Course Description for MATH 601

Course #: **MATH 601**	Course Title: **Theory of Ordinary Differential Equations and Applications (1)**
Prerequisite: **---**	Teaching Language: **English**
Course Level: **First Year**	Credit Hours: **3**

Course Description

Solving first order linear systems ODEs. The fundamental Theorem of first order linear systems. Stability Theory of first order linear systems. Theory of the existence and uniqueness of solutions to first order nonlinear systems of ODEs with respect to parameters and initial conditions. Equilibrium and Linearization of nonlinear systems of ODEs. Stability of nonlinear dynamical systems. Liapunov Method of nonlinear systems. Pre-Predator and coexistence models.

Course Objectives

- To introduce linear systems of 1^{st} order ODEs and their matrix representation.
- To prove the fundamental theorem of linear systems of 1^{st} order ODEs by the exponential of operators
- To understand the various cases of linear systems of 1^{st} order ODEs in the plane.
- To be able to solve linear systems of 1^{st} order ODEs having complex or multiple eigenvalues.
- To learn how to apply stability theorems of linear systems of 1^{st} order ODEs.
- To prove the fundamental existence-uniqueness theorem of nonlinear systems of 1^{st} order ODEs.
- To understand the concepts of maximal interval, flow defined by DEs, stable manifold theorem and Hartman-Grobman Theorem.
- To grasp stability by Liapunov functions.

Course Outcomes

Upon successful completion of the course, the student shall be able to:

- Solve linear systems of 1st order ODEs having complex or multiple eigenvalues.
- Apply stability theorems to linear systems of first order ODEs
- Deal with the various cases of linear systems of 1st order ODEs in the plane.
- Find the stable and unstable manifolds of nonlinear systems of 1st order ODEs.
- Prove the stability by using appropriate Liapunov functions.
- Apply linearization and stability to nonlinear systems of 1st order ODEs.

Textbooks and References

Title	Author	Publisher	Year
Differential equations and Dynamical systems	Lawrence Perko	Springer	2008
Differential equations, A Dynamical system Approach	Hubbard, John H. West, Beverly H.	Springer	2014

Course Contents

Topics	# of lectures	# of weeks
– Uncoupled linear systems and diagonalization	2	1
– Exponential of Operators	2	1
– The Fundamental Theorem for linear systems	2	1
– Linear systems in the plane	2	1
– Complex Eigenvalues	2	1
– Multiple Eigenvalues	2	1
– Stability Theorem – Non-homogeneous Linear Systems	2	1
– Some Preliminary Concepts and Definitions	2	1
– The Fundamental Existence-Uniqueness Theorem – Dependence on ICs and Parameters	2	1
– The Maximal Interval of Existence – The flow Defined by a Differential Equations	2	1
– Linearization – Stable Manifold Theorem	2	1
– The Hartman-Grobman Theorem – Stability and Liapunov Functions	2	1
– Saddles, Nodes, Foci and Centers – Nonhyperbolic Critical Points in the plane	2	1
– Pre-Predators and Coexistence Models	2	1

Teaching Strategies and Assessments

Outcomes	Teaching Strateg-ies	Learning activities	Assess-ments	Evalu-ation
Evaluate various problems of linear systems by exponential of operators.	Lectures	Exercises, Discussion	Home Works	Final Exams
Evaluate various problems of linear systems in the plane.	Lectures	Exercises, Discussion	Home Works	Final Exams
Applying Stability Theorem to linear systems.	Lectures	Exercises, Discussion	Home Works	Final Exams
Applying the linearization method to various nonlinear systems.	Lectures	Exercises, Discussion	Home Works	Final Exams
Evaluating the stable and unstable manifolds of nonlinear systems.	Lectures	Exercises, Discussion	Home Works	Final Exams
Applying the theory of nonlinear systems to Pre-Predator models.	Lectures	Exercises, Discussion	Home Works	Final Exams

Course Description for MATH 697

Course #: **MATH 697**	Course Title: **Selected Topics in Mathematics**
Prerequisite: **Successfully completing 9 credit hours**	Teaching Language: **English**
Course Level: **Second Year**	Credit Hours: **3**

Course Description

Certain mathematics subjects chosen by the instructor and not to be part of the contents of the courses offered by the Department.

Course Description for MATH 676

Course # and code: **MATH 676**	**Course Title: Applied Graph Theory**
Prerequisite: ---	Teaching Language: **English**
Course Level: **Second Year**	Credit Hours: **3**

Course Description

This course aims to introduce students to a variety of different concepts of graph theory, it includes: graphs, connected graphs, some special classes of graph such as (paths, cycles, wheels, regular, complete, partite, …, etc), degrees of vertices, degree sequences, adjacency and incident matrices, isomorphic graphs, trees, connectivity, Menger's Theorem, Eulerian and Hamiltonian graphs, planarity, dual graphs, coloring of vertices(edges, maps), Operations on graphs such as union, addition, and some types of products as (Cartesian, direct, strong), Ramsey numbers, and extremal graphs and Turan's Theorem.

Course Objectives

This course aims to:

- Introduce students to many concepts and definitions used in graph theory.
- Introduce students to different classes of graphs.
- Introduce students to some operations on graphs such as union, addition, and some types of products.
- Develop the ability of students to solve (prove) some simple and complex problems (theorems) in graph theory.
- Introduce students to some open problems in some subjects such as Ramsey numbers and extremal graphs.

Course Outcomes

Upon successful completion of the course, the student shall be able to:

- understanding of the basic definitions, concepts, and theorems in graph theory.
- classify graphs according to their classes, such as connected, planar, non-planar, Eulerian, Hamiltonian … etc.
- master finding degree sequences, adjacency and incidence matrices, connectivity, vertex (edge, map) colorability, and dual graphs.
- find Ramsey numbers for some graphs.
- provide solutions (proofs) of some simple and complex problems (Theorems) in graph theory.

Textbooks and References

Title	Author	Publisher	Year
Introduction to graph theory	Gary Chartrand and Ping Zhang	McGraw Hill	2005
Introduction to graph theory	Douglas B. West	Prentice Hall	2001
Introduction to graph theory	By Robin J. Wilson	Prentice Hall	2010

Course Contents

Topics	# of lectures	# of Weeks
Chapter 1 **Introduction to graphs, Degrees** Basic definitions and examples, connected graphs, classes of graphs, degrees of vertices, regular graphs and degree sequences	8	4
Chapter 2 **Isomorphic Graphs, Trees** Definitions and basic properties. Isomorphism as a relation. Basic definitions and examples. Bridges and spanning trees.	6	3
Chapter 3 **Connectivity and Traversability** Definitions and basic theory, cut vertices, Eulerian graphs, Hamiltonian graphs.	4	2
Chapter 4 **Planarity and duality** Planar graphs, Basic definitions, Examples and basic properties and dual graphs.	4	2
Chapter 5 **Coloring** Definition and Basic Theory, vertex coloring, edge coloring and the 4- color theorem.	4	2
Chapter 6 **Ramsey Numbers and Extremal Graphs** The basic theory of Ramsey numbers, and Turans Theorem	4	2

Teaching Strategies and Assessments

Outcomes	Teaching Strategies	Learning activities	Assess-ments	Evalu-ation
Show understanding of the basic definitions, concepts, and theorems in graph theory.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Be able to classify graphs according to their classes, such as connected, planar, non-planar, Eulerian, Hamiltonian, ..,etc.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Master finding degree sequences, adjacency and incidence matrices, connectivity, vertex (edge, map) colorability, and dual graphs.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Find Ramsey numbers for some graphs.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Provide solutions (proofs) of some simple and complex problems (Theorems) in graph theory.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams

Course Description for MATH 672

Course #: **MATH 672**	Course Title: **Advanced Mathematical Methods (2)**
Prerequisite: **---**	Teaching Language: **English**
Course Level: **Second Year**	Credit Hours: **3**

Course Description

Numerical linear algebra, Matrix definiteness, Matrix factorizations (Crout and Doolittle LU, Cholesky LL^T ,QR, SVD). Applications. Constrained optimization: Characterization, Linearly constrained optimization, Linear programming, Quadratic programming, Nonlinear constrained optimization. Unconstrained optimization methods, First derivative methods, Second derivative methods, Nonderivative methods. Nonlinear programming, Penalty function methods, Barrier function methods.

Course Objectives

- Understand matrix definiteness and different matrix factorizations.
- Use of matrix factorizations to solve different types of problems of applied nature.
- Recognize constrained optimization problems and learn different methods of solving them.
- Recognize unconstrained optimization problems and learn different methods of solving them.
- Understand the concept of linear and nonlinear programming and learn different methods of solving such problems.
- Learn to compare different methods and skills that suit for solving different types of optimization problems.

Course Outcomes

Upon successful completion of the course, the student shall be able to:

- Have good understanding of matrix factorizations and using them.
- Demonstrate understanding of different methods of solving constrained optimization problems.
- Demonstrate understanding of different methods of solving unconstrained optimization problems.
- Characterize an optimization problem and determine appropriate methods for solving them.
- Have ability of solving different types of applied nature from.

Course Contents

Topics	# of lectures	# of weeks
Numerical Linear Algebra - Quick review of undergraduate numerical linear algebra - Matrix definiteness - Matrix factorization. LU, LLT, QR, SVD - Some applications	8	4
Constrained Optimization - Characterization - Linearly constrained optimization, LP, QP - Nonlinearly constrained optimization	8	4
Unconstrained Optimization - Characterization - First derivative methods - Second derivative methods - Nonderivative methods	8	4
Nonlinear Programming - The penalty function method - The barrier function methods	6	3

Teaching Strategies and Assessments

Outcomes	Teaching Strategies	Learning activities	Assessm-ents	Evalu-ation
Understanding of matrix factorizations and using them.	Lectures	Exercises, Discussion	Projects Homeworks	Exams
Understanding of different methods of solving constrained optimization problems.	Lectures	Exercises, Discussion	Projects Homeworks	Exams
Understanding of different methods of solving unconstrained optimization problems.	Lectures	Exercises, Discussion	Projects Homeworks	Exams
Characterize an optimization problem and determine appropriate methods for solving them.	Lectures	Exercises, Discussion	Projects Homeworks	Exams
Ability of solving different types of applied nature from.	Lectures	Exercises, Discussion	Projects Homeworks	Exams

Textbooks and References

Title	Author	Publisher	Year
Matrix Computations	G. Golub and C. Van Loan	John Hopkins University Press	2012
Practical Methods of Optimization	R. Fletcher	John Wiley	2000
Practical Optimization	P. Gill and W. Murray	Emerald Publishing	1982
Operations Research: An Introduction	Hamdy Taha	Pearson Education	2007

Course Description for MATH 671

Course #: **MATH 671**	Course Title: **Advanced Mathematical Methods (1)**
Prerequisite: **----**	Teaching Language: **English**
Course Level: **Second Year**	Credit Hours: **3**

Course Description

Introduction to integral equations, classification of integral equations, integral transformations, some applications of integral equations, Voltera and Fredholm integral equations of the first and second kind, techniques to solve Voltera and Fredholm integral equations of first and second kind, theoretical results about the existence and uniqueness of the solution of the integral equations.

Course Objectives

- To let the students know the integral equations and to classify them.
- To let the students know some models related to the integral equations.
- To let the students know Voltera integral equations of the first and second kind, and to let him know how to solve them.
- To let the students know Fredholm integral equations of the first and second kind, and to let him know how to solve them.
- Understand and prove some theorems related to the existence and uniqueness of the solution of the integral equations.

Course Outcomes

Upon successful completion of the course, the student shall be able to:

- Understand Voltera integral equations of the first and second kind, and to let him know how to solve them.
- Understand Fredholm integral equations of the first and second kind, and to let him know how to solve them.
- Modeling some real problems into integral equations.
- Prove some Theorems related to the existence of solutions of an integral equation.

Course Contents

Topics	# of lectures	# of weeks
Chapter 1 Introduction to Integral Equations 1.1- Various Problems as Integral Equations 1.2- Classifications of Integral Equations 1.3- Some Important Identities and Basic Definitions 1.4- Fourier and Laplace Transforms	6	3
Chapter 2 Modeling of Problems as Integral Equation 2.1- Population Dynamics 2.3- Mechanics Problem 2.4- Initial Value Problem Reduced to Voltera Integral Equation 2.5- Boundary value Problems Reduced to Fredholm Integral	6	3

Equation		
Chapter 3 Voltera Integral Equations 3.1- Voltera Equation of the Second Kind. 3.2- Voltera Equation of the First Kind	6	3
Chapter 5 Fredholm Integral Equations 5.1- Fredholm Integral Equation with Degenerate Kernel 5.2- Fredholm Integral Equation with Symmetric Kernel 5.3- Fredholm Integral Equation of Second Kind 5.4- Fredholm Integral Equation of First Kind	8	4
Chapter 6 Existence of the Solution of the Integral Equations 6.1- Preliminaries 6.2- Fixed Point Theorem of Banach Space	2	1

Teaching Strategies and Assessments

Outcomes	Teaching Strategies	Learning activities	Assessm-ents	Evalu-ation
Understand Voltera integral equations of the first and second kind, and to let him know how to solve them.	Lectures	Exercises, Discussion	Exams Quizzes assignments	Final Exams
Understand Fredholm integral equations of the first and second kind, and to let him know how to solve them.	Lectures	Exercises, Discussion	Exams Quizzes assignments	Final Exams
Modeling some real problems into integral equations.	Lectures	Exercises, Discussion	Exams Quizzes assignments	Final Exams
Prove some Theorems related to the existence of solutions of an integral equation.	Lectures	Exercises, Discussion	Exams Quizzes assignments	Final Exams

Textbooks and References

Title	Author	Publisher	Year
An Introduction to integral Equations with Applications.	A. Jerri	Wiley-Interscience	1999
Linear and nonlinear Integral Equations: Methods and Applications.	Abdul-Majid Wazwaz	Springer	2011
Integral Equations and their applications	M. Rahman	WITpress	2007
A First Course in integral Equations	Abdul-Majid Wazwaz	World Scientifi	2015

Course Description for MATH 665

Course #: **MATH 665**	Course Title: **Dimension Theory**
Prerequisite: **MATH 661**	Teaching Language: **English**
Course Level: **Second Year**	Credit Hours: **3**

Course Description

The concept of inductive dimension of topological space X, Small inductive dimension ind(X), Large inductive dimension lnd(X), Lebesgue covering dimension of a topological space X, Basic properties and the connection between ind, lnd, and dim , Subspaces, dimension of compactifications, Strongly zero-dimensional spaces, Results on products, Unions and sums in dimension theory.

Course Objectives

- Study the inductive dimension of topological space X .
- Study the small inductive dimension ind(X).
- Study the large inductive dimension lnd(X).
- Study the Lebesgue covering dimension of a topological space X.
- Study the basic properties and the connection between ind, lnd, and dim.
- Study the subspaces.
- Study the dimension of compactifications.
- Study the strongly zero-dimensional spaces.
- Study some results on products.
- Study the unions and sums in dimension theory.

Course Outcomes

Upon successful completion of the course, the student shall be able to:

- learn the inductive dimension of topological space X.
- deal with small and large inductive dimension.
- deal with Lebesgue covering dimension of a topological space X.
- learn basic properties and the connection between ind, lnd, and dim.
- deal with subspaces.
- learn the dimension of compactifications.
- deal with the strongly zero-dimensional spaces.
- deal with the unions and sums in dimension theory.

Textbooks and References

Title	Author	Publisher	Year
Dimension Theory	Witold, Wallman, and Hurewicz	Princeton University Press	1968
Standard Treatise on Classical Dimension Theory	Malcolm	Princeton Mathematical Series	2008

Course Contents

Topics	# of lectures	# of weeks
– Inductive dimension of topological space X	4	2
– Small inductive dimension ind(X)	4	2
– Large inductive dimension lnd(X)	4	2
– Lebesgue covering dimension of a topological space X	4	2
– Basic properties and the connection between ind, lnd, and dim	4	2
– Subspaces	2	1
– Dimension of compactifications	2	1
– Strongly zero-dimensional spaces	2	1
– Some results on products	2	1
– Unions and sums in dimension theory	2	1

Teaching Strategies and Assessments

Outcomes	Teaching Strategies	Learning activities	Assessm -ents	Evalu- ation
Have the ability to deal with the inductive dimension of topological space X.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Have the ability to deal with small and large inductive dimension.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Have the ability to deal with Lebesgue covering dimension of a topological space X.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Have the ability to deal with the basic properties and the connection between ind, lnd, and dim.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Have the ability to deal with subspaces.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Have the ability to deal with the dimension of compactifications	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Have the ability to deal with the strongly zero-dimensional spaces.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Have the ability to deal with unions and sums in dimension theory.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams

Course Description for MATH 664

Course #: **MATH 664**	Course Title: **Algebraic Topology II**
Prerequisite: **MATH 663**	Teaching Language: **English**
Course Level: **Second Year**	Credit Hours: **3**

Course Description

More about singular homology, Abstract simplicial complexes, The homology of CW-complexes. The Eilenberg - Steenrod axioms. Poincare's duality. Applications on the fixed point theorem. The Lefschetz fixed point theorem. Eilenberg – Zilber Theorem, Kunneth formula, Fibration, Cohomology groups, Cohomology rings, Computations and applications.

Course Objectives

- To understand the singular homology.
- To introduce abstract simplicial complexes.
- To calculate the homology of CW-complexes.
- To understand the Eilenberg - Steenrod axioms and Poincare's duality.
- To give applications about fixed point theorem.
- To prove some theorems like Lefschetz fixed point theorem. Eilenberg – Zilber Theorem.
- To introduce cohomology groups and cohomology rings.
- To compute some cohomology groups.

Course Outcomes

Upon successful completion of the course, the student shall be able to:

- Understand the singular homology groups.
- Introduce abstract simplicial complexes.
- Calculate the homology of CW-complexes.
- Understand the Eilenberg - Steenrod axioms and Poincare's duality.
- Give applications about fixed point theorem.
- Prove some theorems like Lefschetz fixed point theorem. Eilenberg – Zilber Theorem.
- Introduce cohomology groups and cohomology rings.
- Compute some cohomology groups.

Textbooks and References

Title	Author	Publisher	Year
An Introduction to Algebraic Topology	J. Rotman	Springer-Verlag	1988
Introduction of Topology and geometry	S. Stahl	john Wiley	2005
Topology	J. R. Munkres	Prentice Hall	2000

Course Contents

Topics	# of lectures	# of weeks
More about Singular Homology - Simplicial complexes - Some definitions. - Simplicial approximation. - Simplicial homology. - Comparison with singular homology	8	4
CW-complexes - Quotient spaces. - CW-complexes.	6	3
Main Theorems - Eilenberg - Steenrod axioms. - Poincare's duality. - Lefschetz fixed point theorem. - Eilenberg – Zilber Theorem - Kunneth formula	10	5
Cohomology - **Error! Not a valid link.**. - Applications.	6	3

Teaching Strategies and Assessments.

Outcomes	Teaching Strategies	Learning activities	Assessm -ents	Evalu-ation
Understanding the singular homology, and homotopy axiom	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Introduce abstract simplicial complexes and simplicial homology.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Calculate the homology of CW-complexes.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Understand and prove the Eilenberg -Steenrod axioms and Poincare's duality.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Give applications about fixed point theorems.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Proof Lefschetz fixed point theorem and Eilenberg – Zilber Theorem.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Introduce cohomology groups and cohomology rings.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Compute some cohomology groups	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams

Course Description for MATH 663

Course #: **MATH 663**	Course Title: **Algebraic Topology**
Prerequisite: **---**	Teaching Language: **English**
Course Level: **Second Year**	Credit Hours: **3**

Course Description

Homotopy theory, Fundamental group, Covering spaces, the fundamental group of some surfaces, Applications. Singular homology, the homotopy axiom, the Hurewicz theorem, Exact homology sequences, the singular homology group, Reduced homology, Mayer-Vietoris sequences, Homology of some surfaces, Simplicial complexes, CW-complexes.

Course Objectives

- To introduce the concept of homotopy.
- To calculate the fundamental group of several surfaces and curves.
- To give some applications about surfaces.
- To introduce the singular homology.
- To understand the axiom of homotopy.
- To prove some theorems like Hurewicz theorem.
- To understand the exact homology sequences and reduced homology.
- To calculate the homology of some surfaces.

Course Outcomes

Upon successful completion of the course, the student shall be able to:

- Define homotopy, path homotopy, punctured plane, fundamental group, first homotopy group.
- Calculate the fundamental group of several surfaces and carves with some applications.
- Introduce the singular homology.
- Understand the axiom of homotopy.
- Find the exact homology sequences and reduced homology of the surfaces.
- Apply Mayer-Vietoris sequences.
- Introduce CW-complexes.

Course Contents

Topics	# of lectures	# of weeks
The Fundamental Group - Introduction, the fundamental groupoid.	4	2
Functors - The Functor π_1.	2	1
Covering Spaces - Covering map, local homeomorphism, torus, figure eight space.	4	2
More about the Fundamental Group - The first fundamental group of some surfaces. - Applications.	4	2

Singular Homology - The singular complex. - Homology Functors. - Homotopy axiom. - The Hurewicz theorem.	6	3
Exact Sequences - The category Comp - Exact homology sequences. - Reduced homology.	6	3
Applications - Mayer-Vietoris sequences. - Homology of some surfaces. - Simplicial complexes. - CW-complexes.	4	2

Teaching Strategies and Assessments

Outcomes	Teaching Strategies	Learning activities	Assess m-ents	Evalu-ation
Define homotopy, path homotopy, punctured plane, fundamental group, first homotopy group.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Calculate the fundamental group of several surfaces and carves with some applications.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Introduce the singular homology.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Understand the axiom of homotopy.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Find the exact homology sequences and reduced homology of the surfaces	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Apply Mayer-Vietoris sequences. Introduce CW-complexes.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams

Textbooks and References

Title	Author	Publisher	Year
An Introduction to Algebraic Topology	J. Rotman	Springer-Verlag	1988
Introduction of Topology and geometry	S. Stahl	john Wiley	2005
Topology	J. R. Munkres	Prentice Hall	2000

Course Description for MATH 662

Course #: **MATH 662**	Course Title: **Advanced General Topology II**
Prerequisite: **MATH 661**	Teaching Language: **English**
Course Level: **Second Year**	Credit Hours: **3**

Course Description

Compactifications, the Stone-Cech compactification. Metrizabillity, Urysohn's metrization theorem, Full normality and Stone's coincidence theorem, Alexandroff-Urysohn metrization theorem, Nagata smirnov metrization theorem, Bing's metrization theorem of Moore spaces, Moore metrization theorem. Uniform spaces, Uniform topology, Uniform covers, Operations on Uniform spaces, Uniform continuity, Uniformization, Metrizabillity of Uniform spaces, Totally bounded and complete Uniform spaces, completion. Function spaces, pointwise convergence, Uniform convergence, Uniform metric, compact open topology, Equicontinuity and compactness of spaces of functions, The stone-Weierstrass theorem.

Course Objectives

- Constructing the Stone-Cech compactification.
- Stating several metrization theorems.
- Constructing uniform spaces.
- Constructing functions spaces.
- Constructing and studying the topology of pointwise convergence.
- Constructing and studying the topology of uniform convergence.
- Studying some basic operations on uniform spaces.

Course Outcomes

Upon successful completion of the course, the student shall be able to:
- Have good skills in metrizable spaces.
- Apply definitions and theorems in finding the relationships between spaces.
- Have the ability to deal with new topologies.
- Determine characterizations of certain spaces.
- Finding the relationships between certain spaces.
- Finding different types of topologies.
- Shown the ability of working independently and with groups.

Textbooks and References

Title	Author	Publisher	Year
General Topology	Ryszarad Engelking	Heldermann Verlag	1989
General Topology	Stephen Willard	Addison-Wesley Publishing Company	1970
Counterexamples in Topology	L. A. Steen, J. A. Seebach. Jr	Holt, Rinehart and Winston	1978

Course Contents

Topics	# of lectures	# of weeks
Compact spaces - Compactifications - Stone-Cech compactification. Neighborhood systems	2	1
Metrization spaces - Metrizabillity Urysohn's metrization theorem, Full normality and Stone's coincidence theorem, - Alexandroff-Urysohn metrization theorem, Nagata smirnov metrization theorem, - Bing's metrization theorem of Moore spaces, Moore metrization theorem	8	4
Uniform spaces - Uniform spaces, Uniform topology, - Uniform covers, Operations on Uniform spaces, Uniform continuity, Uniformization, - Metrizabillity of Uniform spaces, Totally bounded and complete - Uniform spaces, completion	10	5
Function spaces - Function spaces, pointwise convergence. - Uniform convergence. - Uniform metric, compact open topology. - Equicontinuity and compactness of spaces of functions. - The stone-Weierstrass theorem.	10	5

Teaching Strategies and Assessments

Outcomes	Teaching Strategies	Learning activities	Assess-ments	Evalu-ation
Have good skills in metrizable spaces.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Apply definitions and theorems in finding the relationships between spaces.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Have the ability to deal with new topologies.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Determine characterizations of certain spaces.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Finding the relationships between certain spaces.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Finding different types of topology.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Shown the ability of working independently and with groups.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams

Course Description for MATH 661

Course #: **MATH 661**	Course Title: **Advanced General Topology I**
Prerequisite: **---**	Teaching Language: **English**
Course Level: **First Year**	Credit Hours: **3**

Course Description

A quick revision of the basic concepts, Neighborhood systems, General product spaces, Tychonoff topology, box topology, Quotient topology and identification spaces, sequences and convergence in first countable spaces, inadequacy of sequences, Nets and filters. More on separation axioms, Jone's Lemma, Urysohn's Lemma, Tietze theorem. More on countability axioms. Covering properties, compact spaces, countably compact spaces, sequentially compact spaces, Lindeloff spaces, local compact spaces, paracompact spaces. Metric spaces, product of metrizable spaces, complete metric spaces and completions, the Baire theorem.

Course Objectives

- To studying certain spaces characterized by covering properties.
- To constructing and studying the Tychonoff "product" topology.
- To testing the separation axioms in a given space. .
- To constructing nets and filters.
- To studying the product of metrizable spaces.
- To studying the images and the inverse images of certain spaces.

Course Outcomes

Upon successful completion of the course, the student shall be able to:

- Have good skills in metric spaces,
- Have good skills in compactness, locally compactness,
- Paracompactness
- Apply definitions and theorems in finding example and counter examples for several types of spaces.
- Have the ability to deal with the product spaces.
- Apply topological, hereditary and productive properties to solve some problems
- Determine characterizations of certain spaces
- Have the ability to distinguish between locally finite, point finite, discrete collections.

Course Contents

Topics	# of lectures	# of weeks
Topological Spaces - A quick revision of the basic concepts - Neighborhood systems	4	2
New Spaces from Old - General product spaces, Tychonoff topology, box topology. - Quotient topology and identification spaces	6	3
Convergence - Sequences and convergence in first countable spaces, inadequacy of sequences. - Nets and filters	4	2
Separation and Countability - More on separation axioms, Jone's Lemma, Urysohn's Lemma, Tietze theorem. - More on countability axioms.	4	2
Compactness - Covering properties, compact spaces. - Countably compact spaces. - Sequentially compact spaces, Lindeloff spaces, - Local compact spaces. - Paracompact spaces.	8	4
Metrizable Spaces - Metric spaces, product of metrizable spaces. - Complete metric spaces and compltions, the Baire theorem.	4	2

Teaching Strategies and Assessments

Outcomes	Teaching Strategies	Learning activities	Assessm -ents	Evalu-ation
Have good skills in metric spaces,	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Have good skills in compactness, locally compactness, paracompactness	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Apply definitions and theorems in finding example and counter examples for several types of spaces.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Have the ability to deal with the product spaces.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Apply topological, hereditary and productive properties to solve some problems	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Determine characterizations of certain spaces	Lectures	Exercises,	Exams	Final

		Discussion	Quizzes	Exams
Have the ability to distinguish between locally finite, point finite, discrete collections.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams

Textbooks

Title	Author	Publisher	Year
General Topology	Stephen Willard	Addison-Wesley	1970
General Topology	Ryszarad Engelking	Heldermann Verlg	1989
Counterexamples in Topology	L.A Steen, J. A. Seebach. Jr.	Holt, Rinehart and Winston	1978

Course Description for MATH 652

Course #: **MATH 652**	Course Title: **Fuzzy Set Theory and its Applications**
Prerequisite: **----**	Teaching Language: **English**
Course Level: **Second Year**	Credit Hours: **3**

Course Description

Fuzzy Sets, Constructing Fuzzy Sets, Operations on Fuzzy Sets, Decomposition, Theorems, Extension Principle, Fuzzy Numbers. Fuzzy Arithmetic, Possibility Theory, Fuzzification in Integration, Applications in Operations Research.

Course Objectives

- Study Fuzzy Sets.
- Study Constructing Fuzzy Sets.
- Study the operations on fuzzy sets.
- Study Decomposition Theorem.
- Study Extension Principle.
- Study Fuzzy Numbers.
- Study Fuzzy Arithmetic.
- Study Possibility Theory.
- Study Fuzzifications in Integrations.
- Applications in Operations Reasearch

Course Outcomes

Upon successful completion of the course, the student shall be able to:

- Construct Fuzzy Sets.
- Understand the operations on fuzzy sets.
- Understand the Decomposition Theorem.
- Understand Extension Principle of fuzzy sets.
- Understand Fuzzy Numbers.
- Understand Fuzzy Arithmetic.
- Understand the Possibility Theory.
- Understand Fuzzifications in Integrations.
- Apply the concepts of fuzzy sets in Operations Reasearch.

Textbooks and References

Title	Author	Publisher	Year
Fuzzy Set Theory and its Applications.	Wang, Zhenyuan, Rong Yang, and Kwong-Sak Leung	World Scientific	2010
Fuzzy Set Theory and its Applications.	H. J. Zimmermann	Kluwer Academic	2001

Course Contents

Topics	# of lectures	# of weeks
Fuzzy Sets	2	1
Constructing Fuzzy Sets	2	1
Operations on Fuzzy Sets	2	1
Decomposition Theorems	2	1
Extension Principle	2	1
Fuzzy Numbers.	2	1
Fuzzy Arithmetic	2	1
Possibility Theory	2	1
Fuzzification in Integration	4	2
Applications in Operations Reasearch	8	4

Teaching Strategies and Assessments

Outcomes	**Teaching Strategies**	**Learning activities**	**Assessm-ents**	**Evalu-ation**
Construct Fuzzy Sets.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Understand the operations on fuzzy sets.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Understand the Decomposition Theorem	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Understand Extension Principle of fuzzy sets.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Understand Fuzzy Numbers.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Understand Fuzzy Arithmetic.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Understand the Possibility Theory.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Understand Fuzzifications in Integrations.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Apply the concepts of fuzzy sets in Operations Reasearch	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams

Course Description for MATH 649

Course #: **MATH 649**	Course Title: **Advanced Number Theory and Cryptography**
Prerequisite: **MATH 641**	Teaching Language: **English**
Course Level: **Second Year**	Credit Hours: **3**

Course Description

Divisibility in integral domains, Euclidean algorithm, Congruences, Finite fields, Quadratic residues and reciprocity law, Some simple cryptosystems, Enciphering matrices, Public key cryptography, RSA, Discrete log, Knapsack, Pseudoprims, The rho method, Fermat factorization, Continued fractions methods, Elliptic curves.

Course Objectives

- To introduce student to the methods and algorithms of factoring of integers and to primality testing.
- To understand the concepts of quadratic residues and reciprocity law.
- To introduce student to some simple cryptosystems.
- To introduce student to the elliptic curves.
- To introduce student to public key cryptography and the discrete log.

Course Outcomes

Upon successful completion of the course, the student shall be able to:

- Understand some factoring methods such as pollard rho and Pollard p *-1*.
- Understand the concepts of quadratic residues and reciprocity law.
- Perform encryptions and decryptions.
- Understand the importance of elliptic curves in cryptography, factoring and primality testing.

Textbooks and References

Title	Author	Publisher	Year
A Course in Number Theory and Cryptography	Neal Koblitz	Springer	2000
Advanced Number Theory with Applications	Mollin	CRC Press	2009

Course Contents

Topics	# of lectures	# of weeks
Some Basic Topics in Number Theory - Divisibility, Euclidean algorithm and congruences	4	2
Finite Fields and Quadratic Residues - Finite fields - Quadratic residues and reciprocity	4	2

Cryptography - Some simple cryptosystems - Enciphering matrices	4	2
Public Key - Public key cryptography - RSA - Discrete log - Knapsack	6	3
Primality and Factoring - Pseudoprims - The rho method - Fermat factorization - The continued fraction methods - The quadratic sieve method	6	3
Elliptic Curves - Elliptic curves and cryptography - Elliptic curves and primality test - Elliptic curves and factoring	6	3

Teaching Strategies and Assessments

Outcomes	**Teaching Strategies**	**Learning activities**	**Assess-ments**	**Evalu-ation**
Understand some factoring methods such as pollard rho and Pollard p *-1*	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Determine the quadratic residues and non-residues.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Perform encryptions and decryptions.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Understand the importance of elliptic curves in cryptography, factoring and primality testing	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams

Course Description for MATH 648

Course #: **MATH 648**	Course Title: **Advanced Linear Algebra**
Prerequisite: **---**	Teaching Language: **English**
Course Level: **Second Year**	Credit Hours: **3**

Course Description

Vector spaces, Dual spaces, Linear transformations and matrices, Invariant subspaces, Characteristic polynomial, Hamilton-Calay's theorem, Jordan normal form, Diagonalizability, Bilinear and quadratic functions, Lagrange algorithm; Sylvester Criterion, Euclidean and Unitary spaces, Orthogonal and unitary transformations; Self adjoint transformations, tensor products, Canonical Isomorphisms of tensor products Tensor algebra of vector spaces.

Course Objectives

- To familiarize the student with the concepts of dual spaces, linear transformations and matrices, invariant subspaces.
- To familiarize the student with canonical forms of linear transformations.
- Enable students to acquire further skills in the techniques of linear algebra.
- To help the students develop the ability to solve problems using linear algebra.
- To develop abstract and critical reasoning by studying proofs of theorems.

Course Outcomes

Upon successful completion of the course, the student shall be able to:

- calculate the invariant subspaces of a linear transformation.
- calculate the canonical forms of a linear transformation.
- orthogonally diagonalize symmetric matrices.
- understand the concepts of dual spaces, bilinear and quadratic functions, orthogonal and unitary transformations.
- use the concepts covered in this course to grasp theoretical results and concepts of other areas of algebra.

Textbooks and References

Title	Author	Publisher	Year
Advanced Linear Algebra	Steven Roman	Springer	2005
Linear Algebra and Geometry	Alexei I. Kostrikin and Yuri I. Manin	Gordon and Breach	1997

Course Contents

Topics	# of lectures	# of weeks
- Vector spaces, Subspaces, Factor spaces, and Isomorphisms	4	2
- Dual spaces, Direct Sums	2	1
- Bases and dimensions	2	1
- Linear transformations and matrices - Change of matrix of linear transformation	2	1
- Invariant subspaces, Characteristic polynomial - Hamilton-Calay's theorem	4	2
- Root decomposition. - Jordan normal form.	2	1
- Minimal polynomials, Diagonalizability	2	1
- Multilinear transformations - Orthogonal complement	2	1
- Bilinear and quadratic functions - Lagrange algorithm; Sylvester criterion	2	1
- Euclidian and Unitary spaces - Orthogonal and unitary transformations; Self adjoint transformations	2	2
- Multilinear functions and tensor products - Canonical isomorphisms of tensor products - Tensor algebra of vector spaces	2	2

Teaching Strategies and Assessments

Outcomes	Teaching Strateg-ies	Learning activities	Assess-ments	Evalu-ation
Calculate the invariant subspaces of a linear transformation.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Calculate the canonical forms of a linear transformation.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Orthogonally diagonalize symmetric matrices.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Understand the concepts of dual spaces, bilinear and quadratic functions, orthogonal and unitary transformations.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Use the concepts covered in this course to grasp theoretical results and concepts of other areas of algebra.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams

Course Description for MATH 647

Course #: **MATH 647**	Course Title: **Algebraic Geometry**
Prerequisite: **MATH 641**	Teaching Language: **English**
Course Level: **Second Year**	Credit Hours: **3**

Course Description

Ideals and affine varieties, Monomial orders, Division procedure, Gröbner bases, Normal forms, Noetherian rings, Existence of Gröbner bases, Buchberger's criterion, Symbolic computation software, Morphisms and coordinate rings, Rational maps, Rational and unirational varieties, Hilbert Nullstellensatz, Irreducible varieties, Primary decomposition, Projective varieties, Projective Nullstellensatz.

Course Objectives

- Apply some of the main results on irreducible decomposition of varieties, and its connection to Noetherian rings.
- Decompose a variety into its irreducible pieces through simple examples.
- Apply some of the main results on primary decomposition of ideals.
- Understand and apply Gröbner bases on monomials, and Buchberger's criterion.
- Explain the relation between algebraic primary decomposition ideals and geometric irreducible decomposition of varieties.
- Understand different versions of Hilbert Nullstellensatz and define related concepts.

Course Outcomes

Upon successful completion of the course, the student shall be able to:

- Define and understand the main concepts of algebraic geometry.
- Understand the concepts: varieties, irreducible varieties.
- Understand the components of the Hilbert Nullstellensatz.
- Define and analyze the concepts of Grobner bases and Buchberger's criterion.
- Solving nonlinear systems of equations using Gröbner bases.

Textbooks and References

Title	Author	Publisher	Year
Introduction to Algebraic Geometry	B. Hassett	Springer	2007
Ideals, Varieties, and Algorithms	David Cox, John Little, and Donal O'Shea	Springer-Verlag	1992

Course Contents

Topics	# of lectures	# of weeks
– Ideals and Affine varieties	1	1
– Monomial Orders, Division Procedure, Gröbner bases, Normal Forms	2	1
– Noetherian Rings, Existence of Gröbner bases	2	1
– Buchberger's criterion, Symbolic computation software	2	1
– Morphisms and coordinate rings	1	1
– Rational Maps, Rational and unirational varieties	2	1
– Elimination Theory and Images of rational maps	1	1
– Nullstellensatz	2	1
– Irreducible Varieties	2	1
– Primary Decomposition	2	1
– Projective space, homogeneous polynomials	2	1
– Projective varieties, Projective Nullstellensatz	2	1
– Morphisms, rational maps	2	1

Teaching Strategies and Assessments

Outcomes	Teaching Strategies	Learning activities	Assess-ments	Evalu-ation
Define and understand the main concepts of algebraic geometry.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Understand the concepts: varieties, irreducible varieties.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Understand the components of the Hilbert Nullstellensatz.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Define, describe and analyze the concepts of Grobner bases and Buchberger's criterion.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Solving nonlinear systems of equations using Gröbner bases.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams

Course Description for MATH 646

Course #: **MATH 646**	Course Title: **Introduction to Group Representations**
Prerequisite: **---**	Teaching Language: **English**
Course Level: **Second Year**	Credit Hours: **3**

Course Description

Groups. Linear representations of groups. Modules. Maschke’s theorem. Character theory. Classification of irreducible representations Schur’s lemma. Restricted and induced representations. Frobenius’s reciprocity. Representations of finite abelian groups. Fourier transform, Fourier’s inversion formula. Representations of the symmetric group: Young subgroups. Faithful representations. Tensor powers of a faithful representation. Burnside's theorem. Decomposition of the Dedekind-Frobenius determinant.

Course Objectives

- To study linear representations of finite groups,
- To give students a concrete introduction to groups theory through their representations.
- To introduce Irreducible and indecomposable representations. Schur lemma.
- To introduce Mashke's theorem, regular representation. characters.
- To introduce Representations of quaternions, Dihedral groups, and permutation groups.
- To study Representations of finite abelian groups. Fourier transform, Fourier’s inversion formula.

Course Outcomes

Upon successful completion of the course, the student shall be able to:
- construct complex irreducible representations for various finite groups of small orders.
- reproduce proofs of basic results that create theoretical; background for dealing with group representations
- apply orthogonality relations for characters of finite groups.
- apply representation theoretic methods to simplify problems from other areas.

Textbooks and References

Title	Author	Publisher	Year
Representation Theory: a First Course	William Fulton and Joe Harris	Springer	2005
Linear Representations of Finite Groups	Jean-Pierre Serre	Springer	1977

Course Contents

Topics	# of lectures	# of weeks
– Groups. Linear representations of groups.	2	1
– Modules. Maschke's theorem.	4	2
– Orthogonality relations for characters. – Properties of characters. Class functions. – Orthogonality relations of characters. – The character table.	6	3
– Irreducible and indecomposable representations. – Schur's lemma. – Restricted and induced representations. – Frobenius reciprocity.	4	2
– Tensor products of vector spaces. – Tensor products of representations.	4	2
– Representations of finite abelian groups. – Fourier transform, Fourier's inversion formula.	2	1
– Representations of the symmetric group: Young subgroups.	2	1
– Faithful representations. Tensor powers of a faithful representation. – Burnside's theorem. Decomposition of the Dedekind-Frobenius determinant.	4	2

Teaching Strategies and Assessments

Outcomes	Teaching Strateg-ies	Learning activities	Assess-ments	Evalu-ation
construct complex irreducible representations for various finite groups of small orders.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
reproduce proofs of basic results that create theoretical; background for dealing with group representations	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
apply orthogonality relations for characters of finite groups to find multiplicities of irreducible constituents of a representation.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
apply representation theoretic methods to simplify problems from other areas that "admit symmetries"	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams

Course Description for MATH 645

Course #: **MATH 645**	Course Title: **Algebraic Number Theory**
Prerequisite: ---	Teaching Language: **English**
Course Level: **Second Year**	Credit Hours: **3**

Course Description

Integral domains, Euclidean domains, Noetherian domains, Dedekind domains, Algebraic number fields, Algebraic integers and integral bases. Integral algebraic elements. Factorization of algebraic integers. Units and primes. Ideals in an algebraic number field. Valuations, Unique factorization of ideal theory. Quadratic fields. Ideal class group.

Course Objectives

- To introduce students to algebraic integers and bases.
- To be able to factorize algebraic integers.
- To understand the concepts of units and prime algebraic integers.
- To compute invariants in algebraic number theory, such as discriminants and automorphism groups.

Course Outcomes

Upon successful completion of the course, the student shall be able to:

- Define, describe and analyze standard examples of algebraic number fields and their rings of integers.
- Understand the fundamental theorems of the algebraic number fields and some of their applications.
- Understand the concepts ideals, ideal classes, unit groups, norms, traces and discriminants.
- Perform algebraic manipulations with these, especially as required for applications to Diophantine equations.

Textbooks and References

Title	Author	Publisher	Year
Introductory Algebraic Number Theory	Saban Alaca Kenneth Williams	Cambridge Press	2004
Algebraic Number Theory	Serge Lang	GTM	1986

Course Contents

Topics	# of lectures	# of weeks
– Integral domains	2	1
– Euclidean domains	2	1
– Noetherian domains	2	1
– Elements integral over a domain	2	1
– Algebraic extensions over a field	2	1
– Algebraic number fields	4	2

– Integral bases	2	1
– Dedekind domains	2	1
– Norms of ideals	2	1
– Factoring primes in a number field	2	1
– Units in real quadratic fields	2	1
– Ideal class group	2	1

Teaching Strategies and Assessments

Outcomes	Teaching Strategies	Learning activities	Assess-ments	Evalu-ation
Define, describe and analyze standard examples of algebraic number fields and their rings of integers.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Understand the fundamental theorems related to the theory of algebraic numbers and some of their applications.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Understand the concepts ideals, ideal classes, unit groups, norms, traces and discriminants.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Perform algebraic manipulations with these, especially as required for applications to Diophantine equations.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams

Course Description for MATH 644

Course #: **MATH 644**	Course Title: **Homological Algebra**
Prerequisite: **---**	Teaching Language: **English**
Course Level: **Second Year**	Credit Hours: **3**

Course Description

Rings and modules, Homomorphisms, Free modules, Projective and injective modules, Categories and functors, Complexes, Homology and co-homology groups, Hom(A, B), Tensor products, Resolutions, The functor (Ext), The functor (Tor).

Course Objectives

- To recognize the concepts of rings, modules, homomorphisms, free modules, projective, injective modules, categories and functors.
- To understand complexes, homology and co-homology groups.
- To learn how to deal with Hom(A, B), tensor products and resolutions
- To understand the concept of the functor (Ext) and the functor (Tor).

Course Outcomes

Upon successful completion of the course, the student shall be able to:

- Deal with the concepts of rings, modules, homomorphisms, free modules, projective, injective modules, categories, functors, complexes, homology, co-homology groups, Hom(A, B), tensor products and resolutions.
- Apply the functor (Ext) and the functor (Tor).

Textbooks and References

Title	Author	Publisher	Year
An Introduction to Homological Algebra	C. A. Weibel	Cambridge University	1994
Homological Algebra	H. Cartan and S. Eilenberg	Princeton University	1956

Teaching Strategies and Assessments

Outcomes	Teaching Strateg-ies	Learning activities	Assess-ments	Evalu-ation
Deal with the concepts of rings, modules, homomorphisms, free modules, projective, injective modules, categories, functors, complexes, homology, co-homology groups, Hom(A, B), tensor products and resolutions.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Apply the functor (Ext) and the functor (Tor).	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams

Course Contents

Topics	# of lectures	# of weeks
– Rings and modules	2	1
– Homomorphisms	2	1
– Free modules	2	1
– Projective modules	2	1
– Injective modules	2	1
– Categories and functors	2	1
– Complexes	2	1
– Homology groups	2	1
– Co-Homology groups	2	1
– Hom(A, B)	2	1
– Tensor products	2	1
– Resolutions	2	1
– The functor (Ext)	2	1
– The functor (Tor)	2	1

Course Description for MATH 643

Course #: **MATH 643**	Course Title: **Modern Algebra III**
Prerequisite: **---**	Teaching Language: **English**
Course Level: **Second Year**	Credit Hours: **3**

Course Description

Noetherian rings and modules, Artinian rings and modules, Hilbert’s basis theorem for polynomial rings for power series rings, Primary decomposition, Nakayama’s lemma, Localization, Integral extensions of rings, Algebraic sets, Hilbert’s nullstellensatz, Noether’s normalization theorem, Radicals, Semi-simple rings, Group rings and Masche’s theorem, Wedderburn-Artin theorem, Modules, Homomorphism of modules.

Course Objectives

- To recognize the concepts of Noetherian (Artinian) rings and modules, primary decomposition, localization and radicals.
- To understand the Hilbert’s theorem, the Nakayama lemma, the Masche’s theorem and the Wedderburn-Artin theorem.
- To learn how to deal with polynomial rings, integral extensions of rings, algebraic sets, semi-simple rings and group rings.
- To understand the concept of homomorphism of modules.

Course Outcomes

Upon successful completion of the course, the student shall be able to:

- Deal with the concepts of Noetherian (Artinian) rings and modules, primary decomposition, localization, radicals, polynomial rings, integral extensions of rings, algebraic sets, semi-simple rings, group rings and homomorphism of modules.
- Apply the Hilbert’s theorem, the Nakayama lemma, the Masche’s theorem and the Wedderburn-Artin theorem.

Textbooks and References

Title	Author	Publisher	Year
Commutative Algebra	D. Eisenbud	Springer-Verlag	1995
Introduction to Commutative Algebra	M. F. Atiyah and I. G. Macdonald	Addison-Wesley	1969

Course Contents

Topics	# of lectures	# of weeks
– Noetherian rings and modules	2	1
– Artinian rings and modules	2	1
– Hilbert's basis theorem for polynomial rings for power series rings	2	1
– Primary decomposition	2	1
– Nakayama's lemma	2	1
– Localization	2	1
– Integral extensions of rings	2	1
– Algebraic sets	2	1
– Hilbert's Nullstellensatz	2	1
– Noether's normalization theorem	2	1
– Radicals	2	1
– Semi-simple rings	2	1
– Group rings and Masche's theorem	2	1
– Wedderburn-Artin theorem, Modules, Homomorphism of modules	2	1

Teaching Strategies and Assessments

Outcomes	Teaching Strateg-ies	Learning activities	Assess-ments	Evalu-ation
Deal with the concepts of Noetherian (Artinian) rings and modules, primary decomposition, localization, radicals, polynomial rings, integral extensions of rings, algebraic sets, semi-simple rings, group rings and homomorphism of modules.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Apply the Hilbert's theorem, the Nakayama lemma, the Masche's theorem and the Wedderburn-Artin theorem.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams

Course Description for MATH 642

Course #: **MATH 642**	Course Title: **Modern Algebra II**
Prerequisite: **MATH 641**	Teaching Language: **English**
Course Level: **Second Year**	Credit Hours: **3**

Course Description

Simple groups and simplicity of A_n. Normal series and solvable groups. Field extensions: Algebraic and transcendental extensions, Algebraic closure. Separable extensions. Normal extensions and normal closure. Splitting fields. Field automorphisims. The Galois group of an extension. The Galois group of a polynomial. The fundamental theorem of Galois theory. Applications: Solvability by radicals, ruler and compass constructions, Finite fields. Purely transcendental extensions. Luroth's theorem.

Course Objectives

This course aims:

- To increase student's knowledge in group theory.
- To introduce field extensions.
- To introduce field automorphisims.
- To investigate the correspondence between subgroups of the Galois group and subfields of the related field extension.
- To introduce some applications of Galois Theory.
- To study some aspects of finite fields.

Course Outcomes

Upon successful completion of the course, the student shall be able to:

- have a good understanding of field extensions.
- calculate field automorphisms of certain fields extension.
- have a good understanding of the fundamental theorem of Galois Theory.
- deal with some applications of Galois Theory.
- demonstrate and grasp the basics of finite fields.

Textbooks and References

Title	Author	Publisher	Year
Abstract Algebra	David Dummit and Richard Foote	John Wiley	2004
Algebra	I. M. Isaacs	Brooks/ Cole	1993
Fields and Rings	Irving Kaplansky	The University of Chicago	1972

Course Contents

Topics	# of lectures	# of weeks
- Simple groups and simplicity of A_n.	2	1
- Normal series and solvable groups	2	1
- Field extensions: Algebraic and transcendental extensions	3	1.5
- Algebraic closure. Separable extensions.	2	1
- Normal extensions and normal closure. Splitting fields	3	1.5
- Field automorphisims, The Galois group of an extension.	3	1.5
- The Galois group of a polynomial.	3	1.5
- The fundamental theorem of Galois Theory.	3	1.5
- Applications: Solvability by radicals, ruler and compass constructions.	2	1
- Finite fields.	3	1.5
- Purely transcendental extensions	2	1

Teaching Strategies and Assessments

Outcomes	Teaching Strategies	Learning activities	Assess-ments	Evalu-ation
have a good understanding of field extensions.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
calculate field automorphisms of certain fields extension.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
have a good understanding of the fundamental theorem of Galois Theory.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
deal with some applications of Galois Theory.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
demonstrate and grasp the basics of finite fields.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams

Course Description for MATH 641

Course #: **MATH 641**	Course Title: **Modern Algebra I**
Prerequisite: **---**	Teaching Language: **English**
Course Level: **First Year**	Credit Hours: **3**

Course Description

Group actions. Sylow theorems. Groups of automorphisims. The fundamental theorem of finitely generated abelian groups. Classification of groups of small orders. Rings. Homomorphisms of rings. Euclidean domains, P.I.D's, and UFD's. Module over a ring, Submodules. Homomorphisms of modules. Direct sum of modules. Free modules.

Course Objectives

- To understand the properties of groups.
- To understand isomorphism theorems extensions.
- To understand Groups acting on sets and the Sylow theorems.
- To understand simple groups.
- To understand solvable and nilpotent Groups.
- To study the free groups and presentations.
- To understand properties of rings.
- To understand some types of rings: Euclidean domains, P.I.D's, and UFD's.
- To understand some properties of modules over a ring, free modules.

Course Outcomes

Upon successful completion of the course, the student shall be able to:

- Deal with the important properties of general groups.
- Understand the action of a group on a set.
- Do calculations concerning the Sylow Theorems.
- Understand the Fundamental Theorem of Finite Abelian groups.
- Understand the concepts of Solvable and Nilpotent groups;
- Deal with some important types of rings: Principal ideal Domains, Euclidean Domains and Unique factorization Domains.
- Grasp the concept of a module over a ring.

Course Contents

Topics	# of lectures	# of weeks
– Review of elementary group theory: groups, subgroups, homomorphisms, quotient groups, Lagrange’s theorem	2	1
– Group actions.	4	2
– Sylow theorems	2	1
– Group of Automorphisims	2	1
– The fundamental theorem of finitely generated abelian groups	3	1.5
– Classification of groups of small orders.	3	1.5
– Euclidean domains, P.I.D's, and UFD's	3	1.5
– Modules, Submodules.	3	1.5

– Homomorphisms of modules.	2	1
– Direct sum of modules	2	1
– Free modules.	2	1

Teaching Strategies and Assessments

Outcomes	Teaching Strategies	Learning activities	Assess-ments	Evalu-ation
Deal with the important properties of general groups.	Lectures, and independent study	Exercises, Discussion	Exams Quizzes	Final Exams
Understand the action of a group on a set.	Lectures, and independent study	Exercises, Discussion	Exams Quizzes	Final Exams
Do calculations concerning The Sylow Theorems.	Lectures, and independent study	Exercises, Discussion	Exams Quizzes	Final Exams
Understand the Fundamental Theorem of Finite Abelian groups.	Lectures, and independent study	Exercises, Discussion	Exams Quizzes	Final Exams
Understand the concepts of Solvable and Nilpotent groups;	Lectures, and independent study	Exercises, Discussion	Exams Quizzes	Final Exams
Deal with some important types of rings: Principal ideal Domains, Euclidean Domains and Unique factorization Domains.	Lectures, and independent study	Exercises, Discussion	Exams Quizzes	Final Exams
Grasp the concept of a module over a ring.	Lectures, and independent study	Exercises, Discussion	Exams Quizzes	Final Exams

Textbooks and References

Title	Author	Publisher	Year
Abstract Algebra	David Dummit and Richard Foote	John Wiley	2004
Algebra	Thomas W. Hungerford	Springer-Verlag.	2000

Course Description for MATH 623

Course #: **MATH 623**	Course Title: **Approximation Theory**
Prerequisite: ------	Teaching Language: **English**
Course Level: **Second Year**	Credit Hours: **3**

Course Description

The general interpolation problem, Polynomial and Trigonometric interpolation, Best approximation, Best approximation in inner product spaces, Projections, best approximation in the maximum norm, Iterative methods for nonlinear equations, Approximation in several variables.

Course Objectives

- Know the interpolation problem in general context.
- Learn the concept of best approximation in inner product spaces and the meaning of projections.
- Finding the best approximation with respect to maximum norm.
- Various iterative methods for nonlinear equations.
- Different approximation methods for multivariable functions.

Course Outcomes

Upon successful completion of the course, the student shall be able to:

- Understand the interpolation problem in its general context
- Find and characterize the best approximation in normed and inner product spaces.
- Understand the concept of projections and their properties in Hilbert space settings.
- Find the best approximation in the Maximum norm.
- Learn various iterative methods for approximating solutions to nonlinear equations.
- Grasp several approximating methods for functions of several variable using polynomials.

Course contents

Topics	# of lectures	# of weeks
Review of Functional Analysis - Linear Spaces - Normed Spaces - Inner Product Spaces - L^p Spaces - Operators	6	2

- Continuous Linear Operators - Linear Functionals - Weak Convergence and Weak Compactness		
Approximation Theory - Interpolation theory - Best Approximation - Best Approximation in Inner product spaces, Projection on closed convex sets - Orthogonal Polynomials - Projection Operators - Uniform Error Bounds	18	6
Nonlinear Equations and Their Solution by Iteration - The Banach Fixed-Point Theorem - Applications to Iterative Methods - Differential Calculus for Nonlinear Operators - Newton's Method	15	5
Multivariable Polynomial Approximation - Notation and the Best Approximation Results - Orthogonal Polynomials	6	2

Teaching Strategies and Assessments

Outcomes	Teaching Strategies	Learning activities	Assessm -ents	Evalu- ation
Understand the interpolation problem in its general context	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Find and characterize the best approximation in normed and inner product spaces	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Understand the concept of projections and their properties in Hilbert space settings	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Find the best approximation in the Maximum norm	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Learn various iterative methods for approximating solutions to nonlinear equations	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Grasp several approximating methods for functions of several variable using polynomials	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams

Textbooks and References

Title	Author	Publisher	Year
Theoretical Numerical Analysis: A functional analysis framework	Kendall Atkison and Weimin Han	Springer	2009
Theoretical Numerical Analysis: An introduction to advanced techniques	Peter Linz	Dover	1979

Course Description for MATH 621

Course #: **MATH 621**	Course Title: **Advanced Numerical Analysis**
Prerequisite: -----	Teaching Language: **English**
Course Level: **First Year**	Credit Hours: **3**

Course Description

Spline interpolation, Numerical solution of nonlinear systems of equations, Numerical solution of partial differential equations, Numerical solution of the eigenvalue problem.

Course Objectives

- Know how to construct spline interpolation and understand the differences among different types of splines.
- Learn different methods of numerical solution of PDE's
- Know Various numerical methods for solution of the eigenvalue problem.
- Knowledge of the concept of the fixed point of systems of nonlinear equations, and relevant existence and uniqueness conditions.

Course Outcomes

Upon successful completion of the course, the student shall be able to:

- Construct linear, quadratic, and cubic splines.
- Derive and apply finite differences methods and finite element methods.
- Know the different numerical methods that solve the eigenvalue problem.
- Learn the concept of fixed point for systems of nonlinear equations including existence and uniqueness conditions.
- Learn various iterative methods for approximating solutions to systems of nonlinear equations and convergence behavior.

Course Contents

Topics	# of lectures	# of weeks
Approximation by Spline Functions - First-Degree and Second-Degree Splines - Natural Cubic Splines - B-Splines: Interpolation and Approximation	6	3
Numerical Solutions of Nonlinear Systems of Equations - Fixed Points for Functions of Several Variables - Newton's Method - Quasi-Newton Methods - Steepest Descent Techniques - Homotopy and Continuation Methods	8	4

Numerical Solutions to Partial Differential Equations - Elliptic Partial Differential Equations - Parabolic Partial Differential Equations - Hyperbolic Partial Differential Equations - An Introduction to the Finite-Element Method	8	4
Boundary-Value Problems for Ordinary Differential Equations - The Linear Shooting Method - The Shooting Method for Nonlinear Problems - Finite-Difference Methods for Linear Problems - Finite-Difference Methods for Nonlinear Problems - The Rayleigh-Ritz Method	8	4

Teaching Strategies and Assessments

Outcomes	Teaching Strategies	Learning activities	Assessm-ents	Evalu-ation
Ability to construct linear, quadratic, and cubic splines	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Know how to Derive and apply finite differences methods and finite element methods.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Know the different numerical methods that solve the eigenvalue problem.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Learn the concept of fixed point for systems of nonlinear equations including existence and uniqueness conditions.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams
Learn various iterative methods for approximating solutions to systems of nonlinear equations and convergence behavior.	Lectures	Exercises, Discussion	Exams Quizzes	Final Exams

Textbooks and References

Title	Author	Publisher	Year
Numerical Analysis	Richard L. Burden and J. Douglas Faires	Brooks Cole	2011
Numerical Mathematics and Computing	Ward Cheney and David Kincaid	Brooks Cole	2012

Course Description for MATH 618

Course #: **MATH 618**	Course Title: **Approximation Theory in Functional Analysis**
Prerequisite: **---**	Teaching Language: **English**
Course Level: **Second Year**	Credit Hours: **3**

Course Description

Convex sets, best approximation, existence of best approximation, uniqueness of best approximation, characterization of best approximation from subspaces. Characterization of best approximation in inner product spaces. Some classes of proximinal linear subspaces. Proximinality and quotient spaces. Strong unique elements of best approximations, Cheybshev subspaces. Metric projections. Continuity properties of metric projections. Best approximation in some vector valued function spaces, space of continuous functions $C(I, X)$ and L^p spaces.

Course Objectives

- Study the concept of best approximation in general Banach spaces, existence and uniqueness.
- Introduce different kinds of proximinal subspaces.
- Study some classes of proximinal linear subspaces.
- Investigate properties of strong unique elements of best approximations.
- Study the concepts of Cheybshev subspaces and their main properties.
- Study the concept of metric projections and their continuity properties.
- Study some kinds of proximinal subspaces in vector valued function spaces such as spaces of continuous functions and L^p spaces.
- Characterize some kind of proximinal subspaces.

Course Outcomes

Upon successful completion of the course, the student shall be able to:

- Understand the notion of best approximation in different norms, existence and uniqueness.
- Differentiate between different kinds of best approximations in Banach spaces, as Chebyshev approximation, strong unique best approximations.
- Characterize some Banach spaces through best approximation.
- Understand the continuity and semi continuity properties of metric projections.
- Understand the best approximation properties of best approximation in the space of continuous functions.
- Understand the properties of best approximation of some subspaces of L^p spaces.

Textbooks and References

Title	Author	Publisher	Year
The Theory of Best Approximation and Functional Analysis	Ivan Singer	J. W. Arrowsmith ltd	1974
Abstract and Convex Analysis	Ivan Singer	John Wilely	1997

Course Contents

Topics	# of lectures	# of weeks
Chapter 1 Characterization of Elements of Best Approximation - 1.1 Existence of elements of best approximation - 1.2 Some classes of proximinal linear subspaces - 1.3 Normed linear spaces in which all closed subspaces are Proximinal - 1.4 Proximinality in quotient spaces - 1.5 Very non- proximinal linear subspaces	8	4
Chapter 2 Uniqueness of Elements of Best Approximations - 2.1 Characterization of Cheybshev and semi-Cheybshev subspaces - 2.2 Existence of Cheybshev and semi-Cheybshev subspaces - 2.3 Cheybshev and semi-Cheybshev subspaces and quotient spaces - 2.4 Strong unique elements of best approximations and Cheybshev subspaces.	8	4
Chapter 3 Metric Projections - 3.1 The mapping **π**a metric projections - 3.2 Continuity of metric projections - 3.3 Weak-continuity of metric projections - 3.4 Lipschitzian metric projections - 3.5 Semi-continuity and continuity of set valued metric projections - 3.6 Continuous selections and linear selection for set valued metric projections	8	4
Chapter 4 Best Approximation in Vector Valued Function Spaces - 4.1 Best approximation in space of continuous bounded functions on a compact set - 4.2 Best approximation in $L^p\ (I, X)$, $1 \leq p \leq \infty$.	4	2

Teaching Strategies and Assessments

Outcomes	Teaching Strategies	Learning activities	Assess-ments	Evalu-ation
Understand the notion of best approximation in different norms, existence and uniqueness.	Lectures	Exercises, Discussion	Home Works	Final Exams
Differentiate between different kinds of best approximations in Banach spaces, as Chebyshev approximation, strong unique best approximations.	Lectures	Exercises, Discussion	Home Works	Final Exams
Characterize some Banach spaces through best approximation.	Lectures	Exercises, Discussion	Home Works	Final Exams
Understand the continuity and semi continuity properties of metric projections.	Lectures	Exercises, Discussion	Home Works	Final Exams
Understand the best approximation	Lectures	Exercises,	Home	Final

properties of best approximation in the space of continuous functions.		Discussion	Works	Exams
Understand the properties of best approximation of some subspaces of L^p spaces.	Lectures	Exercises, Discussion	Home Works	Final Exams

Course Description for MATH 617

Course #: **MATH 617**	Course Title: **Abstract Harmonic Analysis**
Prerequisite: **---**	Teaching Language: **English**
Course Level: **Second Year**	Credit Hours: **3**

Course Description

Fourier Series. Functions Spaces on n-dimensional Euclidean Space. The Fourier Transform on n-dimensional Euclidean Space. Some Applications. Topological Groups. Basic Representation Theory. Compact Groups.

Course Objectives

- To introduce Fourier series and their applications.
- To introduce the Fourier transform on n-dimensional Euclidean space and its applications.
- To generalize and understand harmonic analysis in more abstract sense namely on topological groups.
- To understand the basic concepts of representation theory and compact groups that needed in harmonic analysis.

Course Outcomes

Upon successful completion of the course, the student shall be able to:

- Understand the Fourier series and the Fourier transform on n-dimensional Euclidian space.
- Connect and generalize some of the ideas of the harmonic analysis from n-dimensional Euclidian space to general topological groups.
- Understand the basics of representation theory of locally compact groups.

Course Contents

Topics	# of lectures	# of weeks
Fourier Series	4	2
Functions spaces on n-dimensional Euclidean space	4	2
The Fourier Transform on n-dimensional Euclidean space	4	2
Further Topics and Applications	4	2
Topological Groups	4	2
Basic Representation Theory	4	2
Compact Groups	4	2

Textbooks and References

Title	Author	Publisher	Year
Noncommutative Harmonic Analysis, an Introduction	Raymond C. Fabec Gestur Olafsson	Drexville Publishing	2014
A Course in Abstract Harmonic Analysis	Gerald B. Folland	CRC Press	1995

Teaching Strategies and Assessments

Outcomes	Teaching Strategies	Learning activities	Assess -ments	Evalu- ation
Understand the Fourier series and the Fourier transform on n-dimensional Euclidian space.	Lectures	Exercises, Discussion	Home Works	Final Exams
Connect and generalize some of the ideas of the harmonic analysis from n-dimensional Euclidian space to general topological groups.	Lectures	Exercises, Discussion	Home Works	Final Exams
Understand the basics of representation theory of locally compact groups.	Lectures	Exercises, Discussion	Home Works	Final Exams

Course Description for MATH 616

Course #: **MATH 616**	Course Title: **Theory of Operators**
Prerequisite: **---**	Teaching Language: **English**
Course Level: **Second Year**	Credit Hours: **3**

Course Description

Banach algebra, inverse of an element, compact operators, spectral and resolvent compact linear operators in normed spaces. Seperablity of the range and spectral properties of compact linear operators. Operator equations, Fredholm type theorems. Spectral properties of bounded self adjoint operators. Positive operators. Projections. Spectral families. Special representations of bounded self adjoint operators. Unbounded linear operators and their Hilbert adjoint operators. Symmetric and self adjoint operators. Closed linear operators. Closable operators and their closures. Multiplicand operators and differentiation operators. Polar decomposition. Square root of an operator, partial isometries.

Course Objectives

- Study the theory of Banach algebra.
- Study deeply different kinds of linear operators in Banach spaces, compact operators, self adjoint operators, positive operators, symmetric operators, closed linear operators, closable operators and their closures.
- Study the spectrum and resolvent compact operators in normed spaces.
- Study in the concept of unbounded linear operators normed spaces.
- Introduce the idea of multiplicand operators and differentiation operators.
- Study some kind of operator equations, Fredholm type theorems.

Course Outcomes

Upon successful completion of the course, the student shall be able to:

- Understand the theory of linear operators and differentiate between different kinds of operators.
- Compute the resolvent set, spectral and spectral radius of some kinds of compact operators.
- Understand deeply the spectral theory of linear operators and prove certain properties.
- Understand and analyze some known theorems, as Fredholm type theorem.
- Understand the theory of unbounded operators, closed operators, closable operators and their main properties.
- Study and analyze special families of operators, positive operators, projections, multiplicand operators and differentiation operators.

Textbooks and References

Title	Author	Publisher	Year
Introduction to Linear Operators	Vasile I.	Marcel Dekker	1981
Introductory Functional Analysis with Applications	E. Kreyszig	John Wiley	1989

Course Contents

Topics	# of lectures	# of weeks
Chapter 1 Spectral Theory of Linear Operators in Normed Spaces - 1.1 Spectral Theory in Finite Dimensional Normed Spaces. - 1.2 Basic Concepts Lebesgue Outer Measure. - 1.3 Spectral Properties of Bounded Linear Operators. - 1.4 Further Properties of Resolvent and Spectrum. - 1.5 Use of Complex Analysis in Spectral Theory. - 1.6 Banach Algebras. - 1.7 Further Properties of Banach Algebras.	6	3
Chapter 2 Compact Linear Operators on Normed Spaces and Their Spectrum - 2.1 Compact Linear Operators on Normed Spaces. - 2.2 Further Properties of Compact Linear Operators. - 2.3 Spectral Properties of Compact Linear Operators on Normed Spaces. - 2.4 Further Spectral Properties of Compact Linear Operators. - 2.5 Operators Equations Involving Compact Linear Operators. - 2.6 Further Theorems of Fredholm Type. - 2.7 Fredholm Alternative.	6	3
Chapter 3 Spectral Theory of Bounded Self-Adjoint Linear Operators - 3.1 Spectral Properties of Bounded Self-Adjoint Linea Operators. - 3.2 Further Spectral Properties of Bounded Self-Adjoint Linear Operators. - 3.3 Positive Operators. - 3.4 Square Roots of a Positive Operator. - 3.5 Projection Operators. - 3.6 Further Properties of Projections.	6	3
Chapter 4 Unbounded Linear Operators in Hilbert Space - 4.1 Unbounded Linear Operators and their Hilbert-Adjoint Operators. - 4.2 Hilbert-Adjoint Operators, Symmetric and Self-Adjoint Linear Operators. - 4.3 Closed Linear Operators and Closures. - 4.4 Spectral Properties of Self-Adjoint Linear Operators. - 4.5 Spectral Representation of Unitary Operators. - 4.6 Spectral Representation of Self-Adjoint Linear Operators. - 4.7 Multiplication Operator and Differentiation Operator.	6	3
Chapter 5 Unbounded Linear Operators in Quantum Mechanics - 5.1 Basic Ideas. States, Observables, Position Operator. - 5.2 Momentum Operator. Heisenberg Uncertainty Principle.	4	2

Teaching Strategies and Assessments

Outcomes	Teaching Strategies	Learning activities	Assess-ments	Evalu-ation
Understand the theory of linear operators and differentiate between different kinds of operators.	Lectures	Exercises, Discussion	Home Works	Final Exams
Compute the resolvent set, spectral and spectral radius of some kinds of compact operators.	Lectures	Exercises, Discussion	Home Works	Final Exams
Understand deeply the spectral theory of linear operators and prove certain properties.	Lectures	Exercises, Discussion	Home Works	Final Exams
Understand and analyze some known theorems, as Fredholm type theorem.	Lectures	Exercises, Discussion	Home Works	Final Exams
Understand the theory of unbounded operators, closed operators, closable operators and their main properties.	Lectures	Exercises, Discussion	Home Works	Final Exams
Study and analyze special families of operators, positive operators, projections, multiplicand operators and differentiation operators.	Lectures	Exercises, Discussion	Home Works	Final Exams

Course Description for MATH 613

Course #: **MATH 61**3	Course Title: **Complex Analysis I**
Prerequisite: **---**	Teaching Language: **English**
Course Level: **First Year**	Credit Hours: **3**

Course Description

Conformality (arcs and closed curves, analytic functions in regions, conformal mapping). Linear Transformations (the linear group, the cross ratio, symmetry, oriented circles, families of circles). Fundamental Theorems (line integrals, rectifiable arcs, line integrals as functions of arcs, Cauchy's Theorem for a rectangle, and Cauchy's Theorem in a circular disk). Cauchy's Integral Formula (the index of a point with respect to a closed curve, the integral formula, higher derivatives). Local Properties of Analytic Functions (removable singularities, Taylor's Theorem, zeros and poles, the local mapping, the maximum principle). The General Form of Cauchy's Theorem (chains and cycles, simple connectivity, exact differentials in simply connected regions, multiply connected regions). The Calculus of Residues (the residue theorem, the argument principle, evaluation of definite integrals). Harmonic Functions (definition and basic properties, the Mean-value property, Poisson's Formula, Schwarz's Theorem).

Course Objectives

- Introduce the concept of extended complex plane and its representation by Riemann sphere.
- Study the development of functions of complex variables.
- Investigate the major theorems in complex analysis, the Cauchy's Theorem, Cauchy integral formula including homotopic version, Maximum Modulus Principle and Lowville's Theorem including proofs.
- Investigate the open mapping theorem, Cauchy Goursat theorem and some applications.
- Use Residue theorem to evaluate both complex integrals, line integral and real integrals.
- Use the basic concepts of complex analysis, harmonic functions, Taylor and Laurent series, conformal mapping and meromorphic functions.
- Analyze Zero's and Poles of meromorphic functions and classify singularities.
- Study the concept of the Mobius transforms

Course Outcomes

Upon successful completion of the course, the student shall be able to:

- Prove certain fundamental theorems about analytic functions, e.g. Cauchy integral formula including homotopic version.
- Determine and understand of a deeper aspects of complex variables such as Riemann mapping theorem.
- Use Taylor and Laurent series expansions to derive properties of analytic and meromorphic functions.
- Apply methods of complex analysis to evaluate definite real integrals.
- Explain the theory of analytic functions and prove most important theorems.
- Understand the Mobius transforms mapping and some of their main properties.

Textbooks and References

Title	Author	Publisher	Year
Complex Analysis	Lars, V. Ahlfors,	McGraw- Hill Book	1953
Functions of One Complex Variable	John B. Conway	Springer Verlag	1973

Course Contents

Topics	# of lectures	# of weeks
Chapter 1 Conformality - 1.1 Arcs and Closed Curves - 1.2 Analytic Functions in Region - 1.3 Conformal Mapping	4	2
Chapter 2 Fundamental Theorems - 2.1 Line Integrals - 2.2 Rectifiable Arcs - 2.3 Line Integrals as Functions of Arcs - 2.4 Cauchy's Theorem for a Rectangle - 2.5 Cauchy's Theorem for a Circular Disk	6	3
Chapter 3 Cauchy's Integral Formula - 3.1 The Index of a point with Respect to a Closed Curve - 3.2 The Integral Formula - 3.3 Higher Derivatives	2	1
Chapter 4 Local Properties of Analytic Functions - 4.1 Removable Singularities. Taylor's Theorem - 4.2 Zeros and Poles - 4.3 The Local Mapping - 4.4 The Maximum Principle	4	2
Chapter 5 The General Form of Cauchy's Theorem - 5.1 Chains and Cycles - 5.2 Simple Connectivity - 5.3 Exact Differentials in Simply Connected Regions - 5.4 Multiply Connected Regions.	2	1
Chapter 6 The Calculus of Residues - 6.1 The Residue Theorem - 6.2 The Argument Principle - 6.3 Evaluation of Definite Integrals	6	3
Chapter 7 Harmonic Functions - 7.1 Definition and Basic Properties - 7.2 The Mean-Value Property - 7.3 Poisson's Formula - 7.4 Schwarz's Theorem	4	2

Teaching Strategies and Assessments

Outcomes	Teaching Strategies	Learning activities	Assess-ments	Evalu-ation
Prove certain fundamental theorems about analytic functions, e.g. Cauchy integral formula including homotopic version	Lectures	Exercises, Discussion	Home Works	Final Exams
Determine and understand of a deeper aspects of complex variables such as Riemann mapping theorem.	Lectures	Exercises, Discussion	Home Works	Final Exams
Use Taylor and Laurent series expansions to derive properties of analytic and meromorphic functions.	Lectures	Exercises, Discussion	Home Works	Final Exams
Apply methods of complex analysis to evaluate definite real integrals.	Lectures	Exercises, Discussion	Home Works	Final Exams
Explain the theory of analytic functions and prove most important theorems.	Lectures	Exercises, Discussion	Home Works	Final Exams
Understand the Mobius transforms mapping and some of their main properties.	Lectures	Exercises, Discussion	Home Works	Final Exams

Course Description for MATH 612

Course #: **MATH 612**	Course Title: **Functional Analysis I**
Prerequisite: **---**	Teaching Language: **English**
Course Level: **Second Year**	Credit Hours: **3**

Course Description

Normed and Banach spaces (completion, product and quotients of normed spaces), Finite dimensional normed spaces and subspaces, Boundedness and continuity of linear functional. The dual spaces. Inner product spaces. Hilbert spaces (orthogonal sets, representation of functionals in Hilbert spaces, Hilbert adjoint operator, self-adjoint unitary and normal operators). Hahn-Banach Theorem. Bounded linear functionals in $C[a,b]$. Reflexive spaces. Uniform boundedness Theorem. Open mapping Theorem. Closed linear operators. Closed graph Theorem. Banach fixed point Theorem and its application to integral equations. Basic concepts in the spectral theory in normed spaces. Spectral properties of bounded linear operators. Spectral mapping theorem for polynomials. Holomorphy of the resolvent operator. Spectral radius formula.

Course Objectives

- Present the definition of normed spaces, Banach spaces, product and Quotient of normed spaces and their main properties and give examples on finite and infinite dimensional normed spaces.
- Introduce the definition of linear operators, linear functionals on normed spaces and their properties, Boundedness, continuous etc.
- Develop the idea of dual spaces and give examples.
- Introduce the definition of inner product spaces, Hilbert spaces and their main properties.
- Present the idea of normal and orthonormal sets in Hilbert spaces and representatives of linear functionals.
- Introduce several kinds of bounded linear operators on Hilbert spaces, self-adjoint operators, normal operators and unitary operators.
- Introduce the well-known Theorems in functional analysis: Hahn Banach-theorem, open mapping theorem, closed graph theorem and some of their applications.
- Give an idea about spectral properties of linear operators and spectral mapping theorem for polynomials.

Course Outcomes

Upon successful completion of the course, the student shall be able to:

- Understand some new concepts in normed spaces and Banach spaces and their main properties.
- Differentiate between finite and infinite dimensional normed spaces.
- Understand the idea of linear operators and linear functionals on normed spaces and relate them to their duals.
- Understand the structure of inner product spaces and differentiate between different kinds of linear operators on Hilbert spaces, self-adjoint, normed and unitary operators.

- Understand the different versions of Hahn Banach theorem and its applications.
- Understand the idea of some known theorems in functional analysis open mapping theorem, closed graph theorem, fixed point theorem and some of their applications.
- Have an idea on the spectral properties of bounded linear operators.

Textbooks and References

Title	Author	Publisher	Year
Introductory Functional Analysis with Application	E. Kreysziy	John Wiley	1989
Functional Analysis with Application	A. H. Siddiqi	McGraw- Hill	1989

Teaching Strategies and Assessments

Outcomes	Teaching Strategies	Learning activities	Assess - ments	Evalu- ation
Understand some new concepts in normed spaces and Banach spaces and their main properties.	Lectures	Exercises, Discussion	Home Works	Final Exams
Differentiate between finite and infinite dimensional normed spaces.	Lectures	Exercises, Discussion	Home Works	Final Exams
Understand the idea of linear operators and linear functionals on normed spaces and relate them to their duals.	Lectures	Exercises, Discussion	Home Works	Final Exams
Understand the structure of inner product spaces and differentiate between different kinds of linear operators on Hilbert spaces, self-adjoint, normed and unitary operators.	Lectures	Exercises, Discussion	Home Works	Final Exams
Understand the different versions of Hahn Banach theorem and its applications.	Lectures	Exercises, Discussion	Home Works	Final Exams
Understand the idea of some known theorems in functional analysis open mapping theorem, closed graph theorem, fixed point theorem and some of their applications.	Lectures	Exercises, Discussion	Home Works	Final Exams
Have an idea on the spectral properties of bounded linear operators.	Lectures	Exercises, Discussion	Home Works	Final Exams

Course Contents

Topics	# of lectures	# of weeks
Chapter 1 Metric Spaces - 1.4 Convergence, Cauchy Sequence, Completeness - 1.5 Examples. Completeness Proofs. - 1.6 Completion of Metric spaces	4	2
Chapter 2 Normed Spaces. Banach Spaces - 2.1 Vector Space. - 2.1 Normed Space. Banach Space. - 2.3 Further Properties of Normed Spaces. - 2.4 Finite Dimensional Normed Spaces and Subspaces. 2.5 Compactness and Finite Dimension. - 2.6 Linear Operators. - 2.7 Bounded and Continuous Linear Operators. 2.8 Linear Functionals. - 2.9 Linear Operators and Functionals on Finite Dimensional Spaces. - 2.10 Normed Spaces of Operators. Dual Space.	6	3
Chapter 3 Inner Product Spaces. Hilbert Spaces - 3.1 Inner Product Spaces. Hilbert Space. - 3.2 Further Properties of Inner Product Spaces. - 3.3 Orthogonal Complements and Direct Sums. - 3.4 Orthogonal Sets and Sequences. - 3.6 Total Orthonormal Sets and Sequences. - 3.8 Representation of Functionals on Hilbert Spaces. - 3.9 Hilbert-Adjoint Operator. - 3.10 Self-Adjoint, Unitary and Normal Operators.	4	2
Chapter 4 Fundamental Theorems for Normed and Banach Spaces - 4.2 Hahn-Banach Theorem. - 4.3 Hahn-Banach Theorem for Complex Vector Spaces and Normed Spaces. - 4.5 Adjoint Operator. - 4.6 Reflexive Spaces. - 4.7 Category Theorem. Uniform Boundedness Theorem. - 4.8 Strong and Weak Convergences. - 4.9 Convergence of Sequences of Operators and Functionals. - 4.12 Open Mapping Theorem. - 4.13 Closed Linear Operators. Closed Graph Theorem.	6	3
Chapter 5 Further Applications: Banach Fixed Point Theorem - 5.1 Banach Fixed Point Theorem. - 5.4 Application of Banach's Theorem to Integral Equations.	4	2
Chapter 7 Spectral Theory of Linear Operators in Normed Spaces - 7.1 Spectral Theory in Finite Dimensional Normed Spaces. - 7.2 Spectral Properties of Bounded Linear Operators.	4	2

Course Description for MATH 611

Course #: **MATH 611**	Course Title: **Measure Theory and Integration I**
Prerequisite: **---**	Teaching Language: **English**
Course Level: **First Year**	Credit Hours: **3**

Course Description

Lebesgue outer measure as a generalization of length of an interval. Lebesgue measurable sets. Borel measurable sets. Characterization of Lebesgue measurable sets. Non-measurable sets. Sets of measure zero. Measurable functions and their properties. Step functions. Characteristic functions. Simple functions. Borel measurable functions. Sequences of functions. Convergence in measure. Lebesgue integral of bounded functions. Comparison of Riemann and Lebesgue integrals. Integral of non-negative measurable functions. General Lebesgue integrals. Improper integrals. Differentiation and integration. Functions of bounded variation. Differentiation of an integral. Absolutely continuous functions. L^p-spaces.

Course Objectives

- Discuss the concept of algebra and σ algebra to prepare for defining the outer measure.
- Be able to think deeply in mathematical analysis, understand the theory of outer-measure, Lebesgue measure, Borel measure and measurable functions.
- Extend the theory of integration from Riemann Integral to Lebesgue integral and compare them.
- Introduce different kinds of convergence of a sequence of measurable functions and relate them to Lebesgue integral.
- Introduce the concept of differentiation, bounded variations and absolutely continuous of functions.
- Have an idea about some kind of vector valued function spaces "L^p-spaces".

Course Outcomes

Upon successful completion of the course, the student shall be able to:

- Understand the definition of Lebesgue measure and Lebesgue integral as an extension to Riemann integral.
- Understand the definition of uniform convergence, pointwise convergence, convergent in measure for a sequence of measurable functions and relate them to integration.
- Understand the proof and application of some famous theorems, Fatou's lemma, and Lebesgue convergence theorem.
- Understand the definitions of absolutely continuous functions and relate it to differentiable functions, and functions of bounded variation.
- Understand of the structure of L^p-spaces and some of their properties.

Course Contents

Topics	# of lectures	# of weeks
Chapter 2 Lebesgue Measure - 2.1 Introduction. - 2.2 Lebesgue Outer Measure. - 2.3 The σ-Algebra of Lebesgue Measurable Sets. - 2.4 Outer and Inner Approximation of Lebesgue Measurable Sets. - 2.5 Countable Additivity, Continuity, and the Borel-Cantelli Lemma. - 2.6 Non-measurable Sets. - 2.7 The Cantor Set and the Cantor-Lebesgue Function.	6	3
Chapter 3 Lebesgue Measurable Functions - 3.1 Sums, Products, and Compositions. - 3.2 Sequential Pointwise Limits and Simple Approximation. - 3.3 Littlewood's Three Principles, Egoroff's Theorems, and Lusin's Theorem.	4	2
Chapter 4 Lebesgue Integration - 4.1 The Riemann Integral. - 4.2 The Lebesgue Integral of a Bounded Measurable Function over a Set of Finite Measure. - 4.3 The Lebesgue Integral of a Measurable Nonnegative Function. - 4.4 The general Lebesgue Integral. - 4.5 Countable Additivity and Continuity of Integration. - 4.6 Uniform Integrability: The Vitali Convergence Theorem.	4	2
Chapter 5 Lebesgue Integration: Further Topics - 5.1 Uniform Integrability and Tightness: A General Vitali Convergence theorem. - 5.2 Convergence in Measure. - 5.3 Characterizations of Riemann and Lebesgue Integrability.	4	2
Chapter 6 Differentiation and Integration - 6.1 Continuity of Monotone Functions. - 6.2 Differentiability of Monotone Functions: Lebesgue's Theorem. - 6.3 Functions of Bounded Variation: Jordan's Theorem. - 6.4 Absolutely Continuous Functions. - 6.5 Integrating Derivatives: Differentiating Indefinite Integrals. - 6.6 Convex Functions.	6	3
Chapter 7 The L^p-spaces: Completeness and Approximation - 7.1 Normed Linear Spaces. - 7.2 The Inequalities of Young, Holder, and Minkowski. - 7.3 L^p- space is Complete: The Risez-Fischer Theorem. - 7.4 Approximation and Reparability.	4	2

Textbooks and References

Title	Author	Publisher	Year
Real Analysis	H. L. Royden	Prentice-Hall.	1968
Real variables	A. Torchinsky	Addison- Wesley	1988

Teaching Strategies and Assessments

Outcomes	Teaching Strategies	Learning activities	Assess-ments	Evalu-ation
Understand the definition of Lebesgue measure and Lebesgue integral as an extension to Riemann integral.	Lectures	Exercises, Discussion	Home Works	Final Exams
Understand the definition of uniform convergence, pointwise convergence, convergent in measure for a sequence of measurable functions and relate them to integration.	Lectures	Exercises, Discussion	Home Works	Final Exams
Understand the proof and application of some famous theorems, Fatou's lemma, and Lebesgue convergence theorem.	Lectures	Exercises, Discussion	Home Works	Final Exams
Understand the definitions of absolutely continuous functions and relate it to differentiable functions, and functions of bounded variation.	Lectures	Exercises, Discussion	Home Works	Final Exams
Understand of the structure of L^p-spaces and some of their properties.	Lectures	Exercises, Discussion	Home Works	Final Exams

Course Description for MATH 603

Course #: **MATH 603**	Course Title: **Advanced Partial Differential Equations (1)**
Prerequisite: ----	Teaching Language: **English**
Course Level: **First Year**	Credit Hours: **3**

Course Description

First Order Partial Differential Equations, Quasi-Linear First Order Partial Differential Equations, The Method of Characteristics, First Order Nonlinear Partial Differential Equations, Nonlinear Reaction Diffusion Phenomena, Asymptotic Methods and Nonlinear Evolutions Equations.

Course Objectives

- To let the students classify the first order partial differential equations.
- To let the students know how to solve, linear, quasi-linear, and nonlinear first order partial differential equations by using the method of characteristics and some other special techniques. .
- To let the students know what is the meaning of reaction diffusion process (phenomena), to know some reaction-diffusion partial differential equations (as Burger's and Fisher's equations).
- To let the students know the traveling waves for Burger's and Equations.
- To let the students know how to use the asymptotic methods.
- To let the students know the nonlinear evolution equations.

Course Outcomes

Upon successful completion of the course, the student shall be able to:

- Understand how to solve linear, quasi-linear, and nonlinear first order partial differential equations.
- Understand the reaction diffusion process and to study some special solutions of some reaction-diffusion partial differential equations.
- Understand and apply some asymptotic method to approximate a solution for certain partial differential equations.

Course Contents

Topics	# of lectures	# of weeks
First Order, Quasi-linear Equations and Method of Characteristic • Introduction. • The classification of First Order Equations. • The construction of first order equations. • The geometrical interpretation of first order equations. • The method of characteristics and general solution.	6	3

First Order Nonlinear Equations and Their Applications • Introduction. • The Generalized method of characteristics. • Complete integrals of certain special nonlinear equations • The Hamilton-Jacobi equation and its applications. • Applications of nonlinear optics.	6	3
Nonlinear Diffusion-Reaction Phenomena • Introduction. • Burgers Equation and the plane wave equation. • Traveling wave solution of the Burger's equation. • The exact solution of the Burger's equation. • The asymptotic behavior of the Burger's equation. • The N-wave solution. • Burger's Initial and Boundary value problems. • Fisher equation and diffusion-reaction process. • Traveling wave solution and stability analysis. • Perturbation solution of the Fisher equation. • Method of similarity solutions of diffusion equations. • Nonlinear reaction-diffusion equations.	8	4
Asymptotic Methods and Nonlinear Evolution Equations • Introduction • The reductive perturbation method and quasi linear hyperbolic systems. • Quasi-linear dissipative systems. • Weakly nonlinear dispersive systems and Korteweg-de Vries equation. • Strongly nonlinear dispersive systems and the NLS equation. • The perturbation method of Ostrovsky and Pelinovsky. • The method of multiple scales. • Asymptotic expansion and method of multiple scales. • Derivation of the NLS equation and Davey-Stewartson evolution equations.	8	4

Textbooks and References

Title	Author	Publisher	Year
Nonlinear Partial differential Equations for Scientists and Engineers	Lokenath Debnath	Birkhauser	2012
An Introduction to Nonlinear Partial Differential Equations	David Logan	Wiley	2008
Linear Partial Differential equations for scientist and engineers	Tyn Myint-U	Birkhauser	2007
Applied Partial Differential Equations.	David Logan	Springer	2015

Teaching Strategies and Assessments

Outcomes	Teaching Strategies	Learning activities	Assessm-ents	Evalu-ation
Understand how to solve linear, quasi-linear, and nonlinear first order partial differential equations.	Lectures	Exercises, Discussion	Exams, Quizzes assignments	Final Exams
Understand the reaction diffusion process and to study some special solutions of some reaction-diffusion partial differential equations.	Lectures	Exercises, Discussion	Exams Quizzes assignments	Final Exams
Understand and apply some asymptotic method to approximate a solution for certain partial differential equations.	Lectures	Exercises, Discussion	Exams Quizzes assignments	Final Exams