Nature of the Course: Theory + Tutorial

Credit Value: 5 Credit Hours
Full Marks: 50
Pass Marks: 25
Teaching Hours: 6 Hours / Week

2. Introduction and Rationale of the Course:

Plane algebraic curves constitute one of the oldest and most fundamental subjects in algebraic geometry. The modern theory blends techniques from commutative algebra and complex analysis, and a natural entry point into higher-dimensional algebraic geometry, arithmetic geometry, and complex geometry. This course introduces students to the systematic study of affine and projective curves, their intersection multiplicities, and the corresponding Riemann-Roch theorem. These concepts form the basis for further study in algebraic geometry, arithmetic geometry, and related areas. The course is essential for graduate students preparing for research in algebraic geometry.

This course is aimed at

- Developing a strong theoretical understanding of plane algebraic curves.
- Constructing and presenting rigorous mathematical proofs in the context of algebraic geometry.
- Performing explicit computations involving affine and projective curves, including intersection multiplicities.
- Applying classical and modern techniques to problems in algebraic geometry.
- Building a solid foundation for further study and research in algebraic geometry, arithmetic geometry, and complex geometry.

3. Assessment Methods and Types:

A. Internal Examination:

I. Internal Assessment:

- First Terminal Examination
- Second Terminal Examination

II. Class Participation and Discussion:

- Attendance
- Viva Voce

III. Individual Assignments:

- Homework with Presentation

The internal examination of 20 marks will be conducted by the department of mathematics of related campus and the marks will be submitted to Dean Office, Examination Section IOST, Tribhuvan University, Balkhu.

A candidate must pass the internal and the final examinations separately.

Marks allocation for the internal examination under the homework category:

- Attendance: 2
- First Terminal Examination: 5
- Second Terminal Examination: 5
- Homework with Presentation: 5
- Viva Voce: 3

Marks allocation for the internal examination under the no homework category:

- Attendance: 2
- First Terminal Examination: 6
- Second Terminal Examination: 6
- Presentation: 3
- Viva Voce: 3

B. External Assessment /Examination:

There will be a final examination of 30 marks for the period of two hours organized by IOST, Dean's Office, Tribhuvan University.

4. Unit-Wise Content Details:

Unit	Contents	Allocated Hours
1	**Affine and Projective Curves**: Plane affine curves, Projective plane and projective space, Homogeneous coordinates Tangency, multiplicity, and singular points.	14
2	**Intersection Multiplicities:** Definition and elementary properties, Local rings and passage from affine to projective curves, Algorithms for computing intersection multiplicities, Examples involving conics and cubics.	15
3	**Classical Theorems:** Sum of intersection multiplicities and Nullstellensatz, Bézout's theorem and Max Noether's theorem, Applications to plane algebraic curves.	15
4	**Divisors and Linear Systems:** Coordinate rings and rational functions, Multiplicities and local coordinates divisors, principal divisors, and Picard group, Linear systems.	15
5	**Riemann--Roch Theory:** Riemann's theorem and algebraic genus, Canonical divisor, Riemann--Roch theorem, Applications to elliptic curves.	16

5. Text/Reference Books:

1. Gathmann, Andreas: Plane Algebraic Curves. Lecture Notes, TU Kaiserslautern, 2023.
2. Fulton, William: Algebraic Curves: An Introduction to Algebraic Geometry. Benjamin, New York, 1969.
3. Kunz, Ernst: Introduction to Plane Algebraic Curves. Springer, 2005.
4. Kirwan, Frances: Complex Algebraic Curves. London Mathematical Society Student Texts, Vol. 23, Cambridge University Press, 2nd edition, 1992.
5. Silverman, Joseph H: The Arithmetic of Elliptic Curves. Springer-Verlag, New York, 2nd edition, 2009.
6. Eisenbud, David; Harris, Joe: The Practice of Algebraic Curves: A Second Course in Algebraic Geometry. Vol. 250, American Mathematical Society (AMS), 2024.
7. Hartshorne, Robin: Algebraic Geometry. Springer-Verlag, New York, 1977.

Tribhuvan University

Institute of Science and Technology

1. Profile of the Course

Course Title: Fractal Geometry
Course Code: Math 0545
Level: M. A./ M. Sc. (Mathematics)
Nature of the Course: Theory + Computational

Credit Value: 5 Credit Hour
Full Marks: 50
Pass Marks: 25
Teaching Hours: 6 Hours / Week

2. Introduction and Rationale of the Course

Studying fractal geometry is essential because it provides mathematical frameworks for understanding irregular, fragmented, and infinitely complex structures found throughout nature and science. It extends classical geometry and measure theory to analyze objects with non-integer dimensions, with applications in dynamical systems, geometric measure theory, signal processing, computer graphics, and physics. A deep understanding of fractal mathematics is crucial for modeling complex phenomena, analyzing chaotic systems, and developing algorithms in data science and image processing.

This course is designed as a core/elective subject for the M.A./M.Sc. Mathematics program. The main objectives are to enable students to master dimension theory, iterated function systems, multifractal analysis, and their mathematical foundations; to develop both theoretical proof techniques and computational simulation skills; and to prepare students for research, academia, or applied roles involving complex geometric structures.

This course is aimed to:

- Strengthen mathematical foundations through rigorous understanding of fractal geometry,
- Develop computational tools for fractal generation, dimension calculation, and analysis, and
- Support applications in physics, engineering, computer graphics, and data science.

This course serves as a bridge between classical geometry and modern analysis, providing a foundation for advanced mathematics such as Geometric Measure Theory, Dynamical Systems, Complex Analysis, and applications in Computer Graphics and Data Science.

3. Assessment Methods and Types

A. Internal Examination:

I. Internal Assessment:

- First Terminal Examination: 5
- Second Terminal Examination: 5

II. Class Participation and Discussion:

- Attendance: 2
- Viva Voce: 3

III. Individual Assignments:

- Homework with Presentation: 5

The internal examination of 20 marks will be conducted by the department of mathematics of related campus and the marks will be submitted to Dean Office, Examination Section IOST, Tribhuvan University, Balkhu.

A candidate must pass the internal and the final examinations separately.

Marks allocation for the internal examination under the homework category:

- Attendance: 2
- First Terminal Examination: 5
- Second Terminal Examination: 5
- Homework with Presentation: 5
- Viva Voce: 3

Marks allocation for the internal examination under the no homework category:

- Attendance: 2
- First Terminal Examination: 6
- Second Terminal Examination: 6
- Presentation: 3
- Viva Voce: 3

B. External Assessment /Examination:

There will be a final examination of 30 marks for the period of two hours organized by IOST, Dean's Office, Tribhuvan University.

4. Unit-Wise Content Details:

Unit	Contents	Allocated Hours
1.	**Dimension Theory:** Historical development from integer to fractal dimensions. Topological dimension: inductive definition, covering dimension. Hausdorff dimension: Hausdorff measure definition, properties (monotonicity, countable stability), calculation methods. Box-counting dimension: definition, computational algorithms, equivalence conditions. Packing dimension.	15
2	**Iterated Function Systems and Self-Similarity:** Contraction mappings. Hutchinson operator and attractors. Collage theorem. Open Set Condition. Dimension formulas for self-similar sets. Graph-directed IFS. Affine IFS and self-affine sets. Computational aspects and rendering.	10
3	**Geometric Measure Theory on Fractals:** Density theorems. Tangents and rectifiability. Marstrand's projection theorem, Energy integrals and capacity, Fourier transforms and fractals, Porosity and intersection properties.	15

4	**Multifractal Analysis:** Local dimension and dimension spectrum. Gibbs measures on fractals. Multifractal formalism and $f(\alpha)$ spectrum, Thermodynamic formalism, Analysis of binomial measures on Cantor sets.	20
5	**Applications:** Fractals in dynamical systems (Julia sets, attractors), Random fractals and percolation, Fractals in number theory, Applications to physics, engineering, and data science**.**	15

5. Text/Reference Books:

1. Falconer, K. J. (2014). *Fractal Geometry: Mathematical Foundations and Applications* (3rd ed.). Wiley.
2. Edgar, G. A. (2008). *Measure, Topology, and Fractal Geometry* (2nd ed.). Springer.
3. Mattila, P. (1995). *Geometry of Sets and Measures in Euclidean Spaces*. Cambridge University Press.
4. Pesin, Y. B. (1997). *Dimension Theory in Dynamical Systems*. University of Chicago Press.
5. Mandelbrot, B. B. (1982). *The Fractal Geometry of Nature*. W. H. Freeman.

Tribhuvan University

Institute of Science and Technology

1. Profile of the Course

Course Title: Mathematics for AI
Course Code: Math 0586
Level: M. A./ M. Sc (Mathematics)
Nature of the Course: Theory + Computational + Project

Credit Value: 5 Credit Hours
Full Marks: 50
Pass Marks: 25
Teaching Hours: 6 Hours / Week

2. Introduction and Rationale of the Course

Artificial Intelligence (AI) is advancing at an extraordinary pace, posing both challenges and opportunities for mathematics. As these systems increasingly influence science, industry, and society, there is a growing need to rigorously understand the mathematical structures that underpin modern AI methodologies. This course provides the mathematical foundations of artificial intelligence, covering linear algebra, optimization, probability, and learning algorithms, with strong links to modern AI applications. This course is devoted to the systematic study of the mathematics behind machine learning algorithms, optimization methods, and probabilistic models that form the core of artificial intelligence. By developing a solid theoretical foundation, students will gain a clear understanding of how modern AI systems work and will be prepared to explore further study or research in this rapidly developing field.

This course is aimed at

- Critically evaluating AI systems for performance, fairness, and ethical considerations.
- Developing a rigorous understanding of the mathematical foundations of AI.
- Connecting mathematical theory with computational practice by implementing algorithms.
- Understanding and implementing machine learning algorithms.

3. Assessment Methods and Types

A. Internal Examination:

I. Internal Assessment:
- First Terminal Examination
- Second Terminal Examination

II. Class Participation and Discussion:
- Attendance
- Viva Voce

III. Individual Assignments:
Homework with Presentation

IV. Project cum internship

The internal examination of 30 marks will be conducted by the Department of Mathematics of the related campus, and the marks will be submitted to the Dean Office, Examination Section IOST, Tribhuvan University, Balkhu.
A candidate must pass the internal and the final examinations separately.
Mark's allocation for the internal examination under the homework category:

- Attendance: 2
- First Terminal Examination: 5
- Second Terminal Examination: 5
- Homework: 5
- Viva Voce: 3
- Project: 10

B. External Assessment /Examination:
There will be a final examination of 20 marks for the period of two hours, organized by the IOST, Dean's Office, Tribhuvan University.

Remarks: The modality of evaluation of this course for Homework and Presentation of 5 marks and Project work / Field visits / Internships / Practices / Practical work of 10 marks will be made on the basis of the nature of course in detail and submitted for the approval to IOST, TU, Faculty Board.

4. Unit-Wise Content Details:

Unit	Contents	Allocated Hours
1.	**Basic Concept of Artificial Intelligence:** Defining AI and intelligence, Historical evolution: symbolic AI, ML, neural networks, AI paradigms: symbolic, statistical, network-based, Modern AI: supervised, unsupervised, deep learning, emerging paradigms, Ethics for AI.	12
2	**Foundational Mathematics:** Vectors as data points and feature spaces, Eigenvalues, eigenvectors, spectral decomposition, Singular Value Decomposition (SVD), positive definite matrices, quadratic forms, Matrix calculus, Convexity analysis; sets and functions: gradient descent, stochastic gradient descent.	16
3	**Probability and Information Theory:** Probability spaces, Bayes' theorem, Random variables: discrete and continuous, Joint, marginal, conditional distributions, Multivariate Gaussian for continuous data modeling, Statistical inference: Maximum Likelihood Estimation, Bayesian inference, information theory: entropy, KL divergence, mutual information.	15
4	**Learning Algorithms:** Supervised learning: SVM, kernel tricks, regression, and classification, Unsupervised learning: clustering (K-means, hierarchical), Dimensionality reduction: PCA.	18

5	**Deep Learning and Modern AI:** Natural Neural Networks, Artificial Neural Networks, Forward and Backpropagation, Regularization techniques, Convolutional Neural Networks (CNNs), Generative AI, Transformers: BERT, GPT, and LLMs, diffusion-based models: DALL-E, Stable diffusion.	14

5. Text/Reference Books:

1. Strang, Gilbert: Linear Algebra and Learning from Data. Wellesley--Cambridge Press, 2019.
2. Boyd, Stephen P. Vandenberghe, Lieven: Convex Optimization. Cambridge University Press, Cambridge, 2004.
3. Hastie, Trevor; Tibshirani, Robert; Friedman, Jerome: The Elements of Statistical Learning: Data Mining, Inference, and Prediction. 2nd edition, Springer Series in Statistics, Springer, 2009.
4. Goodfellow, Ian; Bengio, Yoshua; Courville, Aaron: Deep Learning. MIT Press, Cambridge, MA, 2016.
5. Petersen, Kaare Brandt; Pedersen, Michael Syskind: The Matrix Cookbook. Technical University of Denmark. Available at: \url{https://www.math.uwaterloo.ca/~hwolkowi/matrixcookbook.pdf}
6. Deisenroth, Marc Peter; Faisal, A. Aldo; Ong, Cheng Soon: Mathematics for Machine Learning. Cambridge University Press, 2020.
7. Turner, Richard E. An Introduction to Transformers. arXiv preprint arXiv:2304.10557, 2023. Available at: \url{https://arxiv.org/abs/2304.10557}.
8. Nielsen, Michael A: Neural Networks and Deep Learning. Determination Press, 2015.
9. McCulloch, Warren S.; Pitts, Walter: A logical calculus of the ideas immanent in nervous activity. Bulletin of Mathematical Biophysics, Vol. 5, No. 4, pp. 115--133, 1943.
10. Stuart J. Russell and Peter Norvig: Artificial Intelligence A Modern Approach, Third Edition, Pearson, 2016.
11. Stanford University HAI: AI Index Report 2025. Stanford Institute for Human-Centered AI (HAI), 2025.

Note on Supplemental Materials: Given the rapid evolution of Artificial Intelligence, instructors are encouraged to supplement core texts with recent peer-reviewed publications and technical reports to ensure the curriculum reflects current state-of-the-art developments.