Working Paper # 24

Revision of BS Mathematics Program

Sponsored by SNS

Program Description

1. The BS in Mathematics program has been designed to develop analytical skills in the students on one hand and to prepare them for the modern job market on the other hand. The program allows students to explore a broad range of mathematical topics while gaining a depth of expertise in certain areas. Students wishing to pursue careers in scientific research will conveniently gain admission to MS and Ph.D. Programs at national and international universities of good repute. Those who choose other careers will benefit in their respective fields from the skills gained at SNS.

2. The BS Mathematics curriculum emphasizes computational mathematics, pure and applied mathematics and data science, because these areas give students a competitive advantage when beginning their careers in sciences and education. Graduates will be able to work in a knowledge-based society with strong analytical skills and computational tools. Humanities courses are part of the BS Mathematics program to prepare students to fulfill their civic and cultural responsibilities. Humanities courses emphasize social skills and strengthen students' ability to communicate and work with others.

3. The BS Mathematics program offers a final year project which allows students to gain first-hand experience in some facets of research. The experience gained from undergraduate research will be valuable for students planning to pursue graduate studies within the country and abroad.

Rationale for Revision

4. The regular curriculum review provides the opportunity to keep the programs updated. The curriculum review policy of NUST requires a comprehensive review of each UG program (4 years duration) after every 4 years. The four-year BS Mathematics program at SNS was started in 2010. After a period of four years, in 2014, the curriculum was revised. To impart quality education that is at par with national and international standards, the curriculum was revised for the second time in 2019.

5. This revision includes the addition of some new courses, deletion of a few courses,

revision of the contents of a number of courses, and inclusion of the Final Year Project (FYP) in the program. Some courses are reshuffled among semesters in order to align the distribution of courses, as per HEC Policy, over domains such as Compulsory Requirements, Discipline Specific Foundation Courses, General Courses and Elective Courses within Mathematics.

Final Year Project

6. Final Year Project in the BS Mathematics program will allow students to engage in independent mathematical work in an active subject area of Mathematics, guided by a faculty member in the Department of Mathematics. The undergraduate thesis must demonstrate that the student:

a. has developed excellent writing skills
b. gained insight into what is involved in carrying out research studies
c. has developed self-confidence in applying academic knowledge
d. is acquainted with knowledge related to an area of research
e. has determined interest in seeking a graduate degree
f. can critically examine the work of others and relate that work to the thesis.

FYP will be split into two parts namely MATH-498 Final Year Project-I and MATH-499 Final Year Project-II. Grades for FYP in the 7th and 8th semesters will be awarded as per NUST FYP policy.

Program Outcomes

7. BS Mathematics degree opens several exciting and lucrative avenues. Graduates are not only able to pursue careers in higher education and research as MS and Ph.D. scholars, but also get the skills that are needed in modern industrial and financial markets. Globally, mathematicians are employed in banks, stock markets, consultation firms, cryptography, data mining, and computing. Holding a BS Mathematics degree from SNS will ensure that the graduates are well prepared for a wide variety of jobs available in Pakistan and abroad.

Eligibility for admission: HSSC or equivalent with Mathematics.

Total Credit Hours: 131-133

Scheme of Studies

8. BS Mathematics at SNS is a 131-133 credit hours program of studies spread over 8 semesters. The courses are distributed over domains such as Compulsory Requirements, Discipline Specific Foundation Courses, General Courses and Elective Courses within

Mathematics. The distribution of courses is as under:

	HEC Requirements		Revised Curricula (SNS)	
Classification	**Courses**	**CHs**	**Courses**	**CHs**
Compulsory Requirements	9	25	9	26
General Courses	7-8	21-24	8	24
Discipline Specific Foundation Courses	9-10	30-33	10	30
Major Courses + FYP	11-13	36-42	11+FYP	39
Elective Courses within the Major	4	12	4	12/14
Total CHs		**124-136**		**131-133**

Compulsory Requirements				
	HEC		**SNS**	
	Courses	**CHs**	**Courses**	**CHs**
C1	English I (Functional English)	3	English-I	3-0
C2	English II (Communication Skills)	3	Communication and Interpersonal Skills	3-0
C3	English III (Technical Writing and Presentation skills)	3	Technical Writing	3-0
C4	Any Foreign Language	3	Foreign Language	3-0
C5	Islamic Studies/Ethics	2	Islamic Studies	2-0
C6	Pakistan Studies	2	Pakistan Studies	2-0
C7	Discrete Mathematics	3	Discrete Mathematics and Applications	3-0
C8	Elements of Set Theory and Mathematical Logic	3	Set Theory	3-0
C9	Introduction to Computers	3	Fundamentals of Computer Programming	3-1
	Total	**25**		**26**

General Courses				
	HEC		**SNS**	
	Courses	CHs	Courses	CHs
G1	G-1	3	Introduction to Data Science	2-1
G2	G-2	3	Mechanics	3-1
G3	G-3	3	Principles of Microeconomics	3-0
G4	Statistics	3	Introductory Statistics	3-0
G5	Computer Programming	3	Machine Learning for Data Analysis	3-1
G6	Software Packages	3	Mathematical Computing	2-1
G7			Professional Ethics	2-0
G8			Entrepreneurship	2-0
	Total	**21-24**		**24**

Discipline Specific Foundation Courses				
	HEC		**SNS**	
	Courses	CHs	Courses	CHs
F1	Algebra-I	3	Group Theory-I	3-0
F2	Algebra-II	3	Rings and Fields	3-0
F3	Integral Equations	3	Integral Equations	3-0

F4	Calculus I	4	Calculus-I	3-0
F5	Calculus II	3	Calculus-II	3-0
F6	Calculus III	4	Calculus-III	3-0
F7	Complex Analysis	3	Complex Analysis	3-0
F8	Ordinary differential equations	3	Ordinary Differential Equations	3-0
F9	Linear Algebra	4	Linear Algebra	3-0
F10	Affine and Euclidean Geometry	3	Numerical Analysis-II	3-0
	Total	**30-33**		**30**

Major Courses Including Research Project				
	HEC		**SNS**	
	Courses	CHs	Courses	CHs
M1	Number Theory	3	Elementary Number Theory	3-0
M2	Real Analysis-I	3	Real Analysis-I	3-0
M3	Real Analysis-II	3	Real Analysis-II	3-0
M4	Mathematical Methods	3	Mathematical Methods	3-0
M5	Topology	3	Topology-I	3-0
M6	Differential Geometry	3	Differential Geometry	3-0
M7	Classical Mechanics	3	Fluid Mechanics	3-0
M8	Partial Differential Equations	3	Partial Differential Equations	3-0
M9	Functional Analysis	3	Functional Analysis	3-0
M10	Numerical Analysis	4	Numerical Analysis-I	3-0
M11	Probability Theory	3	Probability Theory	3-0
M12	Project	3	Final Year Project	6-0
		36-42		**39**

Elective Courses within the Major				
	HEC		**SNS**	
	Courses	CHs	Courses	CHs
E1	E-1	3	Elective-I (Semester VII)	3-0
E2	E-2	3	Elective-II (Semester VII)	3-0/3-1
E3	E-3	3	Elective-III (Semester VIII)	3-0
E4	E-4	3	Elective-IV (Semester VIII)	3-0/3-1
		12		**12/14**

List of Elective Courses within Major in Mathematics

Course Code	Course Title	Credits	Course Code	Course Title	Credits
MATH-421	Group Theory-II	3-0	MATH-492	Computational Fluid Dynamics	3-0
MATH-426	Module Theory	3-0	PHY-203	Classical Mechanics-I	3-0
MATH-434	Numerical Linear Algebra	3-0	PHY-302	Quantum Mechanics- I	3-0
MATH-435	Introduction to Finite Element Method	3-0	PHY-361	Special Relativity	3-0
MATH-436	Introduction to Approximation Theory	3-0	PHY-462	General Relativity	3-0
MATH-445	Measure and Integration	3-0	ECO-325	Introduction to Econometrics	3-0

MATH-447	Topology-II	3-0	ECO-326	Applied Econometrics	3-0
MATH-463	Stochastic Processes	3-0	DS-403	Data Mining	3-0
MATH-473	Operations Research	3-0	DS-404	Artificial Neural Networks	3-1
MATH-475	Game Theory	3-0	DS 405	Experimental Design for Data Science	3-0
MATH-480	Tensor Calculus	3-0	DS 406	Time Series Analysis and Forecasting	3-0
MATH-456	Discrete Dynamical Systems	3-0	DS 407	Artificial Intelligence	3-1
MATH-471	Cryptography	3-0			

Foreign Languages Courses

S. No.	Course Code	Course	Credits
1	FL-100	Foreign Language – (Chinese-I)	3-0
2	FL-101	Foreign Language – (Turkish)	3-0
3	FL-400	Foreign Language – (Chinese-II) *	3-0

*It is an optional additional course offered in the final year and it will be counted as "Additional Course".

Semester-wise Breakdown

First Year					
Semester-I			Semester-II		
Course Code	**Course Title**	**Credits**	**Course Code**	**Course Title**	**Credits**
MATH-113	Set Theory	3-0	CS-110	Fundamentals of Computer Programming*	3-1
HU-101	Islamic Studies	2-0	FL-XXX	Foreign Language	3-0
HU-107	Pakistan Studies	2-0	HU-108	Communication and InterpersonalSkills	3-0
HU-110	English-I	3-0	MATH-112	Calculus-II	3-0
MATH-111	Calculus-I	3-0	ECO-101	Principles of Microeconomics	3-0
PHY-106	Mechanics	3-1			
Total Credits		17	**Total Credits**		16

*The course CS-110 Fundamentals of Computer Programming will be based on C or C++ language.

Second Year					
Semester-III			**Semester-IV**		
Course Code	**Course Title**	**Credits**	**Course Code**	**Course Title**	**Credits**
MATH-235	Mathematical Computing	2-1	DS-201	Introduction to Data Science	2-1
MATH-213	Calculus-III	3-0	MATH-242	Real Analysis-I	3-0
MATH-263	Probability Theory	3-0	MATH-264	Introduction to Statistics	3-0
MATH-272	Discrete Mathematics and Applications	3-0	MATH-274	Elementary Number Theory	3-0
MATH-221	Linear Algebra	3-0	MATH-251	Ordinary Differential Equations	3-0
			HU-210	Technical Writing	3-0
Total Credits		15	**Total Credits**		18

Third Year					
Semester-V			**Semester-VI**		
Course Code	**Course Title**	**Credits**	**Course Code**	**Course Title**	**Credits**
DS-302	Machine Learning for Data Analysis	3-1	MATH-325	Group Theory-I	3-0
HU-222	Professional Ethics	2-0	MATH-332	Numerical Analysis-I	3-0
MATH-352	Mathematical Methods	3-0	MATH-353	Partial Differential Equations	3-0
MATH-342	Real analysis-II	3-0	MATH-446	Functional Analysis	3-0
MATH-343	Complex Analysis	3-0	MATH-382	Differential Geometry	3-0
MATH-345	Topology-I	3-0	MGT-271	Entrepreneurship	2-0
Total Credits		18	**Total Credits**		17

Fourth Year					
Semester-VII			**Semester-VIII**		
Course Code	**Course Title**	**Credits**	**Course Code**	**Course Title**	**Credits**
CSL-401	Community Services Learning Course*	2-0	MATH-433	Numerical Analysis-II	3-0
MATH-423	Rings and Fields	3-0	MATH-455	Integral Equations	3-0
MATH-491	Fluid Mechanics	3-0	MATH-499	Final Year Project-II	3-0

MATH-498	Final Year Project-I	3-0		Elective-III	3-0
	Elective-I	3-0/3-1		Elective-IV	3-0/3-1
	Elective-II	3-0			
Total Credits		15/16	**Total Credits**		15/16

*Additional Course

Mathematics Courses with Prerequisites

S. No.	Subject Code	Subject	CHs	Prerequisite
1.	MATH-111	Calculus-I	3-0	None
2.	MATH-112	Calculus-II	3-0	None
3.	MATH-113	Set Theory	3-0	None
4.	MATH-213	Calculus-III	3-0	MATH-111 Calculus-I
5.	MATH-221	Linear Algebra	3-0	None
6.	MATH-235	Mathematical Computing	2-1	None
7.	MATH-242	Real Analysis-I	3-0	MATH-111 Calculus-I
8.	MATH-251	Ordinary Differential Equations	3-0	None
9.	MATH-263	Probability Theory	3-0	None
10.	MATH-264	Introduction to Statistics	3-0	MATH-263 Probability Theory
11.	MATH-272	Discrete Mathematics and Applications	3-0	None
12.	MATH-274	Elementary Number Theory	3-0	None
13.	MATH-325	Group Theory-I	3-0	None
14.	MATH-332	Numerical Analysis-I	3-0	None
15.	MATH-342	Real Analysis-II	3-0	MATH-242 Real Analysis-I
16.	MATH-343	Complex Analysis	3-0	None
17.	MATH-345	Topology-I	3-0	None
18.	MATH-352	Mathematical Methods	3-0	MATH-251 Ordinary Differential Equations
19.	MATH-353	Partial Differential Equations	3-0	MATH-251 Ordinary Differential Equations
20.	MATH-382	Differential Geometry	3-0	None
21.	MATH-421	Group Theory-II	3-0	MATH-325 Group Theory-I

22.	MATH-423	Rings and Fields	3-0	MATH-325 Group Theory-I
23.	MATH-426	Module Theory	3-0	MATH-423 Rings and Fields
24.	MATH-433	Numerical Analysis-II	3-0	MATH-332 Numerical Analysis-I
25.	MATH-434	Numerical Linear Algebra	3-0	MATH-221 Linear Algebra
26.	MATH-435	Introduction to Finite Element Method	3-0	MATH-332 Numerical Analysis-I, MATH-353 Partial Differential Equations
27.	MATH-436	Introduction to Approximation Theory	3-0	None
28.	MATH-445	Measure and Integration	3-0	MATH-342 Real Analysis-II
29.	MATH-446	Functional Analysis	3-0	None
30.	MATH-447	Topology-II	3-0	MATH-345 Topology-I
31.	MATH-455	Integral Equations	3-0	None
32.	MATH-456	Discrete Dynamical Systems	3-0	MATH-251 Ordinary Differential Equations
33.	MATH-463	Stochastic Processes	3-0	MATH-263 Probability Theory
34.	MATH-471	Cryptography	3-0	MATH-274 Elementary Number Theory
35.	MATH-473	Operations Research	3-0	None
36.	MATH-475	Game Theory	3-0	None
37.	MATH-480	Tensor Calculus	3-0	None
38.	MATH-491	Fluid Mechanics	3-0	None
39.	MATH-492	Computational Fluid Dynamics	3-0	MATH-491 Fluid Mechanics

List of courses from other disciplines with prerequisites

S. No.	Subject Code	Subject	CHs	Prerequisite
1.	DS-201	Introduction to Data Science	2-1	None
2.	DS-302	Machine Learning for Data Analysis	3-1	None
3.	DS-403	Data Mining	3-0	None
4.	DS-404	Artificial Neural Networks	3-1	DS-302 Machine Learning for Data Analysis
5.	DS 405	Experimental Design for Data Science	3-0	MATH-264 Introduction to Statistics
6.	DS 406	Time Series Analysis and Forecasting	3-0	MATH-264 Introduction to Statistics
7.	DS 407	Artificial Intelligence	3-1	None
8.	CS-110	Fundamentals of Computer Programming	3-1	None
9.	FL-100	Foreign Language (Chinese-I)	3-0	None
10.	FL-101	Foreign Language (Turkish)	3-0	None
11.	FL-400	Foreign Language (Chinese-II)	3-0	FL-100 Foreign Language (Chinese-I)
12.	HU-101	Islamic Studies	2-0	None
13.	HU-107	Pakistan Studies	2-0	None
14.	HU-108	Communication and Interpersonal Skills	3-0	None
15.	HU-110	English-I	3-0	None
16.	HU-210	Technical Writing	3-0	None
17.	HU-222	Professional Ethics	2-0	None

18.	MGT-271	Entrepreneurship	2-0	None
19.	ECO-101	Principles of Microeconomics	3-0	None
20.	ECO-325	Introduction to Econometrics	3-0	MATH-264 Introduction to Statistics
21.	ECO-326	Applied Econometrics	3-0	ECO-325: Introduction to Econometrics
22.	PHY-106	Mechanics	3-1	None
23.	PHY-203	Classical Mechanics-I	3-0	PHY-106 Mechanics
24.	PHY-302	Quantum Mechanics- I	3-0	None
25.	PHY-361	Special Relativity	3-0	None
26.	PHY-462	General Relativity	3-0	PHY-361 Special Relativity

Input from industry and Academia

9. Input on the revised curriculum has been sought from the following academia and industry representatives in an advisory board meeting held on October 24, 2022.

S.No	Name	Designation/ Institution
1	Prof. Dr. Muhammad Sajid	Professor of Department of Mathematics IIU Islamabad
2	Prof. Dr. Shahid Hamid	Professor/ Dean of Natural Sciences, QAU Islamabad.
3	Mr. Tariq Mehmood Khan	CEO Redox (SMC PVT) LTD Islamabad

Minutes of the advisory board meeting are attached.
Suggestions/inputs from the following alumnae have been incorporated in the working paper.

a. Ghafirlia Istafa
b. Zain ul Abdeen

Timeframe of commencement

10. The revised BS Mathematics program will be implemented for Fall 2023 and onward entries.

Approved by DBS/FBS

11. The working paper for the revision of the BS Mathematics program was discussed in several DCRC meetings held from time to time, in the DBS held on October 27, 2022, and in the FBS held on November 4, 2022.

Comments of Academics Directorate

12. No additional requirement of faculty, classrooms & labs. The proposal was deliberated and endorsed by UCRC held on 15 Dec 2022.

Recommendation of Academics Directorate

13. Revision of BS Mathematics at SNS is recommended for approval w.e.f Fall 2023.

14. Academic council is requested for the decision.

Annex A

Changes in BS-Mathematics Courses

Summary of changes

S. No.	Type of change		No. of courses
1	Course Contents revised		12
2	New courses included		8
3	Courses discarded	With replacement	7
		Redundant (Not replaced)	4

Details of changes

S. No.	Code	Subject	CHs	Details of Changes			
				Code change	Title change	Contents revised	Remarks
Details of revisions							
1.	MATH-251	Ordinary Differential Equations	3-0	No	Yes	Yes	Moved from 3rd to 2nd year and contents revised
2.	MATH-353	Partial Differential Equations	3-0	No	No	Yes	Book changed and contents revised
3.	MATH-221	Linear Algebra	3-0	Yes	No	Yes	Moved from 3rd to 2nd semester. Credits reduced to 3-0.
4.	MATH-332	Numerical Analysis-I	3-0	No	No	Yes	Contents revised
5.	MATH-423	Rings and Fields	3-0	No	No	Yes	Contents revised, Book Edition updated
6.	MATH-445	Measure and Integration	3-0	No	No	Yes	Book changed and contents revised
7.	MATH-455	Integral Equations	3-0	No	No	Yes	Book changed and contents revised
8.	MATH-471	Cryptography	3-0	No	No	Yes	Book changed and contents revised
9.	MATH-491	Fluid Mechanics	3-0	No	No	Yes	Book changed and contents revised
10.	DS-201	Introduction to Data Science	2-1	Yes	No	No	
11.	DS-302	Machine Learning for Data Analysis	3-1	Yes	No	No	
12.	FL-100	Foreign Language (Chinese-I)	3-0	No	Yes	No	
Courses with no change							
1.	MATH-272	Discrete Mathematics and Applications	3-0	-	-	-	-
2.	MATH-274	Elementary Number Theory	3-0	-	-	-	-

3.	MATH-426	Module Theory	3-0	-	-	-	-
4.	MATH-433	Numerical Analysis-II	3-0	-	-	-	-
5.	MATH-434	Numerical Linear Algebra	3-0	-	-	-	-
6.	MATH-456	Discrete Dynamical Systems	3-0	-	-	-	-
7.	MATH-473	Operations Research	3-0	-	-	-	-
8.	MATH-492	Computational Fluid Dynamics	3-0	-	-	-	-
9.	MATH-263	Probability Theory	3-0	-	-	-	-
10.	MATH-264	Introduction to Statistics	3-0	-	-	-	-
11.	MATH-325	Group Theory-I	3-0	-	-	-	-
12.	MATH-345	Topology-I	3-0	-	-	-	-
13.	MATH-382	Differential Geometry	3-0	-	-	-	-
14.	MATH-421	Group Theory-II	3-0	-	-	-	-
15.	MATH-447	Topology-II	3-0	-	-	-	-
16.	MATH-480	Tensor Calculus	3-0	-	-	-	-
17.	MATH-111	Calculus-I	3-0	-	-	-	-
18.	MATH-112	Calculus-II	3-0	-	-	-	-
19.	MATH-213	Calculus-III	3-0	-	-	-	-
20.	MATH-235	Mathematical Computing	2-1	-	-	-	-
21.	MATH-242	Real Analysis-I	3-0	-	-	-	-
22.	MATH-342	Real Analysis-II	3-0	-	-	-	-
23.	MATH-343	Complex Analysis	3-0	-	-	-	-
24.	MATH-435	Introduction to Finite Element Method	3-0	-	-	-	-
25.	MATH-436	Introduction to Approximation Theory	3-0	-	-	-	-
26.	MATH-446	Functional Analysis	3-0	-	-	-	-
27.	MATH-463	Stochastic Processes	3-0	-	-	-	-
28.	MATH-475	Game Theory	3-0	-	-	-	-
29.	FL-101	Foreign Language (Turkish)	3-0	-	-	-	-
New courses included							

1.	MATH-352	Mathematical Methods	3-0	-	-	-	-
2.	MATH-113	Set Theory	3-0	-	-	-	-
3.	DS-403	Data Mining	3-0				
4.	FL-400	Foreign Language (Chinese-II)	3-0	-	-	-	-
5.	DS-404	Artificial Neural Networks	3-1		-	-	-
6.	DS 405	Experimental Design for Data Science	3-0				
7.	DS 406	Time Series Analysis and Forecasting	3-0				
8.	DS 407	Artificial Intelligence	3-1				
Courses discarded							
Replaced with new courses							
1.	MATH-354	Calculus of Variations	3-0	-	-	-	Merged in Mathematical Methods
2.	MATH-452	Ordinary Differential Equations-II	3-0	-	-	-	Merged in Mathematical Methods
3.	PHY-107	Electricity and Magnetism	3-1	-	-	-	Replaced with Set Theory
4.	CS-220	Data Structures and Algorithms	3-1	-	-	-	Replaced with DS-302 Machine Learning for Data Analysis
5.	DS-403	Data Mining for Big Data	2-1	-	-	-	Replaced with DS-403 Data Mining
6.	DS-404	Information Visualization	2-1	-	-	-	Replaced with DS-404 Neural Networks
7.	CH-103	Chemistry-I	3-1	-	-	-	Replaced with DS-201 Introduction to Data Science
Discarded courses not replaced							
1	MATH-457	Mathematical Modelling	3-0	-	-	-	Contents overlap with Ordinary Differential Equations and Discrete Mathematics
2	PHY-204	Electrodynamics-I	3-0	-	-	-	PHY-107 Electricity and Magnetism is prerequisite for this course.
3	MATH-483	Spherical Trigonometry	3-0	-	-	-	Offered once in 10 years
4	ECO-111	Principles of Macroeconomics	3-0	-	-	-	Discarded to make space for FYP

Annex B

Detailed Course Contents

MATH-111 Calculus-I

Credit Hours: 3-0
Prerequisite: None

Course Objectives: Calculus serves as the foundation of advanced subjects in all areas of mathematics. The objective of this course is to introduce students to the fundamental concepts of limit, continuity, differential and integral calculus of functions of one variable. This FIRST course of Calculus covers in depth the differential calculus portion of a three-course calculus sequence.
Core Contents: Functions in numerical, graphical, and analytical forms, continuity, limits, derivatives and integrals, derivatives and integrals, Riemann Sum.
Detailed Course Contents: Functions and Their Graphs, Combining Functions; Shifting and Scaling Graphs, Trigonometric Functions, Rates of Change and Tangent Lines to Curves, Limit of a Function and Limit Laws, The Precise Definition of a Limit, One Sided Limit, Continuity, Limits Involving Infinity; Asymptotes of Graphs, Tangent Lines and the Derivative at a Point, The Derivative as a Function, Differentiation Rules, The Derivative as a Rate of Change, Derivatives of Trigonometric Functions, The Chain Rule, Implicit Differentiation, Linearization and Differentials, Extreme Values of Functions on Closed Intervals, The Mean Value Theorem, Monotonic Functions and the First Derivative Test, Concavity and Curve Sketching, Antiderivatives, Area and Estimating with Finite Sums, Sigma Notation and Limits of Finite Sums, The Definite Integral, The Fundamental Theorem of Calculus, Indefinite Integrals and the Substitution Method, Definite Integral Substitutions and the Area Between Curves, Volumes Using Cross-Sections, Arc Length, Areas of Surfaces of Revolution, Inverse Functions and Their Derivatives, Natural Logarithms, Exponential Functions, Indeterminate Forms and L'Hopital's Rule, Inverse Trigonometric Functions, Hyperbolic Functions
Course Outcomes: After completing this course, students should have developed a clear understanding of the fundamental concepts of single variable calculus and a range of skills allowing them to work effectively with the concepts.
After completing this course, students should demonstrate competency in the following skills:

- Use both the limit definition and rules of differentiation to differentiate functions.
- Sketch the graph of a function using asymptotes, critical points, the derivative test for increasing/decreasing functions, and concavity.
- Apply differentiation to solve applied max/min problems.
- Apply differentiation to solve related rates problems.

Textbook: J. Hass, C. Heil and M. E. Weir, Thomas' Calculus, 14th Edition, Pearson, 2017
Reference Books:

- James Stewart, Single Variable Calculus: Early Transcendentals 6th edition, Pacific Grove, Ca: Brooks/Cole, Thompson Learning, 2008.
- H. Anton, I. Bevens, S. Davis, Calculus, 8th Edition, John Wiley & Sons, Inc. 2005.
- Hughes-Hallett, Gleason, McCallum, et al, Calculus Single and Multivariable, 3rd Edition, John Wiley & Sons, Inc. 2002.
- Frank A. Jr, Elliott Mendelson, Calculus, Schaum's outlines series, 4th Ed. 1999.

- C. H. Edward and E. D. Penney, Calculus and Analytics Geometry, Prentice Hall, 1988.
- E. W. Swokowski, Calculus and Analytic Geometry, PWS Publishers, Boston, Massachosetts, 1983.

Weekly Breakdown		
Week	***Section***	***Topics***
1	1.1, 1.2	Functions and Their Graphs, Combining Functions; Shifting and Scaling Graphs
2	1.3, 2.1, 2.2	Trigonometric Functions, Rates of Change and Tangent Lines to Curves, Limit of a Function and Limit Laws
3	2.3-2.5	The Precise Definition of a Limit, One Sided Limit, Continuity
4	2.6	Limits Involving Infinity; Asymptotes of Graphs
5	3.1, 3.2	Tangent Lines and the Derivative at a Point, The Derivative as a Function
6	3.3, 3.4, 3.5	Differentiation Rules, The Derivative as a Rate of Change, Derivatives ofTrigonometric Functions
7	3.6, 3.7, 3.9	The Chain Rule, Implicit Differentiation, Linearization and Differentials
8	4.1, 4.2,	Extreme Values of Functions on Closed Intervals, The Mean Value Theorem
9	**Mid Semester Exam**	
10	4.3, 4.4, 4.7	Monotonic Functions and the First Derivative Test, Concavity and CurveSketching, Antiderivatives
11	5.1, 5.2,	Area and Estimating with Finite Sums, Sigma Notation and Limits of FiniteSums,
12	5.3	The Definite Integrals
13	5.4, 5.5	The Fundamental Theorem of Calculus, Indefinite Integrals and the SubstitutionMethod
14	5.6, 6.1, 6.3	Definite Integral Substitutions and the Area Between Curves, Volumes Using Cross-Sections, Arc Length
15	6.4, 7.1, 7.2	Areas of Surfaces of Revolution, Inverse Functions and Their Derivatives, Natural Logarithms
16	7.3, 7.5	Exponential Functions, Indeterminate Forms and L'Hopital's Rule
17	7.6, 7.7	Inverse Trigonometric Functions, Hyperbolic Functions
18	**End Semester Exam**	

MATH-112 Calculus-II

Credit Hours: 3-0
Prerequisite: None

Course Objectives: This is the second course of Calculus. As continuation of Calculus I, it focuses on techniques of integration and applications of integrals. The course also aims at introducing the students to infinite series, parametric curves and polar coordinates.

Core Contents: Integration techniques and applications of integration, Infinite Series, Vectors and Geometry of Space.

Detailed Course Contents: Techniques of integration: Integrals of elementary, hyperbolic,trigonometric, logarithmic and exponential functions. Integration by parts, substitution and partial fractions. Approximate integration. Improper integrals.

Applications of integrals: Area between curves, average value. Volumes. Arc length. Area of a surface of revolution. Applications to economics, physics, engineering and biology.

Infinite series: Sequences and series. Convergence and absolute convergence. Tests for convergence: divergence test, integral test, p-series test, comparison test, limit comparison test, alternating series test, ratio test, root test. Power series. Convergence of power series. Representation of functions as power series. Differentiation and integration of power series. Taylor and Maclaurin series. Approximations by Taylor polynomials.

Conic section, parameterized curves and polar coordinates: Curves defined by parametric equations. Calculus with parametric curves: tangents, areas, arc length. Polar coordinates. Polar curves, tangents to polar curves. Areas and arc length in polar coordinates.

Course Outcomes: Upon completion of the course, the student will be able to:

- Integrate various types of functions using the various integration methods: substitution rule, integration by parts, trigonometric substitutions, partial fractions and rational substitutions.
- Apply integration to find areas, volumes, arc length, and surface areas and evaluate improper integrals.
- Find the limit of sequences, use various convergence tests (geometric series test, divergence test, integral test, comparison tests, alternating series tests, ratio test, and root test) to determine convergence or divergence of series, estimate sum of some series,
- Find the interval and radius of convergence of power series and represent some functions as power series.
- Find vector projections, equations of lines and planes in space understand quadratic surfaces.

Text Book: Joel Hass, Christopher Heil and Maurice D. Weir, Thomas' Calculus, 14th Edition. Pearson Company, 2017

Reference Books:

1. Stewart, James. Single Variable Calculus: Early Transcendentals 6th edition. PacificGrove, Ca: Brooks/Cole, Thompson Learning, 2008.
2. H. Anton, I. Bevens, S. Davis, Calculus, 8th Edition, John Wiley & Sons, Inc. 2005
3. Hughes-Hallett, Gleason, McCallum, et al, Calculus Single and Multivariable,
4. 3rd Edition. John Wiley & Sons, Inc. 2002.
5. C.H. Edward and E.D Penney, Calculus and Analytics Geometry, Prentice Hall, Inc. 1988.
6. E. W. Swokowski, Calculus and Analytic Geometry, PWS Publishers, Boston,Massachosetts.

Weekly Breakdown		
Week	***Section***	***Topics***
1	8.1, 8.2	Basic Integration Formulas, Integration by Parts
2	8.3-8.5	Trigonometric Integrals, Trigonometric Substitutions, Integration of Rational Functions by Partial Fractions
3	8.8	Improper Integrals
4	10.1, 10.2	Sequences, Infinite Series
5	10.3, 10.4	The Integral Test, Comparison Tests
6	10.5, 10.6	Absolute Convergence, The Ratio and Root Tests
7	10.7, 10.8	Power Series, Taylor and Maclaurin Series
8	10.9, 10.10	Convergence of Taylor Series, Applications of Taylor Series
9	**Mid Semester Exam**	
10	11.1, 11.2	Parametrization of Plane Curves, Calculus with Parametric Curves
11	11.3, 11.4	Polar Coordinates, Graphing Polar Coordinate Equations
12	11.5	Areas and Lengths in Polar Coordinates
13	11.6, 11.7	Conic Sections, Conics in Polar Coordinates, Note: The topic "Quadratic Equations and Rotations" should be covered from Section 10.3 of the 11th Edition of Thomas' Calculus.
14	12.1, 12.2	Three-Dimensional Coordinate Systems, Vectors
15	12.3, 12.4	The Dot Product, The Cross Product
16	12.5	Lines and Planes in Space
17	12.6	Cylinders and Quadratic Surfaces
18	**End Semester Exam**	

<u>MATH-113 Set Theory</u>

Credit Hours: 3-0
Prerequisite: Nil

Course Objectives: Everything mathematicians do can be reduced to statements about sets, equality and membership which are basics of set theory. This course introduces these basic concepts. The course aims at familiarizing the students with cardinals, relations and fundamentals of propositional and predicate logics.
Core Contents: Sets, ordered pairs, Arbitrary union and intersections, Generalized De-Morgan's law, direct and inverse image of functions, Relation on sets, equivalence relations, partially ordered relations, lexicographical ordered, Quotient of Equivalence relation# Conditionally completeness, Well-ordered Classes, Axioms of Choice and their application, Hausdorff's Maximal Principle, Zorn's Lemma, Countability axioms, Ordinality axioms
Course Contents: Building Sentences, Building Classes, Algebra of Classes, Ordered pairs, Cartesian

products, Classes of Ordered pairs, Index Classes, Arbitrary union and intersection and related results, Generalized De-Morgan's laws, Power sets, Basic properties of Function, Surjective, injective and Bijective functions, Composite functions, invertible functions, direct and inverse image of functions, Finite and arbitrary product of family of classes Projection mappings, Relations on Sets, Equivalence Relations and Order Relations, Partition of a set, Pre-image, restriction and quotient of equivalence relations, Partially ordered and Lexicographical ordered Relations, Comparable sets, Order preserving functions and isomorphisms, Maximal, minimal, maximum, minimum elements, upper bound, lower bound, infimum, supremum of a set and their properties, Conditionally Completeness, Lattice, Boolean Algebra, Well-ordered Classes, Sections, Principle of Transfinite Induction, Axioms of Choice and their applications, Hausdorff's Maximal Principle, Zorn's Lemma, Well-ordering theorems and Conclusions, Axioms of Cardinality and their properties, Special properties of infinite cardinal numbers, Axioms of ordinal numbers and its properties

Course Outcomes: Upon completion of this course, the student should be able to understand:

- Arbitrary Union and intersection and Generalized De-Morgan's law, Invertible functions, Direct and inverse image of functions and their properties
- Equivalence, partially ordered relation and Lexicographical ordered relation, partition of a set
- Lattice, infimum, supremum, maximal and minimal elements, Boolean Algebra, conditionally completeness
- Axioms of Choice and their applications, Hausdorff's Maximal Principle, Zorn's Lemma

Text Book: C. C. Pinter, "A Book of Set Theory", Dover Publication, New York, Revised Edition (2014).

Reference Books:

1. A. A. Fraenkel, "Abstract Set Theory", North Holland Publishing Company, (1966).
2. P. T. Johnstone, "Notes on Logics and Set Theory", Cambridge University Press, (1996)
3. R. R. Stoll, "Set Theory and Logic", Dover Publication Inc., New York, (1979)

Weekly Breakdown		
Week	*Section*	*Topics*
1	Chap.1 Sec. 1-3	Building Sentences, Building Classes and related theorems, Algebra of Classes
2	Chap.1 Sec. 4-5	Ordered and unordered pairs, Cartesian products, Classes of Ordered pairs and related theorems
3	Chap. 1 Sec. 6-7	Index Classes, Arbitrary union and intersection and related results, Generalized De-Morgan's laws, Sets, Power sets and related theorems
4	Chap. 2 Sec. 2-4	Functions, Basic properties of Function, Surjective, injective and Bijective functions, Composite functions, invertible functions and related results, direct and inverse image of functions and theorems
5	Chap. 2 Sec. 5-6, Chap. 3 Sec. 1	Finite Product of family of classes, arbitrary product of family of classes and related results, Projection mappings, The axioms of Replacements and theorems, Relations on Sets
6	Chap. 3 Sec. 2-4,	Equivalence Relations and Order Relations, Partition of a set and related results, Pre-image, restriction and quotient of equivalence relations
7	Chap. 4 Sec. 1-2,	Partially ordered and Lexicographical ordered Relations, Comparable sets, Segments of a set, Order preserving functions and isomorphisms, and related results
8	Chap. 4 Sec. 3-4,	Maximal, minimal, maximum, minimum elements, upper bound, lower bound, infimum, supremum of a set and their properties, Conditionally Completeness, Lattice, Sublattice, Boolean Algebra

9	**Mid Semester Exam**	
10	Chap. 4 Sec. 5, Chap. 5 Sec. 1-2	Well-ordered Classes, immediate predecessor, Sections, Principle of Transfinite Induction, Axioms of Choice and their proofs
11	Chap. 5 Sec. 3-4,	Application of Axioms of Choice, Hausdorff's Maximal Principle, Zorn's Lemma
12	Chap. 5 Sec. 5-6,	Well-ordering theorems, Conclusions, and Examples
13	Chap. 7 Sect. 1-3,	Finite and infinite sets, Equipotent of Sets, denumerable set, Properties of infinite sets, and countability axioms
14	Chap. 8 Sec. 1-2, 4	Axioms of Cardinality, Operations on Cardinal numbers, Special properties of infinite cardinal numbers
15	Chap. 9 Sec. 1-2	Axioms of Ordinal numbers, Operations on ordinal numbers and related results
16	Chap. 9 sec. 3	Well-orderedness of ordinal numbers, ordering of ordinal numbers and its properties
17		Review
18	End Semester Exam	

MATH-213 Calculus-III

Credit Hours: 3-0
Prerequisite: MATH-111 Calculus-I

Course Objectives: This is the third course of Calculus and builds up on the concepts learned in first two courses. The students would be introduced to the vector calculus, the calculus of multivariable functions and double and triple integrals along with their applications.
Core Contents: Analytic geometry in three dimensions, Vectors, continuity and limit for a function of three variables, Directional derivatives, Multiple integrals, Green's, Divergence and Stokes' theorems.
Detailed Course Contents: Curves in Space and Their Tangents, Integrals of Vector Functions;Projectile Motion, Arc Length in Space, Curvature and Normal Vectors of a Curve, Tangential and Normal Components of Acceleration, Velocity and Acceleration in Polar Coordinates Functions of Several Variables, Limits and Continuity in Higher Dimensions, Partial Derivatives,The Chain Rule.
Directional Derivatives and Gradient Vectors, Tangent Planes and Differentials, Extreme Values and Saddle Points, Taylor's Formula for Two Variables, Partial Derivatives with Constrained Variables, Double and Iterated Integrals over Rectangles, Double Integrals over General Regions Area by Double Integration, Double Integrals in Polar Form.
Triple Integrals in Rectangular Coordinates, Triple Integrals in Cylindrical and Spherical Coordinates, Substitutions in Multiple Integrals, Line Integrals of Scalar Functions, Vector Fields and Line Integrals: Work, Circulation, and Flux, Path Independence, Conservative Fields, and Potential Functions, Green's Theorem in the Plane, Surfaces and Area, Surface Integrals,Stokes Theorem, The Divergence Theorem and a Unified Theory.

Course Outcomes: After reading this course the students will be able to

- Handle vectors fluently in solving problems involving the geometry of lines, curves, planes, and surfaces in space.
- Visualize and draw graphs of surfaces in space.
- Differentiate functions of vectors.
- Calculate extreme values using Lagrange multipliers.
- Solve double and triple integrals.
- Use various theorems to convert integrals from surface to volume and/or line integrals

Textbook: J. Hass, C. Heil and M. E. Weir, Thomas' Calculus, 14th Edition, Pearson, 2017

Reference Books:

1. J. Stewart, Single Variable Calculus: Early Transcendentals, 6th Edition, Pacific Grove,Ca: Brooks/Cole, Thompson Learning, 2008.
2. H. Anton, I. Bevens, S. Davis, Calculus, 8th Edition, John Wiley & Sons, Inc. 2005
3. Hughes-Hallett, Gleason, McCallum, et al, Calculus Single and Multivariable, 3rd Edition. John Wiley & Sons, Inc. 2002.
4. Frank A. Jr, Elliott Mendelson, Calculus, Schaum's outlines series, 4th Edition, 1999
5. C. H. Edward and E. D. Penney, Calculus and Analytics Geometry, Prentice Hall, Inc.1988
6. E. W. Swokowski, Calculus and Analytic Geometry, PWS Publishers, Boston, Massachusetts, 1983.

Weekly Breakdown		
Week	***Section***	***Topics***
1	13.1, 13.2	Curves in Space and Their Tangents, Integrals of Vector Functions; Projectile Motion
2	13.3-13.5	Arc Length in Space, Curvature and Normal Vectors of a Curve, Tangential and Normal Components of Acceleration
3	13.6	Velocity and Acceleration in Polar Coordinates
4	14.1, 14.2	Functions of Several Variables, Limits and Continuity in Higher Dimensions
5	14.3, 14.4	Partial Derivatives, The Chain Rule
6	14.5, 14.6	Directional Derivatives and Gradient Vectors, Tangent Planes and Differentials
7	14.7	Extreme Values and Saddle Points
8	14.9, 14.10	Taylor's Formula for Two Variables, Partial Derivatives with Constrained Variables
9	**Mid Semester Exam**	
10	15.1, 15.2	Double and Iterated Integrals over Rectangles, Double Integrals overGeneral Regions
11	5.3, 15.4	Area by Double Integration, Double Integrals in Polar Form
12	15.5, 15.7	Triple Integrals in Rectangular Coordinates, Triple Integrals in Cylindrical and Spherical Coordinates
13	15.8, 16.1	Substitutions in Multiple Integrals, Line Integrals of Scalar Functions,
14	16.2	Vector Fields and Line Integrals: Work, Circulation, and Flux
15	16.3-16.5	Path Independence, Conservative Fields, and Potential Functions,Green's Theorem in the Plane, Surfaces and Area
16	6.6, 16.7	Surface Integrals, Stokes' Theorem
17	16.8	The Divergence Theorem and a Unified Theory
18	**End Semester Exam**	

MATH-221 Linear Algebra

Credit Hours: 3-0
Prerequisite: None

Course Objectives: Linear algebra is the study of vector spaces and linear transformations. The main objective of this course is to help students learn in rigorous manner, the tools, and methods essential for studying the solution spaces of problems in mathematics, engineering, the natural sciences, and social sciences and develop mathematical skills needed to apply these to the problems arising within their field of study and to various real-world problems.
Core Contents: Linear systems, Vector Spaces, Vector subspaces, Finite dimensional vector spaces, Linear mappings, Eigen values, Eigen vectors.
Detailed Contents: Matrices, operation on matrices, echelon and reduced echelon form, inverse of a, solution of linear system, Gaussian elimination, determinants of a matrix, computing higher

order determinants, expansion of determinants, vector spaces, subspaces, linear combination and spanning set, linear dependence and independence, finite dimensional vector spaces, bases and dimension of a vector space, operations on subspaces, intersections, sums, eigen values and eigen vectors diagonalization, orthogonal diagonalization, linear transformations, kernel and image of a linear transformation, isomorphism and composition, matrix of a linear map, change of basis, invariant subspaces and direct sums, inner product spaces, norms, Cauchy inequality.

Course Outcomes: On successful completion of this course, students will know

- Matrices, operation on matrices, echelon and reduced echelon form, inverse of a matrix (by elementary row operations), solution of linear system.
- Gauss-Jordan method, Gaussian elimination, determinants of a matrix, computing of determinants, definition of higher order determinants, expansion of determinants.
- Vector spaces, subspaces, linear combination and spanning set, linear dependence and independence.
- Bases and dimension of a vector space, finite dimensional vector spaces.
- Operations on subspaces, intersections, sums of subspaces.
- Eigenvalues and eigenvectors, diagonalization.
- Kernel and image of a linear mapping, isomorphism, invariant subspaces, and direct sums.
- Matrix of a linear map, change of basis.

Text Book: W. K. Nicholson, Linear Algebra with Applications, (2021), Lyryx Learning Inc. (open edition).

Reference Books

S. J. Axler: Linear Algebra Done Right (Undergraduate Texts in Mathematics), 1996, Springer Verlag.

Richard O. Hill: Elementary linear algebra with applications, 3rd edition, 1995, Brooks/Cole.

Steven J. Leon: Linear algebra with applications, 6th edition, 2002, Prentice Hall.

Weekly Breakdown		
Week	***Section***	***Topics***
1	Sec 1.1	Solutions of linear systems and elementary operations.
2	Sec 1.2, 1.3	Gaussian elimination, homogenous equations.
3	Sec 2.1-2.3	Matrix addition, scalar multiplication, transposition, matrix-vector multiplication, matrix multiplication.
4	Sec 2.4, 2.5	Matrix inverses, elementary matrices.
5	Sec. 2.6	Linear transformation.
6	Sec 3.1, 3.2	The cofactor expansion, determinants, and matrix inverses.
7	Sec 3.3	Diagonalization and eigenvalues.
8	Sec 5.1	Vector spaces (R^n), subspaces and spanning.
9	**Mid Semester Exam**	

10	Sec 5.2, 5.3	Linear independence and dimension, Orthogonality.
11	Sec 5.4, 5.5	Rank of a matrix, similarity, and diagonalization.
12	Sec 6.1, 6.2	Vector spaces, examples and basics properties, subspaces and spanning sets.
13	Sec 6.3, 6.4	Linear independence and dimension, finite dimensional spaces.
14	Sec 7.1, 7.2	Linear transformation, examples and elementary properties, kernel and image of linear transformation.
15	Sec 7.3	Isomorphism and composition.
16	Sec 9.1, 9.3	The matrix of a linear transformation, invariant subspaces and direct sums.
17	Sec 10.1, 10.2	Inner product and norms, orthogonal sets of vectors and Gram-Schmidt orthogonalization.
18	**End Semester Exam**	

MATH-235 Mathematical Computing

Credit Hours: 2-1
Prerequisite: None

Course Objectives: The objective of this course is to give practical introduction of the two most broadly utilized numerical computing softwares: MATLAB and Python. The main goal of this course is to make students to learn these softwares so that they are way better prepared for future research areas. This course is planned for the students of Mathematics but students of other disciplines can also opt this subject.
Core Contents: Vectors and matrices, Script and function files, Loops, Array operations, Plotting, Programming and debugging of code
Detailed Course Contents: MATLAB: Introduction to the basic environment, MATLAB Desktop, syntax, variables, strings,
Vectors, Matrices, Basic program writing in MATLAB, Loops (for, while, if loops), Functions, Array operations, solving systems of linear equations, Two and three dimensional plots in MATLAB.
Python: Introduction to basic environment, Core objects, Variables, Input and Output,Programming in Python (for, while loops), Functions and user-defined functions, Plotting.
Course Outcomes: On successful completion of this course, students will be able to:
use these softwares in applications
plot, modify and present graphs to analyze data
program different mathematical methods
use the built-in functions efficiently
use a number of techniques that are useful for future courses like Numerical Analysis and Machine Learning
Textbooks:

1. Gilat, Amos (AG). MATLAB: An introduction with Applications. John Wiley & Sons,2014.
2. Pine, David J (DP). Introduction to Python for Science and Engineering. CRC Press, 2018.

Reference Books:

1. Chapman, Stephen J. MATLAB Programming for Engineers. Nelson Education, 2015.
2. Schneider, David I. An Introduction to Programming using Python. Pearson, 2016.

Weekly Breakdown		
Week	***Section***	***Topics***
1	(AG) 1.1-1.6 , 1.6.1, 1.7, 1.8, 1.8.2 , 1.8.3	Starting MATLAB, MATLAB Windows, Working in the Command Window, Arithmetic Operations with Scalars, Order of Precedence, Using MATLAB as a Calculator, Display Formats, Elementary Math Built-in Functions, Defining Scalar Variables, The Assignment Operator, Useful Commands for Managing Variables, Script Files, Creating and Saving a Script File, Running (Executing) a Script File

2	2.1-2.2.1 2.4-2.5.2	Creating a One-dimensional Array (vector), Creating a Two-dimensional Array (matrix), The zeros, ones and eye commands, The Transpose Operator, Array Addressing, Vector, Matrix
3	2.6-2.10	Using a Colon: In Addressing Arrays, Adding Elements to Existing Variables, Deleting Elements, Built-in Functions for Handling Arrays, Strings and Strings as Variables
4	3.1-3.7	Addition and Subtraction, Array Multiplication, Array Division, Element by Element Operations, Using Arrays in MATLAB Built-in Math Functions, Built-in Functions for Analyzing Arrays, Generation of Random Numbers
5	4.1-4.5.1	The MATLAB Workspace and the Workspace Window, Input to a Script File, Output Commands, the disp command, the fprintf command, The save and load commands, the save Command, the load command, Importing and Exporting Data, Commands for Importing and Exporting Data
6	5.1-5.6, 5.8-5.11	The plot command, Plot of Given Data, Plot of a Function, The fplot Command, Plotting Multiple Graphs in the Same Plot, Using the plot Command, Using the hold on and hold off commands, Using the line Command, Formatting a Plot, Formatting a Plot Using Commands, Plots with Logarithmic Axes, Plots with Error Bars, Histograms, Polar Plots, Putting Multiple Plots on the Same Page, MultipleFigure Windows
7	6.1-6.6	Relational and Logical Operators, Conditional Statements, The if-end Structure, The if-else-end Structure, The if-elseif-else-end Structure, The Switch-case Statement, Loops, for-end Loops, while-end Loops, Nested Loops and Nested Conditional Statements, The break and continue Commands
8	7.1-7.5	Creating a Function File, Structure of a Function File, Function Definition Line, Input and Output Arguments, The H1 Line and Help Text Lines, Function Body, Local and Global Variables, Saving a Function File, Using a User-Defined Function
9	**Mid Semester Exam**	
10	7.6-7.11	Examples of Simple User-Defined Functions, Comparison between Script Files and Function Files, Anonymous Functions, Function Functions, Using Function Handles for Passing a Function into a Function Function, Using a Function Name for Passing a Function into a Function Function, Subfunctions, Nested Functions
11	10.1-0.4	Line Plots, Mesh and Surface Plots, Plots with Special Graphics,The viewCommand
12	(DP) 1.1, 2.1, 2.3, 2.4,	Introduction to Python for Science and Engineering, Interacting with Python, The Spyder Window, The IPython Pane, Interactive Python as a Calculator, Binary Arithmetic Operations in Python, Types of Numbers, Important Note on Integer Division in Python, Names and the Assignment Operator, Legal and Recommended Variable Names, Reserved Words in Python, Script Files and Programs, First Scripting Example: The Editor Pane,

	2.5 -2.8	Python Modules, Python Modules and Functions: A First Look, Some NumPy Functions, Scripting Example 2, Different Ways of Importing Modules
13	3.1-3.3, 3.5	Strings, Lists, Slicing Lists, The range Function: Sequence of Numbers, Tuples, Multidimensional Lists and Tuples, Numpy Arrays, Creating Arrays (1-d), Mathematical Operations with Arrays, Slicing and Addressing Arrays, Fancy Indexing: Boolean Masks, Multidimensional Arrays and Matrices, Difference between Lists and Arrays, Objects,
14	5.1-5.3	Conditionals, If, elif and else Statements, Logical Operators, Loops, for Loops, while Loops, Loops and Array Operations, List Comprehensions
15	6.1-6.7,	An Interactive Session with PyPlot, Basic Plotting, Specifying Line and Symbol Types and Colors, Error Bars, Setting Plotting Limits and Excluding Data, Subplots, Semi-log Plots, Log-log Plots, More Advanced Graphical Output, Plots with Multiple Axes
16	6.8 - 6.9	Mathematics and Greek Symbols, The Structure of matplotlib: OOP and All That Contour and Vector Field Plots, Making a 2D Grid of Points, Contour Plots, Streamline Plots, Three Dimensional Plots
17	7.1-7.4	User Defined Functions, Looping over Arrays in User-Defined Functions, Fast Array Processing for User Defined Functions, Functions with More than one Input or Output, Positional and Keyword Arguments, Variable Number of Arguments, Passing Function Names and Parameters as Arguments, Variable and Arrays Created Entirely within a Function, Passing Lists and Arrays to Functions: Mutable and Immutable Objects, Anonymous Functions: lambda Expressions, NumPy Object Attributes: Methods and Instance Variables
18	**End Semester Exam**	

MATH-242 Real Analysis-I

Credit Hours: 3-0
Prerequisites: MATH-111 Calculus-I

Course Objectives: This is the first rigorous course in analysis and has a theoretical emphasis. It rigorously develops the fundamental ideas of calculus and is aimed to develop the students' ability to deal with abstract mathematics and mathematical proofs.
Core Contents: The Real Number System, Continuity and Limits, Basic Properties of Functions on R, Elementary Theory of Differentiation.
Detailed Course Contents: The Real Number System and Monotone sequences: Real Numbers, Natural Numbers and Sequences, Increasing sequence and its limits.
The Limits of a sequence: Continuity, Limits, One-Sided Limits, Limits at Infinity; Infinite Limits, Limits of Sequences.
Basic Properties of Functions on R: The Intermediate-Value Theorem, Least Upper Bound; Greatest Lower Bound, The Bolzano–Weierstrass Theorem, The Boundedness and Extreme- Value Theorems.
Uniform Continuity, The Cauchy Criterion, The Heine–Borel Theorem.
Differentiation: Local Properties: The Derivative in R, Differentiation formulas, Derivatives and local properties.
Differentiation: Global Properties: The Mean value theorem and its applications, Extension of mean value theorem.
Course outcomes: Students are expected

- To understand rigorously developed fundamental ideas of calculus
- To understand basic properties of functions of single variables, theory of differentiation and integration.

Text Book: Arthur Mattuck, Introduction to Analysis, 1999 Prentice Hall, New Jersey.

Reference Books: R. L. Brabenec: Introduction to Real Analysis, 1997, PWS Publishing Co.

1. E. D. Gaughan: Introduction to Analysis (5th edition), 1997, Brooks/Cole.
2. R. G. Bartle and D. R. Sherbert: Introduction to Real Analysis (3rd edition), 1999, JohnWiley & Sons.

Weekly Breakdown		
Week	***Section***	***Topics***
1	1.1, 1.2, 1.3	Real Numbers, Increasing sequences, Limit of increasing sequences
2	1.6	Decreasing sequences, Completeness property
3	3.1, 3.2, 3.3	Definition of limit, Uniqueness of limits, Infinite limits
4	3.4,3.6,3.7	Limit of a^n, Some limits involving integrals
5	5.1,5.2,5.3, 5.4,5.5	Limits of sums, products, and quotients, Comparison theorem, Location theorem, Sub sequences: Non-existence of limits
6	6.1,6.2.6.3, 6.4,6.5	Nested Intervals, Cluster points of sequences, The Bolzano–WeierstrassTheorem, Cauchy Sequences, Completeness property for sets
7	7.1,7.2,7.3	Series and sequences, Elementary convergence tests, The

		convergenceof series with negative terms
8	7.4,7.5,7.6	Convergence tests, The integral and asymptotic comparison test, series with alternating signs, Cauchy test
9	**Mid Semester Exam**	
10	11.1, 11.2, 11.3	Continuous functions, Limits of functions, Limit theorems for functions
11	11.4, 11.5	Limits and continuous functions, Continuity and sequences
12	12.1,12.2	The existence of zeros, Applications of Bolzano's theorem
13	13.1, 13.2	Compact Intervals, Bounded continuous functions
14	13.3, 13.5	Extremal points of continuous functions, Uniform continuoty
15	14.1,14.2, 14.3	The derivative, Differentiation formulas, Derivatives and local properties
16	15.1,15.2,	The mean value theorem, Applications of the mean value theorem,
17	15.3,15.4	Extension of mean value theorem, L'Hospital rule
18	**End Semester Exam**	

MATH-251 Ordinary Differential Equations

Credit Hours: 3-0
Prerequisite: None

Course Objectives: The course aims is to provide an understanding of ordinary differential equations and to introduce methods for solving them. The course is also expected to provide students with the knowledge and skills necessary for understanding of other subjects of both mathematics and other disciplines in which differential equations are involved.
Core Contents: First order ordinary differential equations, Second and higher order linear differential equations, Linear systems and stability.
Detailed Course Contents: Introduction, classification of differential equations by type, Classification of differential equations, Initial value problems (IVP), Differential equations as mathematical models, Separable variables, Linear equations, exact equations Solution by substitution, homogenous equations, Bernoulli's equation, Linear Models, Non-linear Models
Higher order linear equation: Initial value problems and boundary, value problems. Homogeneous and nonhomogeneous equations.
Undetermined coefficients-superposition approach, Undetermined coefficient-annihilator approach, Variation of parameters, Cauchy-Euler equations. Modeling with Sytem of 1st order ordinary differential equations Solving systems of linear differential equations by elimination, nonlinear differential equations, Homogeneous linear systems, Eigenvalues and eigenvectors, distinct real eigenvalues, repeated eigenvalues, complex eigenvalues, autonomous systems as mathematical models.
Course Outcomes: Upon completion of this course, the student should be able to:

- Solve any type of first order differential equations.
- Set up and solve physical motion problems and problems of population dynamics with first order differential equations.
- Solve system of differential equations.
- Solve second order linear differential equations.
- Solve linear systems of equations.

Text Book: Dennis G. Zill, Michael R. Cullen: Differential equations with boundary value problems, (7th Edition), 2009, Brooks/Cole Cengage Learning, Canada.

Reference Books:

1. William E. Boyce and Richard C. Di Prima: Elementary Differential Equations and Boundary Value Problems (9th Edition), 2009.
2. V. I. Arnold, Ordinary Differential Equations, Springer, 1991.

Weekly Breakdown		
Week	***Section***	***Topics***
1	1.1-1.2	Introduction, classification of differential equations by type. Classification of differential equations, Initial value problems (IVP)
2	1.3, 2.2	Differential equations as mathematical models, Separable variables
3	2.3-2.5	Linear equations, exact equations. Solution by substitution, homogenous equations, Bernoulli's equation
4	3.1-3.2	Linear models, Non-linear models
5	4.1-4.3	Higher order linear equation: Initial value problems and boundary, value problems. Homogeneous and nonhomogeneous equations
6	4.4	Undetermined coefficients-superposition approach
7	4.5	Undetermined coefficient-annihilator approach
8	4.6, 4.7	Variation of parameters, Cauchy-Euler equations.
9	**Mid Term Exam**	
10	3.3	Modeling with System of 1^{st} order ordinary differential equations
11	4.8	Solving systems of linear differential equations by elimination, nonlinear differential equations
12	8.1-8.3	Homogeneous linear systems, Eigenvalues and eigenvectors, distinct real eigenvalues, repeated eigenvalues, complex eigenvalues,
13	8.4	Non-homogenous linear systems, undetermined coefficients, variation of parameters
14	10.2	Stability of Linear Systems and Phase Portraits
15	10.3	Linearization and Local Stability
16	10.4	Autonomous Systems as Mathematical Models
17		Review
18	**End Semester Exam**	

MATH-263 Probability Theory

Credit Hours: 3-0
Prerequisites: None

Course Objectives: An understanding of random phenomena is becoming increasingly important in today's world within social and political sciences, finance, life sciences and many other fields. The aim of this course is to develop the concept of chance in a mathematical framework. A prime objective of the course is to introduce the students to the fundamentals of probability theory and present techniques and basic results of the theory and illustrate these concepts with applications. This course will also present the basic principles of random variablesand random processes needed in applications.
Core Contents: Counting Techniques, Axioms of Probability, Conditional Probability and Independence, Discrete and Continuous Random Variables, Jointly Distributed Random Variables.
Detailed Course Contents: Introduction to Descriptive Statistics: Collection and Presentation of Sample Data, Some Important Features of Sample Data.
Counting Techniques. Axioms of Probability: Sample Space and Events, Axioms of Probability, Some Simple Propositions, Sample Spaces having Equally Likely Outcomes, Probability as a Continuous Set Function, and Probability as a Measure of Belief, Conditional Probability and Independence: Conditional Probability, Bayes's Formula, Independent Events. Discrete Random Variables: Random Variables, Discrete Random Variables, Expected Value, Expectation of a Function of a Random Variable, Variance, The Bernoulli and Binomial Random Variables, Properties of Binomial Random Variables, Computing the Binomial Distribution Function, The Poisson Random Variable, Computing the Poisson Distribution Function, Other Discrete Probability Distributions: The Geometric Random Variable, The Negative Binomial Random Variable, The Hypergeometric Random Variable, Expected Value of Sums of Random Variables, Properties of the Cumulative Distribution Function.
Continuous Random Variables: Expectation and Variance of Continuous Random Variables, The Uniform Random Variable, Normal Random Variable, The Normal Approximation to the Binomial Distribution, Exponential Random Variable, The Distribution Function of a Random Variable.
Jointly Distributed Random Variables: Joint Distribution, Independent Random Variables, Sums of Independent Random Variables, Identically Distributed Uniform Random Variables, Normal Random Variables, Poisson and Binomial Random Variables, Conditional Distributions: Discrete Case, Conditional Distributions: Continuous Case, Joint Probability Distribution of Functions of Random Variables, Exchangeable Random Variables.
Properties of Expectation: Expectation of Sums of Random Variables, Obtaining Bounds from Expectations via the Probabilistic Method, The Maximum–Minimums Identity, Moments of the Number of Events that Occur, Covariance, Variance of Sums and Correlations, Conditional Expectation, Computing Expectations by Conditioning, Computing Probabilities by Conditioning, Conditional Variance, Conditional Expectation and Prediction, Moment Generating Functions, Joint Moment Generating Functions.
Students will be introduced by SPSS
Course Outcomes: Students who successfully complete this course should be able to demonstrate understanding of:

- basic probability axioms and rules
- Discrete and continuous random variables

- Marginal and conditional distributions of bivariate random variables.
- Expectation and moment generating functions.

Text Book:

1. Sheldon M. Ross (B1), A First Course in Probability (8th Ed.) Pearson Education, 2010
2. Sheldon M. Ross (B2), Introductory Statistics (3th Edition) Elsevier, 2010.

Reference Books

- M. H. DeGroot and M. J. Schervish: Probability and Statistics (3rd Edition), Addison-Wesley, 2002.
- Papoulis, Probability, Random Variables, and Stochastic Processes, (3rd Edition), McGraw Hill, 1991.
- Robert B. Ash, Basic Probability Theory, Dover. 2008.
- R. E. Walpole, R. H. Myers, S. L. Myers and Keying Ye, Probability and Statistics for Engineers and Scientists (7th Edition), Prentice Hall, 2002

Students will be required to implement the contents in SPSS

Weekly Breakdown		
Week	***Section***	***Topics***
1	**(B2)** 1.2, 2.2, 3.2-3.5	Introduction to Descriptive Statistics: Collection and Presentation of SampleData. Some Important Features of Sample Data.
2	**(B1)**1.1-1.5	Counting techniques: Permutations, Combinations.
3	2.1-2.3	Sample Space and Events, Axioms of Probability.
4	2.4-2.7	Some Simple Propositions, Sample Spaces having Equally Likely Outcomes, Probability as a Continuous Set Function, Probability as a Measure of Belief.
5	3.1-3.4	Conditional Probabilities, Bayes's Formula, Independent Events.
6	4.1-4.4	Random Variables, Discrete Random Variables, Expected Value, Expectationof a Function of a Random Variable.
7	4.5, 4.6	Variance, The Bernoulli and Binomial Random Variables, Properties of Binomial Random Variables, Computing the Binomial Distribution Function.
8	4.7, 4.8	The Poisson Random Variable, Computing the Poisson Distribution Function,Other Discrete Probability Distributions: The Geometric Random Variable, The Negative Binomial Random Variable, The Hypergeometric Random Variable.
9	**Mid Semester Exam**	
10	4.9,4.10, 5.1-5.3	Expected Value of Sums of Random Variables, Properties of the Cumulative Distribution Function, Expectation and Variance of Continuous Random, Variables, The Uniform Random Variables.
11	5.4, 5.5	Normal Random Variables, The Normal Approximation to the Binomial Distribution, Exponential Random Variable.

12	5.7, 6.1	The Distribution of a Function of a Random Variable, Joint Distribution.
13	6.2-6.3	Independent Random Variables, Sums of Independent Random Variables, Identically Distributed Uniform Random Variables, Normal Random Variables, Poisson and Binomial Random Variables.
14	6.4-6.7	Conditional Distributions: Discrete Case, Conditional Distributions: Continuous Case, Joint Probability Distribution of Functions of RandomVariables, Exchangeable Random variables.
15	7.1-7.3	Expectation of Sums of Random Variables, Obtaining Bounds from Expectations via the Probabilistic Method, The Maximum–Minimums Identity, Moments of the Number of Events that occur.
16	7.4-7.6	Covariance, Variance of Sums, and Correlations, Conditional, Expectation, Computing Expectations by Conditioning, Computing Probabilities by Conditioning, Conditional Variance, Conditional Expectation and Prediction,
17	7.7	Moment Generating Functions, Joint Moment Generating Functions.
18	**End Semester Exam**	

MATH-264 Introduction to Statistics

Credit Hours: 3-0
Prerequisites: MATH-263 Probability Theory

Course Objectives: An understanding of random phenomena is becoming increasingly important in today's world within social and political sciences, finance, life sciences and many other fields. In this course the students are trained to set up mathematical models of processes and systems that are affected by chance. The students would learn techniques of estimation of parameters, confidence intervals, hypothesis testing and quality control.

Core Contents: Introduction to Descriptive Statistics, Distributions of Sampling Statistics, The method of maximum likelihood, Testing Statistical Hypotheses, Hypothesis Tests Concerning Two Populations, Analysis of Variance, Linear Regression, Chi-Squared Goodness-of-Fit Tests, Quality Control.

Detailed Course Contents: Distributions of Sampling Statistics: Sample Mean, Central Limit Theorem, Distribution of the Sample Variance of a Normal Population.
The method of Maximum Likelihood: Point Estimator of a Population Mean,Estimating a Population Variance.
Estimation: Interval Estimators of the Mean of a Normal Population with Known Population Variance, Lower and Upper Confidence Bounds, Interval Estimators of the Mean of a Normal Population with Unknown Population Variance, Lower and Upper Confidence Bounds.
Testing Statistical Hypotheses: Hypothesis Tests and Significance Levels, Tests Concerning the Mean of a Normal Population: Case of Known Variance, One-Sided Tests, The t Test for the Mean of a Normal Population: Case of Unknown Variance.
Hypothesis Tests Concerning Two Populations: Testing Equality of Means of Two Normal Populations:

Case of Known Variances, Testing Equality of Means; Unknown Variances and Large Sample Sizes, Testing Equality of Means; Small-Sample Tests when the Unknown Population Variances are Equal.
Analysis of Variance: Introduction to Analysis of Variance, One-Factor Analysis of Variance, Two-Factor Analysis of Variance; Introduction and Parameter Estimation, Two-Factor Analysis of Variance; Testing Hypotheses.
Linear Regression: Introduction to Linear Regression, Simple Linear Regression Model, Estimating the Regression Parameters, Error Random Variables, Testing the Hypothesis that $\beta = 0$, Coefficient of Determination, Sample Correlation.
Chi-Squared Goodness-of-Fit Tests: Introduction to Chi-Squared Goodness-of-Fit Tests, Testing for Independence in Populations Classified according to Two Characteristics, Testing for Independence in Contingency Tables with Fixed Marginal Totals.
Quality Control: Introduction to Quality Control, The $\bar{X}$ Control Chart for Detecting a Shift in the Mean when the Mean and Variance Are Unknown, S Control Charts, Control Charts for Fraction Defective.

Course Outcomes: After the successful completion of the course, the students are expected to understand:

- basic principles of collection and presentation of data along with some important features
- point and interval estimation of population parameters
- how different hypothesis regarding characteristics of population parameters are tested
- variance and regression analysis and quality control charts.

Text Book: Sheldon M. Ross, Introductory Statistics (3th Edition) Elsevier, 2010.

Reference Books:

1. F. Daly, D. J. Hand, M. C. Jones , A. D. Lunn , K. J. McConway, Elements of Statistics, Pearson Education, 1995. (referred as FK)
2. M. H. DeGroot and M. J. Schervish: Probability and Statistics (3th Edition) Addison-Wesley, 2002.
    A. Papoulis, Probability Random Variables and Stochastic Processes, (3thEdition) McGraw Hill, 1991.
3. R. A. Johnson, Probability and Statistics for Engineers, Prentice-Hall 1994.
4. R. E. Walpole, R. H. Myers, S. L. Myers and Keying Ye, Probability and Statistics for Engineers and Scientists (7th Edition), Prentice Hall, 2002.

Students will be required to implement the contents in SPSS

Weekly Breakdown		
Week	***Section***	***Topics***
1	7.3,7.4, 7.6	Sample Mean, Central Limit Theorem, Distribution of the Sample Mean, Distribution of the Sample Variance of a Normal Population.
2	6.3**(FK)**	The method of Maximum Likelihood,
3	8.2, 8.4	Point Estimator of a Population Mean, Estimating a Population Variance.
4	8.5,8.6	Interval Estimators of the Mean of a Normal Population with Known Population Variance, Lower and Upper Confidence Bounds, Interval Estimators of the Mean of a Normal Population with Unknown Population

		Variance, Lower and Upper Confidence Bounds.
5	9.2-9.4	Hypothesis Tests and Significance Levels, Tests Concerning the Mean of a Normal Population: Case of Known Variance, One-Sided Tests, The t Test for the Mean of a Normal Population: Case of Unknown Variance.
6	10.2,10.3	Testing Equality of Means of Two Normal Populations: Case of KnownVariances, Testing Equality of Means: Unknown Variances and Large Sample Sizes.
7	10.4, 10.5	Testing Equality of Means: Small-Sample Tests when the Unknown Population Variances are Equal, Paired-Sample t Test.
8	11.1, 11.2	Introduction to Analysis of Variance, One-Factor Analysis of Variance.
9	**Mid Semester Exam**	
10	11.3,11.4	Two-Factor Analysis of Variance: Introduction and Parameter Estimation, Two- Factor Analysis of Variance: Testing Hypotheses.
11	12.1-12.3	Introduction to Linear Regression, Simple Linear Regression Model, Estimating the Regression Parameters.
12	12.4,12.5, 12.9	Error Random Variables, Testing the Hypothesis that $\beta = 0$, Coefficient ofDetermination, Problems, Sample Correlation.
13	13.1, 3.2	Introduction to Chi-Squared Goodness-of-Fit Tests**.**
14	13.3, 13.4	Testing for Independence in Populations Classified according to Two Characteristics, Testing for Independence in Contingency Tables with Fixed Marginal Totals.
15	15.1, 15.2	Introduction to Quality Control, The X Control Chart for Detecting a Shift inthe Mean. When the Mean and Variance are unknown, S Control Charts.
16	15.3	Control Charts for Fraction Defective.
17		Review
18	**End Semester Exam**	

MATH-272 Discrete Mathematics and Applications

Credit Hours: 3-0
Prerequisites: None

Course Objectives:
To introduce students to language and methods of the area of Discrete Mathematics.
To help students in gaining the understanding of mathematical reasoning and to develop their problem solving skills.
To show students how discrete mathematics can be used in modern computer science.
Core Contents: Logic and proofs, sets and functions; Algorithms and their analysis; Mathematical reasoning, induction and recursion; Counting; Relations; Graphs and Trees.
Detailed Course Contents: Fundamentals: Logic, Propositional Equivalences, Predicates and Quantifiers, Nested Quantifiers, Methods of proof, Sets, Functions
Algorithms and their analysis: Algorithms, The growth of functions, Complexity of algorithms. Mathematical reasoning, induction and recursion: Proof Strategy, Sequences and summations, Mathematical induction, Recursive definitions and structural induction, Recursive algorithms, Program correctness.
Counting: The basics of counting, the pigeonhole principle, Recurrence relations, Generating functions, Inclusion-exclusion
Relations: Relations and their properties, n-ary relations and their applications, representing relations, Closure of relations, Equivalence relations, and Partial orderings
Graphs and Trees: Introduction to graphs, Graph terminology, Graph Isomorphism, Connectivity, Euler and Hamilton paths, Trees, Application of trees.
Course Outcomes: Upon successful completion of the course, students should have the following skills:

- Use of mathematical and logical notation to define and formally reason about mathematical concepts such as sets, relations, functions and discrete structures like trees, graphs, and partial orders;
- Evaluate elementary mathematical arguments and identify fallacious reasoning
- Construct inductive hypothesis and carry out simple induction proofs;
- Compare the asymptotic growth rates of basic functions; derive asymptotic bounds, and limits, for simple series and recurrence relations
- Reason mathematically about basic (discrete) structures (sets, graphs, and trees) used in computer science.

Text Book: Kenneth H. Rosen: Discrete Mathematics and its Applications, 5th Edition, McGraw-Hill
Reference Book: Susana S. Epp: Discrete Mathematics with Applications, fourth edition, Cengage Learning.

Weekly Breakdown		
Week	***Section***	***Topics***
1	1.1-1.3	Logic, Propositional Equivalences, Predicates, Quantifiers
2	1.4,1.5	Nested Quantifiers, Methods of Proof

3	1.6-1.8, 2.1	Sets and Functions, Algorithms
4	2.2, 2.3	The Growth of Algorithms, Complexity of Algorithms
5	3.1 ~ 3.3	Proof Strategy, Sequences, Summations, Mathematical Induction
6	3.4, 3.5	Recursive, Structural Induction, Recursive Algorithms
7	3.6	Program Correctness
8	4.1 ~ 4.2	Basics of Counting, The Pigeonhole Principal
9	**Mid Semester Exam**	
10	4.3 ~ 4.4	Permutations, Combinations, Binomial Coefficients
11	6.1-6.2	Recurrence Relations, Solving Recurrence Relations
12	6.4, 6.5	Generating Functions, Inclusion-Exclusion
13	7.1 ~ 7.3	Relations, n-ary Relations, Representing Relations
14	7.4 ~ 7.6	Closures of Relations, Equivalence Relations, Partial Orderings
15	8.1 ~ 8.3	Introduction to Graphs, Graph Terminologies, Graph Isomorphism
16	8.4, 8.5	Connectivity, Euler and Hamilton Paths
17	8.7	Planar Graphs
18	**End Semester Exam**	

MATH-274 Elementary Number Theory

Credit Hours: 3-0
Prerequisite: None

Course Objectives: The focus of the course is on study of the fundamental properties of integers and develops ability to prove basic theorems. The specific objectives include study of division algorithm, prime numbers, Euclidean algorithm, Congruences, Fermat and Euler's theorem, Diophantine equations, perfect numbers, primitive root theorem.
Core Contents: Divisibility and Factorization, Congruences, Arithmetic Functions, Quadratic Residues, Primitive Roots, Diophantine Equations
Detailed Course Contents: Divisibility and Factorization: Divisibility, Prime numbers, Greatestcommon divisors, Euclidean algorithm, Fundamental theorem of arithmetic
Congruences: Congruences, linear congruences in one variable, Chinese remainder theorem, Wilson's Theorem, Fermat's theorem, Euler's theorem
Arithmetic Functions: Arithmetic functions, multiplicative functions, Euler's Phi-function, Perfect numbers, Moebius function, Moebius inversion formula,
Quadratic Residues: Quadratic residues and non-residues, Legendre symbol, Law of quadratic reciprocity,
Primitive Roots: Order of an integer, Primitive roots for primes, Primitive root theorem Diophantine Equations: Linear Diophantine equations, Pythagorean triples, Representation of integers as sum of squares
Course Outcomes: Students are expected:

1. To understand the concept and properties of divisibility greatest common divisor.
2. Student's must understand and be able to use the Fermat's little theorem, Wilson's theorem.
3. To understand and to apply the Mobius inversion formula.
4. Compute the set of all solutions to linear congruence. Be able to apply CRT and reduce general systems of linear congruences to systems studied by CRT.
5. Describe the set of all solutions to linear Diophantine equations.

Text Book: K.H. Rosen, Elementary Number Theory and its Applications, 5th edition, Addison- Wesley, 2005.
Reference Books:

1. J. K. Strayer, Elementary Number Theory, Waveland Press, INc. 2001
2. D.M. Burton, Elementary Number Theory, McGraw-Hill, 2007.

Weekly Breakdown		
Week	***Section***	***Topics***
1	1.3-1.5	Mathematical Induction, The Fibonacci Numbers, Divisibility
2	3.1	Prime numbers
3	3.3, 3.4	Greatest Common Divisors, The Euclidean Algorithm,

4	3.5, 3.6	Fundamental Theorem of Arithmetic, Factorization Methods
5	3.6, 3.7	Fermat Numbers, Linear Diophantine Equations
6	4.1 ~ 4.3	Introduction to Congruences, Linear Congruences, The Chinese Remainder Theorem
7	4.4, 4.5	Solving Polynomial Congruences, Systems of Linear Congruences
8	6.1	Wilson's Theorem, Fermat's Little Theorem
9	**Mid Semester Exam**	
10	6.2, 6.3	Pseudoprimes, Euler's Theorem
11	7.1, 7.2	The Euler Phi-Function, the Sum and Number of Divisors
12	7.3, 7.4	Perfect Numbers, Mersenne Primes, Mobius Inversion
13	9.1	Order of an Integer, Primitive Roots
14	9.2, 9.3	Primitive Roots for Primes, Existence of Primitive Roots
15	11.1,11.2	Quadratic Residues an Nonresidues, the Law of Quadratic Reciprocity
16	11.3,11.4	The Jacobi Symbol, Euler Psedudoprimes
17		Review
18	**End Semester Exam**	

MATH-325 Group Theory-I

Credit hours: 3-0
Prerequisite: None

Course Objectives: This course aims to introduce students to the basic concepts of group theory. Algebra, developed by the Muslims, started as generalized arithmetic but went on to deal with linear, quadratic, cubic and quartic equations and systems of such equations. Later, Galois and Abel developed group theory to prove that there is no canonical solution of higher order polynomial equations by means of radicals. Two further branches of development followed the solution of simultaneous linear equations (leading to linear algebra) and the more formal structure of groups and their extensions (leading to rings and fields). This course presents the basic concepts of group theory.

Detailed Course Contents: Sets and relations, partitions and equivalence relations, binary operations, group, dihedral group, quaternion group, group of n^{th} roots of unity, group of residues, general linear group, subgroups, order of a group, order of an element of a group, cyclic groups, cyclic subgroups, generating sets, permutation, group of permutations, cycles, transpositions, even and odd permutations, alternating groups, decomposition of a permutation into disjoint cycles, cosets, index of a subgroup in a group, Lagrange's theorem, consequences of Lagrange's theorem, normal subgroups, product of subgroups, group homomorphism, properties of a homomorphism, kernel of a homomorphism, isomorphism, factor groups, the first isomorphism theorem, center subgroup.

Learning Outcomes: On successful completion of this course, students will know

- Equivalence relations on sets, equivalence classes.
- Binary operation, group, subgroup, order of a group
- Dihedral group, quaternion group, group of n^{th} roots of unity, group of residues, general linear group.
- Permutation, group of permutations, cycles, transpositions, even and odd permutations.
- Alternating group, decomposition of a permutation into disjoint cycles.
- Coset, index of a subgroup in a group, Lagrange's theorem.
- Normal subgroups, centre subgroup, commutator subgroup.
- Group homomorphism, kernel of a homomorphism, isomorphism.
- Factor group, the first isomorphism theorem.
- Product of subgroups.

Text book: J. A. Gallian, Contemporary Abstract Algebra, 8th ed. Brooks/Cole, CA, 2013.

Reference book:

1. W. Keith Nicholson, Introduction to Abstract Algebra, (3rd edition), 2007, John Wiley &sons.
2. J. H. Fraleigh: A first course in abstract algebra (7th edition), 1998, Addison-Wesley publishing.
3. N. Herstein, Abstract Algebra, third edition,1995, Prentice Hall.

Weekly Breakdown		
Week	***Section***	***Topics***
1	Ch. 0	Equivalence relations, partition, equivalence classes partition, examples and related results. Functions, types of functions and composition of functions.

2	Ch. 1,2	Binary operations, groups, definitions and examples. Group of integers modulo n, dihedral group.
3	Ch. 2	Group of quaternion, group of n^{th} roots of unity, general linear group. Elementary properties of groups.
4	Ch. 3	Subgroups, order of a group, order of an element of a group, subgroup tests,cyclic subgroups, subgroup generated by a subset of a group. The center subgroup, entralizer and normalizer subgroups.
5	Ch. 4	Cyclic groups, Properties of the cyclic groups, related theorems, examples,generators of finite cyclic groups, generators of Z_n.
6	Ch. 5	Permutation of a set, permutation group of a set, symmetric group S_n, cycle notation, product of disjoint cycles, product of disjoint cycles commute.
7	Ch. 5	Order of a permutation, transpositons (2-cycles) and related theorems, even and odd permutations, the alternating group of degree n.
8	Ch. 7	Cosets, properties of cosets, index of a subgroup in a group, definition examples related results, and the theorem of Lagrange.
9	**Mid Semester Exam**	
10	Ch. 7	Consequences of Lagrange's theorem, converse of the Lagrange theorem, Product of subgroups.
11	Ch. 9	Definition examples of direct product of groups. Normal subgroups, definitions, examples and related results.
12	Ch. 9	Factor groups, examples and related theorems.
13	Ch. 10	Group homomorphism, Properties of a homomorphism, kernel of a homomorphism, definitions, examples and related results.
14	Ch. 10	Properties of elements under homomorphism, properties of subgroups under homomorphism, kernels are normal.
15	Ch. 6,10	Normal subgroups are kernels. Isomorphism of groups. Cayley's theorem.
16	Ch. 10	The isomorphism theorems for groups, applications.
17		Review
18	**End Semester Exam**	

MATH-332 Numerical Analysis-I

Credit Hours: 3-0
Prerequisite: None
Course Objectives: Numerical Analysis deals with the approach to develop numerical algorithms for the mathematical problems which are not easily solvable with exact or analytical methods. The key topics of this subject include arithmetic errors, interpolation, numerical integration, numerical solution of algebraic linear and nonlinear equations, and short introduction of numerical solutions for ODEs.
Core contents: Approximations and Errors, Tridiagonal Matrices, Interpolating Polynomial, Quadrature rules, Euler's Method, Runge-Kutta Methods.
Course Contents: Approximations and Errors; Bisection method, Secant Method, False-Position Method, Newton-Raphson Method, Fixed Point Iteration; Gauss-Elimination and Gauss-Jordan Methods,

LU-Factorization, Cholesky Decomposition, Vector and Matrix Norms, Condition Number for Matrices, Tridiagonal Matrices; Interpolation, Linear and Quadratic Interpolation, Lagrange Polynomials, Newton's Interpolating Polynomial; Divided Differences, Forward and Backward Differences, Splines, Cubic Splines; Method of Least Squares; Numerical Integration, Trapezoidal Rule for Equally Spaced Data, Simpson's One-Third and Three-Eighth Rules for Equally Spaced Data; Derivation of Two-Point Gauss-Legendre Formulas, Higher Point Formulas, Error Analysis; Euler's Method and Second Order Runge-Kutta Methods for ODEs.

Course Outcomes: On successful completion of this course students will be able to:

- familiar with the fundamental concepts of numerical analysis.
- learn and implement programming of different numerical methods in MATLAB

Text Book: Numerical Analysis by Richard L. Burden and J. Douglas Faires, 9th Edition, Publisher: Cengage Learning, 2010. (BF)

Reference Books

1. Applied Numerical Analysis by Curtis F. Gerald and Patrick O. Wheatley, 7th Edition, Publisher: Pearson, 2003.
2. Numerical Methods for Engineers by Steven C Chapra and Raymond P Canale, 6th Edition Publisher: McGraw-Hill, 2009

Weekly Breakdown		
Week	***Section***	***Topics***
1	1.2 1.3, 2.1	Round-off Errors and Computer Arithmetic: Definition 1.15 and Definition 1.16 Algorithms and Convergence: Definition 1.17, Definition 1.18 The Bisection Method: Bisection Technique
2	2.2, 2.3	Fixed-Pont Iteration: Fixed-Point Iteration Newton's Method and Its Extensions: Newton's Method, Convergence using Newton's Method, The Secant Method
3	2.3, 2.4, 2.6	Newton's Method and Its Extensions: The Method of False Position, Error Analysis for Iterative Methods: Order of Convergence Zeros of Polynomials and Muller's Method: Algebraic Polynomials, Horner's Method
4	3.1, 3.3	Interpolation and the Lagrange Polynomials: Lagrange Interpolating Polynomials Divided Differences: Newton's Divided Difference Formula, Forward Differences, Newton's Forward Difference Formula
5	3.3, 3.4	Divided Differences: Backward Differences, Newton's Backward-Difference Formula, Centered Differences Hermite Interpolation: Hermite Polynomials, Hermite Polynomials Using Divided Differences
6	3.5, 4.1	Cubic Spline Interpolation: Piecewise-Polynomial Approximation, Cubic Splines, Construction of a Cubic Spline, Natural Splines Numerical Differentiation: Three-Point Formulas, Three-Point Endpoint Formula, Three-Point Midpoint Formula
7	4.2, 4.3	Richardson's Extrapolation: Richardson's Extrapolation. Elements of Numerical Integration: The Trapezoidal Rule, Simpson's Rule, Closed Newton-Cotes Formulas, Open Newton-Cotes Formulas
8	4.4, 4.7	Composite Numerical Integration: Composite Numerical Integration. Gaussian Quadrature: Legendre Polynomials, Gaussian Quadrature on Arbitrary Intervals
9	**Mid Semester Exam**	
10	4.9, 6.5	Improper Integrals: Left Endpoint Singularity, Right Endpoint Singularity, Infinite Singularity Matrix Factorization: LU Factorization

11	6.6	Special Type of Matrices: Cholesky Factorization, Band Matrices, Tridiagonal Matrices, Crout Factorization for Tridiagonal Linear Systems
12	7.1, 7.3, 7.4	Norms of Vectors and Matrices: Vector Norms, Distance between Vectors in R^n, Matrix Norms and Distances The Jacobi and Gauss-Seidal Iterative Techniques: Jacobi's Method, The Gauss-Seidal Method, General Iteration Methods Relaxation Techniques for Solving Linear Systems: Successive Over Relaxation (SOR)
13	7.5	Error Bounds and Iterative Refinement: Condition Numbers, Iterative Refinement
14	8.1	Discrete Least Square Approximation: Linear Least Squares, Polynomial, Least Squares
15	5.1, 5.2	The Elementary Theory of Initial Value Problems: The Elementary Theory of Initial Value Problems, Well-Posed Problem. Euler's Method: Euler's Method
16	5.4	Runge-Kutta Methods: Runge-Kutta Methods of Order Two
17		Review
18	**End Semester Exam**	

MATH-342 Real Analysis-II

Credit Hours: 3-0
Prerequisites: MATH-242 Real Analysis-I

Course Objectives: This is the second rigorous course in analysis is a continuation of MATH-242. This course rigorously develops differentiation and integration theory in $R^{n,}$ Sequences and series and their convergence, improper integrals and Riemann–Stieltjes integrals.

Core Contents: The Riemann Integral, Improper integrals, Sequences and series of Functions, Infinite sets and Lebesgue Integral

Detailed Course Contents: Differentiation and Integration: Integrability, Interability of monotone and continuous functions, Basic properties of integrable functions, First Fundamental theorem of Calculus, existence and uniqueness of antiderivatives, the logarithem and exponentialfunctions.

Sequences and series of functions: Pointwise and uniform convergence, Criteria for uniform convergence, continuity and uniform convergence, power series and analytic functions

Improper Integrals: Basic definitions, Comparison theorems, The gamma functions, Absolute and conditional convergence.

Infinite sets and Lebesgue Integral: Infinite sets, Sets of measure zero, Measure zero and Riemann integrability, Lebesgue integrals.

Continuous functions on Plane: Norms and distance in plane, Convergence of sequence, Continuous functions, Limit and continuity.

Course outcomes: Students are expected:

- To understand rigorously developed fundamental ideas of differentiation and integration
- To understand basic theory of infinite series and power series
- To understand Leibniz rule and its applications.

- To understand the Riemann Integral and their applications

Text Book: Arthur Mattuck, Introduction to Analysis, 1999 Prentice Hall, New Jersey

Reference Books:

1. R. L. Brabenec: Introduction to Real Analysis, 1997, PWS Publishing Co.
2. E. D. Gaughan: Introduction to Analysis (5th edition), 1997, Brooks/Cole.
3. R. G. Bartle and D. R. Sherbert: Introduction to Real Analysis (3rd edition), 1999, John Wiley & Sons.

Weekly Breakdown		
Week	***Section***	***Topics***
1	18.1,18.2, 18.3, 18.4	Introduction; Partitions, Integrability, Integrabilty of monotone and continuous functions, Basic properties of integrable functions
2	19.1, 19.2, 19.3	Refinement of partitions, Definition of the Riemann integral, Riemann sums.
3	19.4,19.5, 19.6	Basic properties of integrals, the interval addition property, piecewise continuous and monotone functions
4	20.1, 20.2,20.3	The first fundamental theorem of calculus, Existence and uniqueness of antiderivatives, Other relations between derivatives and integrals.
5	20.4, 20.6	The logarithm and exponential functions, Growth rate of functions
6	21.1,21.2	Improper integrals, Basic definitions, Comparison theorems
7	21.4	Absolute and conditional convergence
8	22.1	Point wise and uniform convergence,
9	**Mid Semester Exam**	
10	22.2	criteria for uniform convergence
11	22.3,	Continuity and uniform convergence,
12	22.4,22.5	Integration and differentiation term by term
13	23.1, 23.2	Infinite sets, Sets of measure zero, Lebesgue integration
14	24.1, 24.2	Norms and distances in plane, convergence of sequences,
15	24.3,24.4	Functions on R2, Continuous functions
16	24.5,24.6	Limits and continuity, compact sets in R2
17		Review
18	**End Semester Exam**	

MATH-343 Complex Analysis

Credit Hours: 3-0
Prerequisites: None
Course Objectives: Complex variables is an important area from a purely mathematical point ofview, as well as a powerful tool for solving a wide Varity of applied problems. It is founds its applications in many mathematical disciplines, including in particular real analysis, differential equations, algebra and topology. This course develops the theory of functions of a complex variable, emphasizing their geometric properties and some applications. It also treats the traditional theorems, algorithms, and applications of complex analysis. These include: finding of complex roots for polynomial equations and complex integration, residue theory and its applications.
Core contents: Complex Numbers, Analytic Functions, Elementary Functions, Integrals, Series, Residues and Poles, Conformal Mapping
Detailed Course Contents: Complex Numbers: Sums and Products, Basic Algebraic Properties, Further Properties , Vectors and Moduli , Complex Conjugates , Exponential Form , Products and Powers in Exponential Form , Arguments of Products and Quotients , Roots of Complex Numbers , Examples, Regions in the Complex Plane.
Analytic Functions: Functions of a Complex Variable, Mappings, Mappings by the Exponential Function, Limits, Theorems on Limits, contents, Limits Involving the Point at Infinity, Continuity, Derivatives, Differentiation Formulas, Cauchy–Riemann Equations, Sufficient Conditions for Differentiability, Polar Coordinates, Analytic Functions, Examples, Harmonic Functions, Uniquely Determined Analytic Functions, Reflection Principle.
Elementary Functions: The Exponential Function, The Logarithmic Function, Branches and Derivatives of Logarithms, Some Identities Involving Logarithms, Complex Exponents, Trigonometric Functions, Hyperbolic Functions, Inverse Trigonometric and Hyperbolic Functions.
Integrals: Derivatives of Functions w(t), Definite Integrals of Functions w(t), Contours, Contour Integrals, Some Examples, Examples with Branch Cuts, Upper Bounds for Moduli of Contour Integrals, Antiderivatives, Cauchy–Goursat Theorem, Simply Connected Domains, Multiply Connected Domains, Cauchy Integral Formula, An Extension of the Cauchy Integral Formula, Some Consequences of the Extension, Liouville's Theorem and the Fundamental Theorem of Algebra, Maximum Modulus Principle
Series: Convergence of Sequences, Convergence of Series, Taylor Series, Laurent Series, Absolute and Uniform Convergence of Power Series, Continuity of Sums of Power Series, Integration and Differentiation of Power Series, Uniqueness of Series Representations, Multiplication and Division of Power Series.
Residues and Poles: Isolated Singular Points, Residues, Cauchy's Residue Theorem, Residue at Infinity, The Three Types of Isolated Singular Points, Residues at Poles, Zeros of Analytic Functions, Zeros and Poles, Behavior of Functions Near Isolated Singular Points
Applications of Residues: Evaluation of Improper Integrals, Improper Integrals from Fourier Analysis, Indented Paths, Definite Integrals Involving Sines and Cosines.

Course outcomes: Students are expected to understand:

- The complex number and their geometric interpretation.
- Functions of a complex variable, limits, continuity.
- The all-important concepts of the derivative of a complex function and analyticity of afunction.
- The trigonometric, exponential, hyperbolic, and logarithmic Functions.

- The famous Cauchy-Goursat theorem and the Cauchy integral formulas.
- Concepts of complex sequences and infinite series and the Laurent series, residues, andthe residue theorem and its applications

Text Book: James W. Brown and R.V. Churchill, Complex Variables and Applications, 8th ed., McGraw-Hill, 2009.

Reference Books

1. Fundamentals of Complex Analysis, 3rd Edition, E.B. Saff and Arthur D. Snider.Prentice Hall, 2003.
2. Visual Complex Analysis, Tristan Needham, Oxford University Press, 1997.
3. Dennis G. Zill A First Course In Complex Analysis With Applications, 2003 by Jonesand Bartlett Publishers.

Weekly Breakdown		
Week	***Section***	***Topics***
1	1-13	Sums and Products, Basic Algebraic Properties, Further Properties, Vectors and Moduli, Complex Conjugates.
2	16-34	Exponential Form, Products and Powers in Exponential Form, Arguments of Products and Quotients, Roots of Complex Numbers, Regions in the Complex Plane.
3	35-52	Functions of a Complex Variable, Mappings, Mappings by the Exponential Function, Limits, Theorems on Limits, contents, Limits Involving the Point at Infinity.
4	53-88	Continuity, Derivatives, Differentiation Formulas, Cauchy–Riemann Equations, Sufficient Conditions for Differentiability, Polar Coordinates, Analytic Functions, Examples, Harmonic Functions, Uniquely Determined Analytic Functions, Reflection Principle.
5	89-100	The Exponential Function, The Logarithmic Function, Branches and Derivatives of Logarithms, Some Identities Involving Logarithms.
6	101-116	Complex Exponents, Trigonometric Functions, Hyperbolic Functions, Inverse Trigonometric and Hyperbolic Functions.
7	117-126	Derivatives of Functions w(t), Definite Integrals of Functions w(t), Contours
8	127-145	Contour Integrals, Some Examples, Examples with Branch Cuts, Upper Bounds for Moduli of Contour Integrals, Antiderivatives.
9	**Mid Semester Exam**	
10	150-175	Cauchy–Goursat Theorem, Simply Connected Domains, Multiply Connected Domains, Cauchy Integral Formula, An Extension of the Cauchy Integral Formula, Some Consequences of the Extension, Liouville's Theorem, Fundamental Theorem of Algebra and Maximum Modulus Principle(without proof)
11	181-209	Convergence of Sequences and Series, Taylor Series, Laurent Series, Absolute and Uniform Convergence of Power Series,
12	211-228	Continuity of Sums of Power series, Integration and Differentiation of Power Series, Uniqueness of Series Representations, Multiplication and Division of Power Series.
13	229-243	Isolated Singular Points, Residues, Cauchy's Residue Theorem, Residue at Infinity, The Three Types of Isolated Singular Points
14	244-257	Residues at Poles, Zeros of Analytic Functions, Zeros and Poles, Behavior of Functions Near Isolated Singular Points.
15	261-279	Evaluation of Improper Integrals, Improper Integrals from Fourier Analysis, Indented Paths
16	288-290	Definite Integrals Involving Sines and Cosines
17		Review

18	**End Semester Exam**

MATH-345 Topology-I

Credit Hours: 3-0
Prerequisite: None

Course Objectives: This course covers the fundamentals of metric and topological spaces. After the completion of this course, students would be familiar with bases, initial topology, final topology, subbase, quotient topology and completeness. They would be able to determine whether a function defined on a metric or topological space is continuous or not and what homeomorphisms are. The students would be able to determine the distance between two objectsin different metric spaces.
Detailed Course Contents: Definition of Topology and Examples, Open and Closed Sets in Topology, Bases, Subbases, Link between Topology and Bases, Interior and Closure of Sets, Limits Points and Boundary of Sets, Subspace Topology, Product Topology, Quotient Topology, Continuity, Open and Closed Maps, Initial and Final Topology, Homeomorphisms, Metrics, Open Balls, Properties of Metrics, and related results, Metrizability, Convergence in metric and topological space, 1^{st} countable and 2^{nd} Countable space, Lindelöf Space and Separable Space, T0, T1, T2, Regular and Normal Space
Course Outcomes: Students are expected to understand:

- Basic Concepts of topology, Bases, subbases, limits, closure and boundary points
- Continuity, Open and Closed Maps,
- Homeomorphisms and Topological invariants
- Initial, Final, Subspace and Product Topology
- Metric Spaces, Properties of metric spaces Convergence in Metric and topologicalspaces
- 1st Countable, 2nd Countable Spaces
- Introduction to Compactness and connectedness
- T0, T1, T2, Regular and Normal Spaces

Text Books: James R. Munkres, “Topology”, Prentice Hall, Inc. 2nd Edition (2000)
Reference Books:

1. S. Willard, “General Topology”, Addison Wesley, (1970)
2. W. A. Sutherland, “Introduction to Metric and Topological Spaces”, 2nd Edition, Oxford University Press, (2009)
3. K. D. Joshi, “Introduction to Topology”, Wiley Eastern Limited, (1984)
4. M. D. Crossley, “Essential Topology”, Springer, (2010)
5. R. Engelking, “General Topology”, Heldermann Verlag Berlin, Volume 6, (1989)
6. C. Adams & R. Franzosa, “Introduction to Topology: Pure and Applied”, Pearson,(2009).

Weekly Breakdown		
Week	***Section***	***Topics***
1	12	Definition of Topology, Examples, Coarser and Finer Topology, Open and Closed sets
2	13	Bases, Subbases, Local Bases, Link between Topology and Bases
3	14, 15	Ordered Topology, Finite Product Topology

4	16, 17	Subspace Topology, Closure of Sets, Related Results
5	17	Interior and Limit Point of sets, Boundary of set and Related results
6	18	Continuous maps and related theorems, Open and Closed Maps
7	18, 19	Homeomorphism, Topological invariants, Infinite Product Topology
8	20	Metrics, Open Balls, Closed balls and Examples, Metric Topology
9	**Mid Semester Exam**	
10	21	Properties of Metric Spaces and Metrizability, Convergence in topology and metric spaces
11	22	Quotient Topology, Initial and Final Topology
12	23, 26	Compactness and Connectedness, Some Examples
13	30	1st countable and 2nd countable space and related results
14	31	T0, T1 and T2 Spaces and Related Results
15	31	T3 and Regular Spaces and Related Results
16	32, 33	T4 and Normal Spaces and Related Results, Urysohn Lemma
17		Review
18	**End Semester Exam**	

MATH-352 Mathematical Methods

Credit Hours: 3-0
Prerequisites: MATH-251 Ordinary Differential Equations
Course Objectives: The course provides an in depth knowledge of some topics in applied mathematics that permeate various scientific disciplines. It includes techniques to derive power series solutions of ODEs with variable coefficients. Laplace transform and its application in treating of ODEs are also covered. Fourier Series, Sturm-Liouville problems and Variational problems are also included as core contents.
Core Contents: Series Solutions, Laplace Transform, Fourier Series, Sturm-Liouville Problems, Variational problems.
Detailed Course Contents: Series Solutions: Review of Power Series, Ordinary and Singular Points, Power-Series Solutions about Ordinary and Singular Points, Bessel Function and its Properties, Legendre's Equation. Laplace Transform: Definition of Laplace Transform, Transform of Derivatives, Properties of Laplace Transform, Systems of Linear ODEs. Green's Function: Boundary Value Problems Involving Ordinary Differential Equations, Construction of Green's Function, Green's Function for Ordinary Differential Equations. Fourier Series, Sturm-Liouville Problems, Variational problems.
Course Outcomes: Upon completion of this course, the student should be able to:

- Understand the power series method and implement it for solving ordinary differential equations.
- Construct Green's function and use it to solve a variety of ODEs
- Understand basics of calculus of variations.

Text Books:

1. Dennis G. Zill and Michael R. Cullen: Differential equations with boundary value problems, (7th Edition), 2009, Brooks/Cole Cengage Learning, Canada (Referred as Zill)
2. A. J. Jerri, Introduction to integral equations with applications, John Wiley & Sons,1999 (Referred as AJ)
3. Bruce van Brunt, The Calculus of Variations, Springer-verlag New York lnc, 2004 (Referred as BB)

Reference Books:

1. N. Finizio and G. Ladas, An Introduction to Differential Equations, Wadsworth Publishing Company Belmont, California, 1982
2. William E. Boyce and Richard C. DiPrima: Elementary Differential Equations and Boundary Value Problems (9th Edition), 2009, John Wiley & Sons, Inc.
3. K.T. Tang, Mathematical Methods for Engineers and Scientists Vol 3, Springer-Verlag Berlin Heidelberg 2007
4. Louis Komzsik, Applied Calculus of Variations for Engineers, CRC Press, 2009.
5. Bernard Dacorogna, Introduction to the calculus of variations, World Scientific Publishing, 1992.
6. Robert Weinstock, Calculus of variations with applications to physics and engineering, McGraw-Hill, 1952

Weekly Breakdown		
Week	**Section**	**Topics**
1	6.1.1, 6.1.2 (Zill)	Review of Power-Series; Ordinary and Singular Points; Power-Series Solutions about Ordinary Points
2	6.2	Regular and Irregular Singular Points; Classification of Singular Points; Frobenius Theorem
3	6.3.1	Bessel's Equation; Bessel functions of first and second kinds; Properties of Bessel functions and their Applications
4	6.3.2	Legendre's Equation; Legendre's Polynomials and their Properties
5	7.1, 7.2.1, 7.2.2	Definition of the Laplace Transform; Inverse Transform; Transform of Derivatives
6	7.3.1,7.3.2	Translation of the t−axis; Translation on the x−axis; Solving Initial Value Problems using Laplace Transform
7	7.4.1-7.4.3, 7.5	Derivative of a Transform; Convolution Theorem; Transform of Periodic Functions, The Dirac Delta Function, Initial-Value Problems, Systems of Linear Differential Equations
8	4.1(AJJ)	Construction of the Green's Functions: Non-homogeneous differential equations, Construction by variation of parameter, orthogonal representation,
9	**Mid Semester Exam**	
10	4.2	Boundary value problems and Greem's function.
11	11.1,11.2 (Zill)	Orthogonal Functions, Fourier Series
12	11.3, 11.4	Fourier Cosine and Sine Serie, Sturm-Liouville problems
13	11.5	Bessel and Legendre Series: Fourier-Bessel Series, Fourier-Legendre Series
14	2.1, 2.2	The First Variation: The Finite-Dimensional Case, The Euler-Lagrange Equation
15	2.3-2.5	Some Special Cases, A Degenerate Case, Invariance of the Euler-Lagrange Equation
16	3.1-3.3	Some Generalizations: Functionals Containing Higher-Order Derivatives, Several Dependent Variables Two Independent Variables

17	4.1, 4.2	Isoperimetric Problems: The Finite-Dimensional Case and Lagrange Multipliers, The Isoperimetric Problem.
18	**End Semester Exam**	

MATH-353 Partial Differential Equations

Credit Hours: 3-0
Prerequisite: MATH-251 Ordinary Differential Equations

Course Objectives: The course aims at developing an understanding about fundamental concepts of partial differential equations. Thus, the subject will provide students with the knowledge and skills necessary for an adequate understanding of other subjects of both mathematics and other disciplines in which differential equations are involved, with the final aim of being able to solve problems that arise in all the engineering fields that are governed by differential equations.
Core Contents: First order partial differential equations, second order partial differential equations, The Cauchy problem, and wave equations, Methods of separation of variables, Integral transform methods
Course Contents: Basic concepts and definitions, Mathematical problems, Linear operators, Superposition principle, Classification of first-order equations, Construction of a first-order equation, Geometrical interpretation of a first-Order Equation, Method of characteristics and general Solutions, Canonical forms of first-order linear equations, Method of separation of variables (1st order PDEs), Second-order equations in two independent variables, Canonical forms, Equations with constant coefficients, General solutions, The Cauchy, problem, Homogeneous wave equations, Initial boundary-value problems, Equations with nonhomogeneous boundary conditions, Vibration of finite string with fixed ends, Nonhomogeneous wave equations, Separation of variables, The vibrating String Problem, Dirichlet problem for a cube, Dirichlet problem for a cylinder, Dirichlet problem for a sphere, Three-dimensional wave and heat equations, Fourier transforms, Properties of Fourier transforms, Convolution theorem of the Fourier transform, The Fourier transforms of step and impulse functions, Fourier Sine and Cosine transforms, Solving PDEs by Laplace transforms.
Course Outcomes: Upon completion of this course, the student should be able to:

- Recognize and classify first order partial differential equations
- Reduce second order partial differential equations to canonical form and find general solution.
- Derive heat and wave equations.
- Solve partial differential equations by method of separation of variables.
- Apply transform methods to solve partial differential equations.

Text Book: Tyn Myint-U, Lokenath, Debnath Linear Partial Differential Equations for Scientists and Engineers, Birkhäuser, (2007).
Reference Books:

1. David. Bleecker, George. Csordas, Basic Partial Differential Equations, Chapman & Hall (1995).
2. Prem K. Kythe, Michael R. Schäferkotter and P. Puri, Partial Differential Equations and Boundary Value Problems (2nd Ed), Chapman & Hall, (2002).
3. J. Wloka, Partial Differential Equations, Cambridge University press, (1987).
4. David Borthwick, Introduction to Partial Differential Equations, Springer (2016).

Weekly Breakdown		
Week	***Section***	***Topics***
1	1.2,1.3, 1.4,1.5	Basic concepts and definitions, Mathematical problems, Linear operators, Superposition principle
2	2.2-2.4	Classification of first-order equations Construction of a first-order equation Geometrical interpretation of a first-Order Equation
3	2.4	Method of characteristics and general Solutions
4	2.6,2.7	Canonical forms of first-order linear equations, Method of separation of variables (1st order PDEs)
5	4.1, 4.2	Second-order equations in two independent variables, Canonical forms
6	4.3, 4.4	Equations with constant coefficients General solutions
7	5.1, 5.3,5.4	The Cauchy problem, Homogeneous wave equations, Initial boundary-value problems
8	5.5-5.7	Equations with nonhomogeneous boundary conditions, Vibration of finite string with fixed ends, Nonhomogeneous wave equations
9	**Mid Semester Exam**	
10	7.1, 7.2, 7.3,	Separation of variables, The vibrating String Problem
11	7.5, 7.7	The Heat conduction problem, The Laplace and beam equations
12	7.8, 12.1, 12.2	Nonhomogeneous problems, Introduction, Fourier transforms
13	12.3, 12.4	Properties of Fourier transforms, Convolution theorem of the Fourier transform
14	12.5,12.6	The Fourier transforms of step and impulse functions, Fourier Sine and Cosine transforms
15	12.8-12.9	Laplace transform, Properties of Laplace transform.
16	12.10-12.11	Convolution Theorem of the Laplace Transform, Solving PDEs by Laplace transforms
17		Review
18	**End Semester Exam**	

MATH-382 Differential Geometry

Credit Hours: 3-0

Prerequisite: None

Course Objectives: After having completed this course, the students would be expected to understand classical concepts in the local theory of curves and surfaces. Also the students will be familiar with the geometrical interpretation of the terminology used in the course.

Core Contents: Parametric representation of curves and surfaces, tangent and normal vectors, curvatures, fundamental forms.

Detailed Course Contents: Nature and purpose of differential geometry, concept of mapping. Coordinates in Euclidean space, vectors in Euclidean space, basic rules of vector calculus in Euclidean space, concept of a curve in differential geometry, examples of special curves. Arc length, tangent and normal plane, osculating plane, principal normal, curvature, osculating circle. Binormal, moving trihedron

of a curve, torsion. Formulae of Frenet, motion of the trihedron, vector of Darboux.
Spherical images of a curve, contact, osculating sphere, natural equations of a curve, examples ofcurves and their natural equations. Involutes and evolutes, Bertrand curves. Concept of a surface in differential geometry curves on a surface, tangent plane to a surface. First fundamental form. Concept of Riemannian geometry. Summation convention, properties of the first fundamental form. Contravariant and covariant vectors, Contravariant, covariant, and mixed tensors (Concepts of tensor from theses sections). Normal to a surface, definition of normal section and curvature with some results. Second fundamental form, Arbitrary and normal sections of a surface. Meusnier's theorem. Asymptotic lines, are elliptic, parabolic, and hyperbolic points of a surface. Principal curvature, lines of curvature, Gaussian and mean curvature. Formulae ofWeingarten and Gauss. Fundamental theorem of theory of surfaces.

Course Outcomes:

- Student should be able to understand the concept of a curve in differential geometry.
- Student should know the Frenet-Serret theorem and their applications.
- Student should be familiar with concept of surfaces in differential geometry.
- Student should be able to understand fundamental forms.

Text Book: Andrew Pressley (2ed) Elementary Differential Geometry-Springer (2010).

Reference Books:

1. Erwin Kreyszig, Differential Geometry, Dover Publications, Inc. New York, (1959).
2. R.S. Millman, G. D. Parker, Elements of Differential Geometry, Prentice-Hall Inc, (1977).
3. Alfred Gray, Modern Differential Geometry of Curves and Surfaces, Chapman & Hall/CRC (2005).

Weekly Breakdown		
Week	***Section***	***Topics***
1	1.1, 1.2	Parametrization of curves in R2, Tangent vector, Arc-Length, Unit speed curves.
2	1.3, 1.4,	Reparametrization of curves, Singular points, Regular curves, Closed curves.
3	2.1	Curvature of curves, Curvature of space curves, derivation of formula for curvature.
4	2.2	Signed unit normal, Turning angle of curve, Signed curvature. Osculating circle, centre of curvature, radius of curvature, envelope of curves, involute and evolute of curve.
5	2.3	Space curves: torsion, principal normal, binormal, derivation of formula for torsion for non-unit speed curves, some particular cases, Derivation of Frenet-Serret equations, Generalized helix.
6	3.1,3.2	Global properties of curves: Simple closed curves, positively oriented curves. Wirtinger's inequality, The isoperimetric inequality.
7	4.1, 4.2	Introduction to surfaces, parametrization of surfaces: ellipsoid, paraboloid, hyperboloid, helicoid, torus, etc. Smooth surfaces, regular surfaces, allowable surfaces, reparameterization of surfaces.
8	4.3-4.5	Smooth maps, diffeomorphism and diffeomorphic surfaces. Tangents and derivatives, tangent plane, parametric curves on surfaces. Normals and orientability.
9	**Mid Semester Exam**	
10	5.1,5.2	Level surfaces, Quadric surfaces, Parametrization of quadric surfaces in nonstandard form.

11	5.3, 6.1	Ruled surfaces and surface of revolutions. Length of curves on surfaces, First fundamental form.
12	6.2, 6.3	Isometries of surfaces, tangent developable. Conformal mappings of surfaces, Surface area by first fundamental form, invariants of first fundamental forms.
13	7.1, 7.2	The second fundamental form, The Gauss and Weingarten maps.
14	7.3,7.4	The normal and geodesic curvatures, normal section, asymptotic curves on surfaces, Meusnier's theorem, parallel transport and covariant derivative.
15	8.1, 8.2	Gaussain and mean curvatures, minimal surface, Principal curvatures. Elliptic, parabolic and hyperbolic points, line of curvature, umbilic points, principal directions and principal directions.
16	9.1-9.2	Geodesics: definition and basic properties, Geodesic equations.
17		Review
18	**End Semester Exam**	

MATH-421 Group Theory-II

Credit Hours: 3-0
Prerequisite: MATH-325 Group Theory-I
Course Objectives: This course is the continuation of the course "Group Theory-I" and covers some advanced topics in group theory such as internal and external direct products of groups, classification of finitely generated abelian groups, commutator subgroup, group action on a set, conjugate elements, conjugacy classes, Sylow's theorems, simple groups, free groups,automorphisms of groups.
Core Contents: Direct product of groups, group action on a set, conjugate elements, conjugacy classes, Cauchy' s theorem for abelian groups, Sylow's theorems, free groups, automorphisms of groups.
Detailed Course Contents: Direct product of groups, internal direct product, external direct product, computation in factor group, the correspondence theorem, commutator subgroup, simple groups, group action on a set, conjugate subgroups, conjugate elements and conjugacy classes, the class equation of a group, p-groups, Sylow p-subgroups, cauchy theorem for abelian groups, Sylow's first theorem, Sylow's 2nd and 3rd theorems, applications of Sylow's theorems, automorphisms, group of automorphisms, inner automorphisms, group of automorphisms of a cyclic group, generators and relations, free groups.
Course Outcomes: On successful completion of this course, students will know

- Direct product of groups, external direct product, internal direct product
- The classification of finitely generated abelian groups
- The correspondence theorem for groups
- Commutator subgroup
- Conjugate subgroups, conjugate elements and conjugacy classes
- Group action on a set
- The class equation of a group
- p-groups, Sylow p-subgroups, Cauchy's theorem for abelian groups
- Sylow's theorems , simple groups, applications of Sylow's theorems
- Automorphisms, group of automorphisms, Inner automorphisms,
- Group of automorphisms of a cyclic group
- Free groups.

Text Books:

1. J. B. Fraleigh**,** A first course in abstract algebra (7th Ed.), 1998, Addison-Wesley publishing.(referred as J.F)
2. I.N. Herstein, Topics in Algebra (2nd Ed.), New York, John Wiley & sons, Inc., 1975. (referred as I.H)

Reference Books:

1. W. K. Nicholson, Introduction to Abstract Algebra, (3rd Ed)**,** 2007, John Wiley & sons.
2. J. A. Gallian, Contemporary Abstract Algebra. (7th Ed.) Cole, Belmont, CA, 2009.

Weekly Breakdown		
Week	***Section***	***Topics***
1	J.F Sec.11	Direct product of groups, internal direct product, examples and related results.

2	J.F Sec.11	External direct product of groups, examples and related results.
3	J.F Sec. 11	Classification of finitely generated abelian groups.
4	J.F Sec.15	Factor-group computation, the correspondence theorem, applications of the correspondence theorem.
5	J.F Sec.15	Simple groups, commutator subgroups, examples and related results.
6	J.F Sec. 16	Group action on a set, examples and related results.
7	J.F Sec.36	Conjugate elements and conjugacy classes, the class equation of a group.
8	J.F Sec 36	p-Groups, Sylow p-subgroups, definitions, examples and related results.
9	**Mid Semester Exam**	
10	J.F Sec.36	Cauchy theorem for abelian groups, Sylow's first theorem.
11	J.F Sec.36	Sylow's 2nd and 3rd theorems.
12	J.F Sec. 37	Applications of Sylow's theorems to simple groups.
13	J.F Sec.38, 39	Free abelian groups, proof of the fundamental theorem for finitely generated abelian group.
14	J.F Sec.39	Free groups, group presentations.
15	I.H Sec. 2.8	Automorphisms, group of automorphisms definitions and examples and related results.
16	I.H Sec. 2.8	Inner automorphisms, group of automorphisms of a cyclic group, and related results.
17		Review
18	**End Semester Exam**	

MATH-423 Rings and Fields

Credit Hours: 3
Prerequisite: MATH- 325 Group Theory-I

Course Objectives: In abstract algebra, ring theory is the study of rings, an algebraic structure in which addition and multiplication are defined and have similar properties to those operations defined for the integers. Ring theory studies the structure of rings and their representations. Ring theory was originated in mid-nineteenth century by Richard Dedekind.
Core Contents: Rings, subrings, integral domains, fields, ideals, factor rings, polynomial rings, ring homomorphisms, field extensions, finite fields.
Detailed Contents: Rings, properties of rings, ring of Gaussian integers, subrings, subring test, zero devisors, integral domains, fields, finite integral domains, characteristic of a ring, ideals, ideal test, principal ideal, prime ideals, maximal ideals, factor ring, existence of factor ring, ring homomorphism, ring isomorphism, properties of ring homomorphism, kernel of a homomorphism, natural homomorphism from ring to its factor ring, the field of quotients, polynomial rings, reducibility and irreducibility tests, principal ideal domains, construction of finite fields, extension fields, the fundamental theorem of field theory, splitting fields, algebraic extensions,
Course Outcomes: On successful completion of this course, students will know rings, properties of rings, ring of Gaussian integers, subrings, subring test, zero devisors, integral domains, fields, finite integral domains, characteristic of a ring, ideals, principal ideal, prime ideals, maximal ideals, factor ring, ring homomorphism, ring isomorphism, properties of ring homomorphism, kernel of a homomorphism, applications of first isomorphism theorem, the field of quotients, polynomial rings, reducibility and irreducibility tests, principal ideal domains, finite fields, extension fields, the fundamental theorem of field theory, splitting fields. algebraic extensions, degree of an extension, finite extensions.
Textbook: J. A. Gallian, Contemporary Abstract Algebra. 8th ed. Brooks/Cole, Belmont, CA, 2013.
Reference Books:

1. W. Keith Nicholson, Introduction to Abstract Algebra, (3rd edition), 2007, John Wiley & sons.
2. J. B. Fraleigh, A first course in abstract algebra (7th edition), 1998, Addison-Wesley publishing.
3. I.N. Herstein, Topics in Algebra (2nd edition), New York, John Wiley & sons, Inc., 1975.

Weekly Breakdown		
Week	***Section***	***Topics***
1	Ch.12	Rings, definition and examples, properties of rings, uniqueness of identity and inverses, direct sum of rings.
2	Ch.12	Subrings, definition and examples, subring test, Gaussian integers, applications of subring tests. The group of unit elements of a commutative ring. Boolean ring.
3	Ch.13	Zero divisors, integral domains, cancellation property with respect to multiplication, fields, finite integral domains. The ring of integers modulo a prime *p*.
4	Ch.13	Characteristic of a ring, characteristic of a ring with unity, characteristic of an

		integral domain, Ideals, ideal test,
5	Ch.14	Examples related to ideal test, principal ideals, Factor ring, existence of factor ring.
6	Ch.14	Prime ideals, maximal ideals, examples, and related theorems, idempotent elements, nilpotent elements, and related results.
7	Ch.15	Ring homomorphism, examples, ring isomorphism, Properties of ring homomorphism, kernels and ideals, the first isomorphism theorem for rings.
8	Ch.15	Ideals and kernels, homomorphism from the ring of integers to a ring with unity and its consequences. The field of quotients.
9	**Mid Semester Exam**	
10	Ch.16	The ring of polynomials over a commutative ring, the ring of polynomials over integral domains, the division algorithm for ring of polynomials over a field, factor theorem, remainder theorem.
11	Ch.16 & Ch. 17	Principal ideal domain, polynomial ring over a field is a principal ideal domain, reducible and irreducible polynomials over an integral domain.
12	Ch.17	Reducibility tests, reducibility tests for degree 2 and 3, content of a polynomial, primitive polynomial, Gauss's Lemma, reducibility over ring of rational numbers implies reducibility over ring of integers.
13	Ch.17	Irreducibility tests, mod p irreducibility tests, examples, Eisenstein's criterion, irreducibility of p-th cyclotomic polynomial, the rational root theorem.
14	Ch.17	Characterization of maximal ideals in a ring of polynomials over a field, construction of fields.
15	Ch.19 & Ch.20	Revision of vector space, Extension fields, fundamental theorem of field theory, splitting fields
16	Ch.21	Algebraic extensions.
17		Review
18	**End Semester Exam**	

MATH-426 Module Theory

Credit Hours: 3-0

Prerequisite: MATH-423 Rings and Fields

Course Objectives: In abstract algebra, the concept of a module over a ring is a generalization of the notion of vector space over a field, where the corresponding scalars are the elements of an arbitrary ring. Modules also generalize the notion of abelian groups, which are modules over the ring of integers. Much of the modern development of commutative algebra emphasizes modules. Both ideals of a ring R and R-algebras are special cases of R-modules, so module theory encompasses both ideal theory and the theory of ring extensions. This course focuses the basic concepts and results of Module Theory.

Core Contents: Modules, Modules over PID's, Artinian & Noetherian Modules.

Detailed Course Contents: Modules: Modules, submodules, operations on submodules, generation of modules, finitely generated modules, direct sum of modules, cyclic modules, free modules, quotient modules, homomorphisms of modules, isomorphism theorems of modules, short exact sequences of modules, group of module homomorphisms, simple modules.

Modules over PID's: Modules over PID's.

Artinian & Noetherian Modules: Artinian Modules, Noetherian Modules, modules of finite length, Artinian rings, Noetherian rings, radicals, nil radical Jacobson radical.

Course Outcomes: On successful completion of this course, students will know about

- Modules, submodules, generation of modules.
- Finitely generated modules.
- Cyclic modules, free modules, quotient modules.
- Homomorphisms of modules, isomorphism modules.
- Short exact sequences of modules.
- Group of module homomorphisms.
- Artinian Modules, Noetherian Modules.
- Modules of finite length.
- Artinian rings, Noetherian rings.
- Radicals, nil radical, Jacobson radical.

Text Book: C. Musili, Introduction to Rings and Modules, 2nd Ed., 1994, Narosa Publishing.

Reference Books:

1. M. F. Atiyah, I. G. Macdonald, Introduction to Commutative Algebra, Addison-Wesley Publishing Company, 1969.
2. David S Dummit, Richard M. Foote, Abstract Algebra, 2004, John Wiley & Sons.Thomas.
3. W. Hungerford, Algebra, Springer-Verlag, New York Inc. 1974.

Weekly Breakdown		
Week	***Section***	***Topics***
1	Sec. 5.1	Modules, submodules, definitions and examples, Generation of modules
2	Sec. 5.1, Sec. 5.2	Finitely generated modules, Direct sum of modules
3	Sec. 5.3	Cyclic modules, Free modules
4	Sec. 5.6, Sec. 5.7	Quotient modules, Homomorphisms of modules
5	Sec. 5.7	Isomorphism theorems of modules
6	Sec. 5.7	Short exact sequences of modules, group of module homomorphisms
7	Sec. 5.8	Simple modules
8	Sec. 5.9	Modules over PID's
9	**Mid Semester Exam**	
10	Sec. 6.1	Artinian Modules
11	Sec. 6.2	Noetherian Modules
12	Sec. 6.3	Modules of finite length
13	Sec. 6.4	Artinian rings
14	Sec. 5.7	Short exact sequences of modules, group of module homomorphisms
15	Sec. 5.8	Simple modules
16	Sec. 5.9	Modules over PID's
17		Review

18	**End Semester Exam**

MATH-433 Numerical Analysis-II

Credit Hours: 3-0
Prerequisite: MATH-332 Numerical Analysis-I

Course Objectives: Numerical Analysis deals with the approach to develop numerical algorithms for the mathematical problems which are not easily solvable by using exact or analytical methods. The key topics of this subject include numerical solutions of ordinarydifferential equations, numerical solutions of partial differential equations and findingeigenvalues numerically. This is the second course on numerical mathematics in SNS.

Core contents: Numerical Solution of Ordinary Differential Equations, Numerical Solution ofPartial Differential Equations, Eigenvalue Problems.

Detailed Course Contents: Numerical Solution of Ordinary Differential Equations: Euler'smethod, Modified Euler's Method, Truncation Error and Stability, The Taylor Series Method, Multistep Method, Adams Multistep Methods, Runge-Kutta Methods, Differential equations of Higher Order, System of Differential Equations, Shooting Methods, Boundary Value Problems. Numerical Solution of Partial Differential Equations: Elliptic, Hyperbolic and ParabolicEquations, Explicit and Implicit Finite Difference Methods, Stability Analysis and Convergence. Eigenvalue Problems: Estimation of Eigenvalue, Gerschgorin's Theorem and its Applications, Power method, Inverse Power Method, Shift of Origin and Deflation Method.

Learning Outcomes: On successful completion of this course, students will be able to:

- analyze and construct the numerical solutions of ordinary differential equations
- obtain numerical solutions of partial differential equations
- familiar with obtaining eigenvalues of a matrix numerically
- implement numerical methods in MATLAB

Text Book:

1. Numerical Analysis by Richard L. Burden and J. Douglas Faires, 9th Edition Publisher: Cengage Learning, 2010. (BF)
2. Fundamentals of Engineering Numerical Analysis by Perviz Moin, 2nd Edition Publisher: Cambridge University Press, 2010. (PM)

Reference Books:

1. Numerical Methods for Engineers by Steven C Chapra and Raymond P Canale, 6th Edition Publisher: McGraw-Hill, 2009.
2. Numerical Solutions of Partial Differential Equations: Finite Difference Method by G. D. Smith, 3rd Edition, Oxford University Press, USA, 1986.
3. The Numerical Solution of Ordinary and Partial Differential Equations by Granville Sewell, 2nd Edition, Wiley-Interscience, 2005.
4. Introduction to Numerical Analysis Using MATLAB by Rizwan Butt, First Edition Publisher: Jones & Bartlett Learning, 2009.

Weekly Breakdown		
Week	***Section***	***Topics***

1	5.1 (BF) (BF)	The Elementary Theory of Initial Value Problems: Introduction of IVP Euler's Method: Euler's Method, Error Bounds for Euler's Method
2	5.3 (BF) (BF)	Higher Order Taylor Methods: Higher Order Taylor Methods, Taylor Method of Order n, Runge-Kutta Methods: Runge-Kutta Methods of Order Two
3	5.4 (BF)	Runge-Kutta Methods: Midpoint Method, Modified Euler Method, Higher Order Runge-Kutta Methods, Runge-Kutta Order Four, Computational Comparison
4	5.6 (BF) 27	Multistep Methods: Multistep Methods, Adams-Bashforth Explicit Methods: Two, Three, Four and Five Step Methods , Adams-Moulton Implicit Methods: Two, Three and Four Step Methods, Predictor Corrector Methods
5	5.8 (BF) (BF)	Extrapolation Methods: Extrapolation Methods Higher Order Equations and Systems of Differential Equations: Higher Order Equations And Systems of Differential Equations, Higher Order Differential Equations
6	5.1(BF)	Stiff Differential Equations: Stiff Differential Equations
7	4.2 4.4 (PM) 5.10 (BF)	Stability Analysis for ODE: Stability Analysis for ODE Stability: Stability, One-Step Methods, Multistep Methods
8	11.1 (BF) (BF)	The Linear Shooting Method: The Linear Shooting Method, Linear Boundary Value Problem, Reducing Round-Off Error, The Shooting Method for Nonlinear Problems: Newton Iteration, Nonlinear Shooting with Newton's Method
9	**Mid Semester Exam**	
10	9.1 (BF) 9.3 (BF)	Linear Algebra and Eigenvalues: Gerschgorin Circle, The Power Method: The Power Method, Accelerating Convergence, Symmetric Matrices
11	9.3 (BF)	The Power Method: Inverse Power Method, Deflation Methods
12	12.1 (BF)	Introduction to Partial Differential Equation, Elliptic Partial Differential Equations: Elliptic Partial Differential Equations, Selecting a Grid, Finite Difference Method, Examples: Laplace Equation, Poisson Equation
13	12.2 (BF)	Parabolic Partial Differential Equations: Forward Difference Method, Example 1:Heat Equation, Stability Considerations, Backward Difference Method, Example 2: Heat Equation with Backward Difference Method, Crank-Nicolson Method
14	5.7 (PM)	Multi-Dimensions: Heat Equation in Two Dimension
15	12.3 (BF) (BF)	Hyperbolic Partial Differential Equations: Hyperbolic Partial Differential Equations, Improving the Initial Approximation. Example 1: Wave EquationAn Inroduction to the Finite Element Method: An Introduction to the Finite Element Method, Defining the Elements, Triangulating the Region
16	5.2 (PM)	von Neumann Stability Analysis
17		Review
18	**End Semester Exam**	

MATH-434 Numerical Linear Algebra

Credit Hours: 3-0

Prerequisite: MATH-221 Linear Algebra

Course Objectives: Numerical linear algebra is of great practical importance in scientific computation and is used in mathematics, natural sciences, computer science and social science. Even nonlinear problems usually involve linear algebra in their solution. The focus of the course is to explore applications in industry including direct implications for internet applications.

Core Contents: Review of matrix operations, QR factorization and least squares, conditioning and stability, numerical solutions of systems of linear equations including direct methods, error analysis, structured matrices, iterative methods, least squares and algorithms for eigenvalues and eigenvectors.

Detailed Course Contents: Matrix computations: Matrix-vector multiplication, Orthogonal vectors and matrices, Norms, Singular value decomposition (SVD).

QR Factorization and Least Squares: Projectors, QR factorization, Gram-Schmidt Orthogonalization, MATLAB, Householder triangularization, Least square problems. Conditioning and stability: Conditioning and condition numbers, Floating point arithmetic, Stability, Stability of householder triangularization, Stability of back substitution, Conditioning of least squares problems, Stability of least squares algorithm.

System of Equations: Gaussian Elimination, Pivoting, Stability of Gaussian Elimination, Cholesky Factorization.

Eigenvalues: Eigenvalue problems, Overview of eigenvalue algorithms, Reduction to Hessenberg or tridiagonal form, Rayleigh quotient, Inverse iteration, QR algorithms without shifts, QR algorithms with shifts, Computing the SVD.

Iterative methods: Overview of iterative methods, The Arnoldi iteration, The Lancoz iteration, Gauss quadrature, Conjugate gradients, Bi-orthogonalization methods, Preconditioning.

Course Outcomes: By the completion of this course the students would be able to:

- Use numerical linear algebra as building bricks in computation.
- Use computer algorithms, programs and software packages to compute solutions to currentproblems.
- Critically analyze and give advice regarding different choices of models, algorithms, andsoftware with respect to efficiency and reliability.
- Critically analyze the accuracy of the obtained numerical result and to present it in avisualized way.

Text Book: L. N. Trefethen and D. Bau, Numerical Linear Algebra, 1st Edition, Philadelphia, PA: Society for Industrial and Applied Mathematics, 1997. ISBN: 9780898713619.

Reference Books:

1. Bai et al., Templates for the Solution of Algebraic Eigenvalue Problems: A Practical Guide (Software, Environments and Tools), 1st Edition, Philadelphia, PA: Society for Industrial and Applied Mathematics, 2000. ISBN: 9780898714715.
2. Barret et al., Templates for the Solution of Linear Systems: Building Blocks for Iterative Methods (Miscellaneous Titles in Applied Mathematics Series No 43), 1st Edition, Philadelphia, PA: Society for Industrial and Applied Mathematics, 1993. ISBN:

9780898713282

Weekly Breakdown		
Week	***Section***	***Topics***
1	1.1, 1.2	Matrix-vector multiplication, Orthogonal vectors and matrices
2	1.3, 1.4	Norms, Singular value decomposition (SVD)
3	2.1-2.3	Projectors, QR factorization, MATLAB
4	2.4, 2.5	Householder triangularization, Least square problems.
5	3.1, 3.2	Conditioning and condition numbers, Floating point arithmetic
6	3.3-3.5	Stability, Stability of householder triangularization, Stability of back substitution
7	3.6, 3.7	Conditioning of least squares problems, Stability of least squares algorithm
8	4.1, 4.2	Gaussian Elimination, Pivoting
9	**Mid Semester Exam**	
10	4.3, 4.4	Stability of Gaussian Elimination, Cholesky Factorization,
11	5.1, 5.2	Eigenvalue problems, Overview of eigenvalue algorithms
12	5.3, 5.4	Reduction to Hessenberg or tridiagonal form, Rayleigh quotient
13	5.5-5.7	Inverse iteration, QR algorithms without shifts, QR algorithms with shifts
14	5.8, 6.1, 6.2	Computing the SVD, Overview of iterative methods, The Arnoldi iteration
15	6.3-6.5	The Lancoz iteration, Gauss quadrature, Conjugate gradients
16	6.6, 6.7	Bi-orthogonalization methods, Preconditioning.
17		Review
18	**End Semester Exam**	

MATH-435 Introduction to Finite Element Method

Credit Hours: 3-0
Prerequisite: MATH-332 Numerical Analysis-I, MATH-353 Partial Differential Equations
Course Objectives: The finite element method is an effective approach for solving complicated engineering problems those cannot be handled by classical analytical methods. In this course the fundamentals of this method will be emphasized. The key objective of this course is to introduce the mathematical concepts of the finite element method for obtaining approximate solutions of the ordinary and partial differential equations. The learning process will be enhanced through rigorous assignments on mathematical softwares such as Matlab, Mathematica and Maple.
Detailed Course Contents: Introduction to finite element method and its applications; Direct approaches for discrete systems; Strong and weak forms for one dimensional problems; Approximation of trial solutions; Weight functions and Gauss quadrature for one dimensional problems; Finite elements formulation for one dimensional problems.
Learning Outcomes: On successful completion of this course the students will be able to:
Understand the basics of finite element approach.
Apply the finite element method for one-dimensional problems.
Implement the method on computational softwares such as Mathematica, Maple, Matlab.
Textbook: J. Fish and T. Belytschko , A first course in finite elements by, John Wiley & Sons, 2007.
Recommended Books:
Fundamentals of finite element analysis by David V. Hutton and Dave Hutton, Ist Edition, Publisher: Tata MeGraw Hill India, 2003.
The Finite element method using MATLAB by Young W. Kwon and Hyochoong Bang, Second Edition, Publisher: CRC Press, 2000.
A first course in finite elements by Jacob Fish and Ted Belytschko, John Wiley & Sons, 2007.

Weekly Breakdown		
Week	***Section***	***Topics***
1	1.1, 1.2	Background; Applications of finite elements
2	2.1-2.3	Describing the behavior of a single bar element; Equation for a system; Application to other linear systems
3	2.4, 2.5	Two-dimensional truss systems; Tranformation law
4	27 2.6	Three-dimensional truss system
5	3.1	The strong form in one-dimensional problems
6	3.2, 3.3	The weak form in one-dimension; Continuity
7	3.4	The equivalece between the weak and strong forms
8	3.5, 3.6	One dimensional stress analysis with arbitrary boundary conditions; One dimensional heat conduction with arbitrary boundary conditions
9	**Mid Semester Exam**	

10	3.7, 3.8	Two point boundary value problem with generalized boundary conditions; Advection diffusion
11	3.9, 3.10	Minimum potential energy; Integrability
12	4.1-4.3	Two node linear element, quadratic one dimensional element; Direct construction of shape functions in one dimension
13	4.4-4.6	Approximation of the weight function, global approximation and continuity; Gauss quadrature
14	5.1-5.3	Development of discrete equation: simple case, element marices for two nodes element; Application to heat conduction and diffusion problems
15	5.4-5.6	Development of discrete equations for arbitrary boundary conditions; Two point boundary value problem with generalized boundary conditions; Convergence of the finite element method
16	5.7	Finite element method for advection-diffusion equation
17		Review
18	**End Semester Exam**	

MATH-436 Introduction to Approximation Theory

Credit Hours: 3-0

Prerequisite: None

Course Objectives: Classical topics like Taylor series and Fourier series deal with approximation of a function by relatively simpler functions. Weierstrass Theorem leads to the fact that every contiuous function can be approximated to arbitrary accuracy by a polynomial ofa suitable degree. Fourier series approximates a function f in terms of members of a complete orthonormal set of functions. Smoothness of f is reflected in the fast convergence of the series to

This course leads the student through these topics to the relatively modern concept ofwavelets. This is an important branch of mathematics with technical applications in several areas such as signal processing. This has applications to solving boundary value problems which model problems in diverse areas of science and technology. As a branch of mathematics, the theory leads to approximation in function spaces such as a Hilbert space or a Sobolev space.

Course Contents: Approximation with polynomials; infinite series; best n-term approximation, Fourier analysis, Parseval Theorem; wavelets, application of wavelets, multiresolution analysis, Haar wavelets, Daubechies' wavelets.

Detailed Course Contents: Approximation of a function on an interval; Weierstrass' Theorem, Taylor's Theorem. Infinite series of numbers, estimating the sum of a series, Power series. Series of functions, uniform convergence. Fourier series, Fourier Theorem and approximation.

Fourier series and signal analysis, Generalized Fourier series, Hilbert spaces. Fourier series in complex form, Parseval's Theorem. Regularity and decay of Fourier coefficients. Best n-term approximation, The Fourier transform.

Wavelet systems, the Haar wavelet, Daubechies' wavelets, Wavelets and signal processing, Wavelets and fingerprints, wavelet packets. Multiresolution analysis, The role of Fourier transform.

Learning Outcomes: On successful completion of this course the students will be able to:

- understand the basics of approximation theory,
- apply the wavelet method to solve simple problems,
- use softwares such as Mathematica, Maple, Matlab etc. to implement built-in codes for the solution of problems.

Text Book: Approximation Theory: From Taylor Polynomials to Wavelets, O. Christensen and K.L. Christensen, Birkhauser, Berlin, 2004.

Reference Book: E.W. Cheney, Introduction to Approximation Theory, McGraw-Hill, New York, 1966

Weekly Breakdown		
Week	***Section***	***Topics***
1	1.1- 1.3	Approximation of a function on an interval; Weierstrass' Theorem, Taylor's Theorem.
2	2.1-2.2	Infinite series of numbers, estimating the sum of a series, Power series.
3	20 2.3, 2.5	Series of functions, uniform convergence.
4	28 3.1-3.2	Fourier series, Fourier Theorem and approximation.
5-6	3.3	Fourier series and signal analysis

7	3.4	Generalized Fourier series, Hilbert spaces.
8	3.5-3.6	Fourier series in complex form, Parseval's Theorem.
9	**Mid Semester Exam**	
10	3.7-3.8	Regularity and decay of Fourier coefficients. Best n-term approximation
11	3.9	The Fourier transform
12	4.1	Wavelet systems, the Haar wavelet, Daubechies' wavelets
13	4.2	Wavelets and signal processing
14	4.3-4.4	Wavelets and fingerprints, wavelet packets.
15	5.2-5.3	Multiresolution analysis
16	5.4	The role of Fourier transform.
17		Review
18	**End Semester Exam**	

MATH-445 Measure and Integration

Credit Hours: 3-0
Prerequisite: MATH- 342 Real Analysis-II
Course Objectives: The course aims at an understanding of Lebesgue measure and integration and gives an alternative when Riemann integration fails. In this course the most fundamental concepts are presented: Sigma Algebra, Measurable Function, Outer Measure, Borel Measure, Lebesgue measure, Lebesgue integration and Lebesgue Differentiation.
Core Contents: Insufficiency of Riemann integrals, Outer Measure, σ -Algebra, Measurable sets and Measurable Space, Borel Sets & Borel Measure, S-Measurable function, Measure Space & Measure Functions, Lebesgue measure & Lebesgue Measurable functions, Egorov's Theorem, Lebesgue Integrals, Bounded Convergence Theorem, Dominated Convergence Theorem, L^1-Norm and Lebesgue spaces, Lebesgue Differentiation theorems, Lebesgue Density Theorem
Course Contents: Riemann intgerals, Insufficiency of Riemann integrals, Outer Measures, Properties of Outer Measure, σ -Algebra and its properties, Measurable Sets & Measurable Space, Borel Measure, Measurable Functions, Borel Measurable Functions, Properties of Borel Measurable Functions, S-measurable functions, Limit of S-measurable functions, Measures, Measure spaces, Measure preserving orders, Lebesgue Measure, Relationship among Measure, Borel Measure and Outer Measure and their properties, Lebesgue Measurable sets and properties, Egorov's Theorem and its conclusions, Lebesgue Measurable functions and its properties, Simple Functions, Lower and Upper Lebesgue Sum, Lebesgue integrations of Simple and Characteristic functions, Monotone Convergence Theorem, Lebesgue integration of some Real-valued functions and their properties, Bounded Convergence Theorem, Dominated Convergence Theorem, Relationship between Riemann integral and Lebesgue integrals, L^1-Norm and Lebesgue spaces, Lebesgue Differentiation theorems, Lebesgue Density Theorem
Course Outcomes: Upon completion of this course, the student should be able to:
Recognize Insufficiency of Riemann integrals, Outer Measure, σ -Algebra
Borel Measure, Borel Measurable Functions, S-measurable functions, Lebesgue Measure
Egorov's Theorem, Lower and Upper Lebesgue Sum, Lebesgue integrations of Simple and Characteristic functions
Bounded Convergence Theorem, Dominated Convergence Theorem, Lebesgue Differentiation theorems, Lebesgue Density Theorem
Text Book: S. Axler, "Measure, Integration & Real Analysis", Springer, (2020).
Reference Books:
S. J. Taylor, "Introduction to Measure and Integration", Cambridge University Press, (2010).
M. T. Nair, "Measure and Inegration: A first Course", Taylor & Francis Group, NY, (2019)
C. S. Kubrusly, "Essentials of Measure Theory", Springer, (2015)

Weekly Breakdown		
Week	***Section***	***Topics***
1	Sec. 1A-1B	Review of Riemann Integral, Insufficiency of Riemann Integral and Examples
2	Sec. 2A	Outer Measure on R, Examples, Properties of Outer Measure, Outer Measure on Closed Intervals
3	Sec.2A-2B	Non-Additive Outer Measure and Examples, σ -Algebra, examples and properties, Measurable sets, and Measurable Spaces

4	Sec. 2B	Borel Sets, Examples, Direct & Inverse Image of σ -Algebra and their properties, Measurable Functions and Borel Measurable Functions
5	Sec. 2B-2C	Relationship between Continuity and Borel Measurable functions, Algebraic Properties of Borel Measurable Functions, S-measurable functions, Limit of S-measurable functions, Measures and Examples
6	Sec. 2C	Measure spaces, Measure preserving orders, measure of an increasing union, measure of a decreasing intersection, Countable Subadditivity properties of Measure spaces
7	Sec. 2D	Lebesgue Measure, Relationship among Measure, Borel Measure and Outer Measure and their properties
8	Sec. 2D-2E	Lebesgue Measurable set, examples and properties, Comparison of Pointwise and Uniform convergence
9	**Mid Semester Exam**	
10	Sec. 2E	Egorov's Theorem and its conclusions, Lebesgue Measurable functions and its properties. Simple Functions, Relationship between Lebesgue measurable functions and Borel Measurable functions
11	Sec. 3A	Lower and Upper Lebesgue Sum, Examples, Lebesgue integrations of Simple and Characteristic functions, Monotone Convergence Theorem
12	Sec. 3A-3B	Integral -type sums for simple functions, Lebesgue integration of some Real-valued functions and their properties, Bounding a Lebesgue integral,
13	Sec. 3B	Bounded Convergence Theorem, almost everywhere convergence, Dominated Convergence Theorem, Relationship between Riemann integral and Lebesgue integrals
14	Sec. 3B	L1-Norm and Lebesgue spaces, Examples and their properties.
15	Sec. 4A-4B	Markov's inequality, Hardy-Little maximal inequality, Lebesgue Differentiation theorem First Version
16	4B	Lebesgue Differentiation Theorem second version, Density in Lebesgue spaces, Lebesgue Density Theorem
17		Review
18	**End Semester Exam**	

MATH-446 Functional Analysis

Credit Hours: 3-0

Prerequisites: None

Course Objectives: This course extends methods of linear algebra and analysis to spaces of functions, in which the interaction between algebra and analysis allows powerful methods to be developed. The course will be mathematically sophisticated and will use ideas both from linear algebra and analysis.

Core contents: Metric Spaces, Normed Spaces and Banach Spaces, Inner Product Spaces and Hilbert Spaces.

Detailed Course Contents: Metric Spaces: Metric spaces, Examples of metric spaces, Open sets, Closed sets, Convergence, Cauchy sequce in metric space, Neighborhood, Completeness of metric spaces. Normed Spaces and Banach Spaces: Vector Space, Normed Space, Banach Space, Properties of Normed Spaces, Finite Dimensional normed spaces and subspaces, Compactness and finite dimension. Linear Operators, Bounded and Continuous linear operators, Linear Functionals, Linear Operators and Functionals on finite dimensional spaces. Normed spaces of Operators, Dual Spaces.

Inner Product Spaces and Hilbert Spaces: Inner product space, Hilbert space, Properties of inner product spaces, Orthogonal complements and direct sums, Orthonormal sets and sequences.

Text Book: Erwin Kreyszig "Introductory Functional Analysis with Applications" 1989. John Wiley and Sons.

Reference Books:

1. John B. ConwayA Course in Functional Analysis, Springer, 1990.
2. Brezis, Haim Functional Analysis, Sobolev Spaces and Partial Differential E quations, Springer 2010.

Weekly Breakdown		
Week	***Section***	***Topics***
1	1.1-1.2	Metric spaces, Examples of metric spaces,
2	1.3-1.4	Open sets, Closed sets, Neighborhood,
3	2.1-2.3	Convergence, Cauchy sequence in metric space.
4	2.4-2.5	Completeness of metric spaces.
5	2.6	Completion of Metric Spaces
6	2.7	Vector Space, Normed Space, Banach Space, Properties of Normed Spaces.
7	2.8	Finite Dimensional normed spaces and subspaces, Compactness and finite dimension
8	2.9	Linear Operators,
9	**Mid Semester Exam**	
10	2.10	Bounded and Continuous linear operators
11	3.1-3.2	Finite Dimensional normed spaces and subspaces, Compactness and finite dimension
12	3.3	Linear Functional
13	3.4	Linear Operators and Functional on finite dimensional spaces
14	3.6	Normed spaces of Operators, Dual Spaces
15	3.10	Inner product space, Hilbert space, Properties of inner product spaces
16	4.2	Orthogonal complements and direct sums
17		Review
18	**End Semester Exam**	

MATH-447 Topology-II

Credit Hours: 3-0
Prerequisite: MATH-345 Topology-I

Course Objectives: This course is the continuation of the course "Metric & Topological Spaces" and covers some advanced topics in Topology such as Connectedness, Connectedness in terms of closed sets, Connected Components, Path Connectedness and Local Connectedness, Compactness, Limit Point Compactness and countable Compactness, Local Compactness, Lindelöf Space and Separable Space, Alexandroff Compactification, Stone-Cech Compactification and Local Finiteness.
Core Contents: Topological Spaces, Bases, Subspaces, Product topology, Connectedness, Theorems related to connectedness, Connected Sets for Real line, Connected Components and applications, Path Connectedness and related results, Local Connectedness and Related Results. Compactness, Compactness in terms of Closed Sets, Properties of Compact Spaces, Limit point Compactness, Countable Compactness and Related theorems, Local Compactness and Related Theorems. Lindelöf Space and Separable Space, Related Theorems, Alexandroff Compactification, Stone-Cech Compactification and Local Finiteness.
Course Outcomes: Students are expected to understand

- Connectedness, Connected Components and Applications
- Path Connectedness and Local connectedness
- Compactness, Compactness in terms of Closed sets
- Limit Point Compactness, Countable Compactness and Local compactness
- Lindelöf Space and Separable Space
- Alexandroff Compactification
- Stone-Cech Compactification
- Local Finiteness

Text Books: James R. Munkres, "Topology", Prentice, Hall, Inc., 2nd Edition (2000)
Reference Books:

1. W. J. Pervin, "Foundation of General Topology", Academic Press, London, 2nd Edition, (1965).
2. J. Dugundji, "Topology", Allyn and Bacon Series in Advanced Mathematics, (1978).
3. N. Bourbaki, "Elements of Mathematics, General Topology", Addison Wesley, (1966).
4. S. Willard, "General Topology", Addison Wesley, (1970).
5. J. Kelly, "General Topology", Springer, (2005).

Weekly Breakdown		
Week	***Section***	***Topics***
1	12, 13	Revision of Topological Spaces and Examples
2	15, 16, 18	Bases for Topology, Subspace and Product Topology, Continuous Maps
3	23	Connectedness, Theorems and Examples
4	24	Connected Sets for Real line, Connected Components and applications
5	25	Local Connectedness and Related Results

6	25	Path Connectedness and related results
7	26	Compactness, Examples and related results
8	27	Compact subspaces for Real Lines
9	**Mid Semester Exam**	
10	28	Limit Point Compactness and Related Theorems
11	28	Countable Compactness and Related Theorems
12	29	Local Compactness and Related Theorems
13	30	Lindelöf and Separable Spaces and Examples
14	30	Relationship between 2nd Countable, Lindelöf and Separable Space, and related theorems
15	38	Alexandroff Compactification and Stone-Cech Compactification, and Related Results
16	39	Local Finiteness and Related Results
17		Review
18	**End Semester Exam**	

MATH-455 Integral Equations

Credit Hours: 3-0
Prerequisites: None
Course Objectives: Integral equations have been of considerable significance in the history of mathematics. This course is mainly concerned with linear integral equations and a brief discussion of a simple type of non-linear connection between differential and integral equations.
Core Contents: Classification of integral equations, Connection with differential equations, Integral equations of the convolution type, Method of successive approximations, Integral equations, Numerical methods for integral equations.
Detailed Contents: Introduction and motivation, Classification of integral equations. Some important identities, multiple integrals reduced to a single integral, generalized Leibnitz rule.
Numerical solutions of Fredholm integral equations. Convergence of integrals and basic definitions, Review of the Laplace transform. Review of Fourier transform, The Hankle transform, The Mellin transform, The Hilbert transform. Basic numerical integration(review), the smoothing effect of integration, Interpolation, and numerical solution of integral equations. Modeling of problems as integral equations: Hanging chain, Abels problem. Initial value problems reducible to integral equations, boundary value problems reducible to integral equations. Volterra integral equations of second kind, the resolvent kernel method for Volterra integral equations. Method of successive approximation for Volterra integral equations. Laplace transform method for Volterra integral equations, integrodifferential equations. Volterra integral equation of the first kind. Volterra integral equation of the first kind with difference kernel-Laplace transform method. Abel's generalized integral equation. Numerical solution of Volterra integral equations. Fredholm integral equations and the Green's function. Nonhomogeneous Fredholm integral equations with degenerate kernel, Fredholm alternatives. Approximating kernel by degenerate one. Fredholm integral equations with symmetric kernel: Some basic approximation methods for integral equations: Numerical evaluation of eigenvalues, collocation method. Fredholm integral equations of first kind: Fredholm equations of first kind with symmetric kernel, ill posed problems.
Course Outcomes: The students will be able to:

- Understand the theory of linear integral equations
- Apply different techniques to solve integral equations
- Understand the connection between differential and integral equations
- Solve the various integral equations by numerical methods

Text Book: A. J. Jerri, Introduction to integral equations with applications, John Wiley & Sons,1999
Reference Books:

1. R. P. Kanwal, Linear Integral Equations Theory and Technique, Academic Press 1971.
2. Abdul-Majid Wazwaz, Linear and Nonlinear Integral Equations: Methods and Applications, Springer 2011.
3. B. L. Moiseiwitsch, Integral equations, Longman London and New York, 1977.

Weekly Breakdown		
Week	***Section***	***Topics***
1	1.2, 1.3.1, 1.3.2	Introduction and motivation, Classification of integral equations. Some important identities, multiple integrals reduced to a single integral, generalized Leibnitz rule.

2	1.3.3, 1.4.1	Convergence of integrals and basic definitions, Review of the Laplace transform.
3	1.4.2, 1.4.3	Review of Fourier transform, The Hankle transform, The Mellin transform, The Hilbert transform.
4	1.5.1, 1.5.2, 1.5.3	Basic numerical integration(review), the smoothing effect of integration, Interpolation, and numerical solution of integral equations.
5	2.3.1, 2.3.2	Modeling of problems as integral equations: Hanging chain, Abels problem.
6	2.4, 2.5	Initial value problems reducible to integral equations, boundary value problems reducible to integral equations.
7	3.1.1, 3.1.2,3.1.3	Volterra integral equations of second kind, the resolvent kernel method for Volterra integral equations. Method of successive approximation for Volterra integral equations. Laplace transform method for Volterra integral equations, integrodifferential equations.
8	3.2	Volterra integral equation of the first kind. Volterra integral equation of the first kind with difference kernel-Laplace transform method. Abel's generalized integral equation.
9	**Mid Semester Exam**	
10	3.3, 4.2	Numerical solution of Volterra integral equations. Fredholm integral equations and the Green's function.
11	5.1.1, 5.1.2	Nonhomogeneous Fredholm integral equations with degenerate kernel, Fredholm alternatives
12	5.1.3, 5.2.1	Approximating kernel by degenerate one. Fredholm integral equations with symmetric kernel: Helbert Schmidt theorem, Mercer's theorem, existence of solutions
13	5.2.2	Solutions of Fredholm integral equations of second kind with symmetric kernel.
14	5.3.3	Some basic approximation methods for integral equations: Numerical evaluation of eigenvalues, collocation method
15	5,4.1, 5.1.2	Fredholm integral equations of first kind: Fredholm equations of first kind with symmetric kernel, ill posed problems
16	5.5	Numerical solutions of Fredholm integral equations.
17		Review
18	**End Semester Exam**	

MATH-456 Discrete Dynamical Systems

Credit Hours: 3-0

Prerequisites: MATH-251 Ordinary Differential Equations

Course Objectives: The field of dynamical systems and especially the study of chaotic systems is one of the important breakthrough in science in this 20^{th} century. The purpose of the course is to introduce the ideas on discrete dynamical systems at the level of undergraduate students. The principal objectives of the course are to elaborate the elements of discrete dynamical systems andto consider particular systems with complex behavior.

Core Contents: Orbits, Graphical Analysis, Fixed and Periodic Points, Bifurcations, The Role of the Critical Orbit, Fractals

Detailed Course Contents: Orbits: Iteration, Orbits, Types of Orbits, The Doubling Function.Graphical

Analysis: Orbit Analysis, The Phase Portrait.
Fixed and Periodic Points: Attraction and Repulsion, Calculus of Fixed Points, Periodic Points, Rates of Convergence.
Bifurcations: Dynamics of the Quadratic Map, The Saddle-Node Bifurcation, The Period- Doubling Bifurcation,The Transition to Chaos.
Chaos: Properties of a Chaotic System Manifestations of Chaos, Feigenbaum's Constant.
The Role of the Critical Orbit: The Schwarzian Derivative,The Critical Point and Basins ofAttraction, Newton's Method
Fractals: The Cantor Set, The Sierpinski Triangle, The Koch Snowflake, Topological Dimension, Fractal Dimension, Iterated Function Systems.

Course Outcomes: The students are expected to understand

- Mathematical aspects of theory of dynamical systems.
- The geometric aspects of discrete dynamical systems
- Bifurcations and chaos in discrete dynamical systems
- Fractals and fractal dimensions

Text Book: Robert L. Devaney, A First Course in Chaotic Dynamical Systems, Perseus Books Publishing, L.L.C., 1992.

Reference Books

1. Richard Holmgren, A First Course in Discrete Dynamical Systems, Springer, 1996
2. Mustafa R.S. Kulenovic, Orlando Merino, Discrete Dynamical Systems and DifferenceEquations with Mathematica, Chapman & Hall, 2002.
3. Rex Clark Robinson, An Introduction to Dynamical Systems: Continuous and Discrete, American Mathematical Socity, 2012.

Weekly Breakdown		
Week	***Section***	***Topics***
1	2.1, 2.4	Examples of Dynamical Systems from Finance, Ecology, Finding Roots and Solving Equations (Review).
2	3.1, 3.2	Iteration, Orbits.
3	3.3, 3.5	Types of Orbits, The Doubling Function.
4	4.1,4.2	Graphical Analysis, Orbit Analysis.
5	4.3, 5.1,5.2	The Phase Portrait, Fixed and Periodic Points, A Fixed Point Theorem, Attraction and Repulsion.
6	5.3-5.6	Calculus of Fixed Points, Periodic Points, Rate of convergence.
7	6.1-6.4	Bifurcations, Dynamics of the Quadratic Map, The Saddle-Node Bifurcation, The Period-Doubling Bifurcation.
8	7.1-7.3	The Quadratic Family, The Cantor Middle-Thirds Set.
9	**Mid Semester Exam**	
10	8.1,8.2	The Orbit Diagram, The Period-Doubling Route to Chaos.
11	10.1-10.3	Three Properties of a Chaotic System, Other Chaotic Systems, Manifestations of Chaos.
12	12.1, 12.2	The Schwarzian Derivative, The Critical Point and Basins of Attraction.
13	13.1,13.2,	Newton's Method, Basic Properties, Convergence1 and Nonconvergence
14	14.1	Fractals, Chaos Game.
15	14.2,14.3	The Cantor Set Revisited. The Sierpinski Triangle.
16	14.4-14.6	The Koch Snowflake, Topological Dimension, Fractal Dimension.
17	14.6	Iterated Function Systems.
18	**End Semester Exam**	

MATH-463 Stochastic Processes

Credit Hours: 3-0
Prerequisites: MATH-263 Probability Theory

Course Objectives: This course is intended as an introduction to stochastic processes. The course will introduce the students to a broad range of stochastic processes that underlay models in fields such as engineering, computer science, management science, the physical and social sciences, and operations research. The focus of this course will be discrete time Markov chains, continuous Markov processes, Stationary processes, Brownian motion, Poisson Process, Gaussian Process and Stochastic Calculus

Core Contents: Markov Chains, Continuous-Time Markov Chains, Random processes, Stationary processes, Brownian motion, Poisson Process, Gaussian Process and Stochastic Calculus

Detailed Course Contents: Introduction to stochastic process and review of conditional probability. Markov chain computation and mathematical induction. Limiting distribution, stationary distribution, irreducible markov chains, periodicity, ergodic markov chains, time reversibility, absorbing chains, regeneration and the strong markov property. Limit theorems. Branching processes, mean generation size, probability generating functions and extinction probability. Markov chain montecarlo, metropolis–hastings algorithm and gibbs sampler. Poisson process, arrival, interarrival times, infinitesimal probabilities, thinning, superposition, Uniform distribution, spatial poisson process, nonhomogeneous poisson process and parting paradox. Continuous-time markov chains, alarm clocks and transition rates, infinitesimal generator, long-term behavior, time reversibility, queueing theory, poisson subordination. Brownian motion, brownian motion and random walk, gaussian process, Transformations and properties, variations and applications, martingales. Stochastic calculus, ito integral and stochastic differential equations.

Learning Outcomes: The students are expected to understand:

- mathematical aspects of theory of Stochastic Processes
- discrete and Continuous-Time Markov Chains
- Random Processes and Stationary Processes
- Poisson and Gaussian Process
- Stochastic Calculus

Text Book: Robert P. Dobrow, Introduction to stochastic processes with r John Wiley & Sons, Inc., 2016.

Recommended Books

1. Sheldon M. Ross, Introduction to Probability Models (9th Edition) Elsevier 2007.
2. Mark Pinsky, Samuel Karlin, An Introduction to Stochastic Modeling, Elsevier2007.
3. Samuel Karlin and Howard M. Taylor, A First Course in StochasticProcesses, (2nd Edition), Academic Press, 1975.
4. Cinlar, E., Introduction to Stochastic Processes, Prentice-Hall, Englewood Cliffs, New Jersey, 1975
5. Heyman D., and Sobel, M., Stochastic Models in Operations Research, (Vol. 1), McGraw-Hill, 1982
6. Wolff, R., Stochastic Modeling and the Theory of Queues, Englewood Cliffs, NJ,1989

Weekly Breakdown		
Week	***Section***	***Topics***
1	1.1-1.5	Introduction to stochastic process and review of conditional probability.
2	2.1-2.6	Markov Chain computation and mathematical induction. Classification of chains
3	3.1-3.5	Limiting Distribution, Stationary Distribution, Irreducible Markov Chains, Periodicity
4	3.6-3.10	Ergodic Markov Chains, Time Reversibility, Absorbing Chains, Regeneration and the Strong Markov Property. Limit Theorems.
5	4.1-4.4	Branching Processes, Mean Generation Size, Probability Generating Functions, Extinction Probability
6	5.1-5.3	Markov Chain Monte Carlo, Metropolis–Hastings Algorithm and Gibbs Sampler
7	6.1-6.4	Poisson Process, Arrival, Interarrival Times, Infinitesimal Probabilities, Thinning, Superposition
8	6.5-6.8	Uniform Distribution, Spatial Poisson Process, Nonhomogeneous Poisson Process and Parting Paradox.
9	**Mid Semester Exam**	
10	7.1-7.3	Continuous-Time Markov Chains, Alarm Clocks and Transition Rates, Infinitesimal Generator,
11	7.4-7.7	Long-Term Behavior, Time Reversibility, Queueing Theory, Poisson Subordination
12	8.1-8.3	Brownian Motion and Random Walk, Gaussian Process
13	8.4-8.6	Transformations and Properties, Variations and Applications, Martingales
14	9.1-9.2	Stochastic Calculus, Ito Integral
15	9.3	Stochastic Differential Equations
16		Applications and Revisions
17		Revision
18	**End Semester Exam**	

MATH-471 Cryptography

Credit Hours: 3-0
Prerequisite: MATH-274 Elementary Number Theory

Course Objectives: Cryptography is the practice and study of techniques for secure communication in the presence of third parties. The focus of the course is about constructing and analyzing protocols that overcome the influence of adversaries and which are related to various aspects in information security such as data confidentiality, data integrity and authentication.

Detailed Course Contents: Overview of cryptology, Cryptanalysis, Module arithmetic and integer rings, Symmetric Cryptography, Shift Ciphers and affine Ciphers, Introduction to stream ciphers, Random numbers and unbreakable stream ciphers, Shift register based stream ciphers, Introduction to data encryption standards (DES), Overview of DES algorithm, Internal structure of DES, Key Schedule, Decryption of DES, Advanced encryption standard, Galois field, Encryption with Block-Ciphers: Modes of Operation, Increase the Security of Block Ciphers, Symmetric vs Asymmetric Cryptology, Practical Aspects of Public-Key Cryptology, Essential Number Theory for Public-Key Algorithms

Course Outcomes:

- To understand the concept and importance of Information security and its applications in computer security and Financial Markets.
- Student's must understand and be able to understand the classical ciphers and their cracking by using elementary number theory

Text Book: C. Paar and J. Pelzl, Understanding Cryptography, Springer, 2nd Edition, 2010.

Reference Books:

1. J. Katz, Y. Lindell, Introduction to Modern Cryptography, Chapman and Hall, 2007.
2. J. Hoffstein, J. Pipher, J. H. Silverman, An Introduction to Mathematical Cryptography, Springer, 2008.
3. Buchmann, J., Introduction to Cryptography, Springer, 2004
4. J. Menezes, P. C. van Oorschot, S. A. Vanstone, Handbook of Applied Cryptography, CRC Press; 1st edition, 1996.

Weekly Breakdown		
Week	***Section***	***Topics***
1	1.1-1.3	Overview of cryptology, symmetric cryptography, Cryptanalysis,
2	1.4	Module arithmetic and integer rings, Shift ciphers and affine ciphers
3	2.1	Introduction to stream ciphers (stream ciphers vs block ciphers; Encryption and decryption with stream ciphers)
4	2.2-2.3	Random numbers and unbreakable stream ciphers, Shift register based stream ciphers
5	3.1-3.2	Introduction to data encryption standards (DES), Overview of DES algorithm
6	3.3	Internal structure of DES • Initial and final permutation The f-function
7	3.3 (Contd.),	Key Schedule, Decryption of DES

	3.4	
8	4.1-4.2	Introduction to Advanced encryption standard (AES), Overview of AES algorithm
9	**Mid Semester Exam**	
10	4.3	Existence of finite fields; Prime fields, Extension fields $GF\ (2^m)$
11	4.3 (Contd.)	Addition and subtraction in $GF\ (2^m)$, Multiplication in $GF\ (2^m)$, Inversion in $GF\ (2^m)$
12	4.4	Byte substitution layer, Diffusion layer, Key addition layer
13	4.4 (Contd.), 4.5	Key schedule, Decryption of AES
14	5.1	Encryption with Block-Ciphers: Modes of Operations
15	5.3	Increase the Security of Block Ciphers
16	6.1-6.2	Symmetric vs Asymmetric Cryptology, Practical Aspects of Public-Key Cryptology
17	6.3	Essential Number Theory for Public-Key Algorithms
18	**End Semester Exam**	

MATH-473 Operations Research

Credit Hours: 3-0
Prerequisite: None

Course Objectives: The objective is to provide a fundamental account of the basic results and techniques of linear programming (LP) and its related topics in operations research. There is an equal emphasis on all aspects of understanding, algorithms and applications. The course serves, together with topic on network models, as essential concept and background for more advanced studies in operations research. The main focus of the course is on Linear Programming Models, Duality Problems and Sensitivity analysis, Transportation Models and Network Flow Models.

Core Contents: Linear Programming, Duality and Sensitivity Analysis, Transportation Models, Network Flow Problems

Detailed Course Contents: Linear Programming: Linear programming, formulations and graphical solution, Simplex method, M-Technique and two-phase technique, Special cases in Simplex method
Duality and Sensitivity Analysis: The dual problem, primal-dual relationships, Dual simplex method, Sensitivity and postoptimal analysis
Transportation Models: Transportation problem formulations, North-West corner Method, Least-Cost and Vogel's approximations methods, The method of multipliers, The assignment model Network Flow Problems: Minimal spanning tree algorithm, Shortest route-problem, Maximalflow models

Course Outcomes:

- To understand the basic techniques in operations research and formulations of the problems
- To understand the fundamental concept and approach of linear programming appropriate to the further study of operations research;
- To demonstrate knowledge and understanding of the underlying techniques of the Simplex Method and its extensions such as the revised Simplex and dual Simplex algorithms;
- To understand and apply the theory of LP duality such as in the theory and computations of Network Optimization

Text Book: Hamdy A. Taha, Operations Research - An Introduction, Prentice Hall; 9th edition, 2010.
Reference Books

1. Paul A. Jensen, Jonathan F. Bard, Operations Research Models and Methods, JohnWiley and Sons Publishing Company, 2003.
2. Glenn H. Hurlbert, Linear Optimization, Springer, 2010.

Weekly Breakdown		
Week	***Section***	***Topics***

1	1.1, 1.2	Operation Research Models, Solving the OR Models
2	2.1	Two-Variable LP Model
3	2.2	Graphical LP Solutions and Selected LP Applications
4	3.1, 3.2	LP Models in equation form, Transition from Graphical to Algebraic Solution
5	3.3, 3.4	The Simplex Method, Artificial Starting Solution
6	3.5	Special Cases in Simplex Method
7	3.6	Sensitivity Analysis
8	4.1, 4.2	Definition of Dual Problem, Primal-Dual Relationship
9	**Mid Semester Exam**	
10	4.4	Dual Simplex Algorithm
11	4.5	Post-Optimal Analysis
12	5.1, 5.2	Definition of the Transportation Model, Nontraditional Transportation Models
13	5.3, 5.4	The Transportation Algorithm, The Assignment Model
14	6.2	Minimal Spanning Tree Algorithm
15	6.3	Shortest-Route Problem
16	6.4	Maximal Flow Models
17		Revision
18	**End Semester Exam**	

MATH-475 Game Theory

Credit Hours: 3-0
Prerequisites: None

Course Objectives: Game Theory is the study of mathematical models of conflict and cooperation between intelligent rational decision-makers. The main objective of this course is understand the combinatorial games, cooperative and non-cooperative games, and Nash equilibrium.

Core Contents: Detailed Contents: Introduction to game theory, Nash Equilibrium, Mixed Strategy Equilibrium, Mixed Strategy Equilibrium, Extensive Games with Perfect Information.

Detailed Course Contents: Introduction to game theory: The theory of rational choice, Coming attractions. Nash Equilibrium (Theory): Strategic games, the Prisoner's Dilemma, Bach or Stravinsky, Matching Pennies, the Stag Hunt. Nash equilibrium, Examples of Nash equilibrium Best response functions, Dominated actions, Equilibrium in a single population: symmetric games and symmetric equilibria.
Nash Equilibrium (Illustrations): Cournot's model of oligopoly. Bertrand's model of oligopoly, Electoral competition, The War of Attrition.
Mixed Strategy Equilibrium: Strategic games in which players may randomize, Mixed strategy Nash equilibrium, Dominated actions, Pure equilibria when randomization is allowed.
Extensive Games with Perfect Information (Theory): Strategies and outcomes, Nash equilibrium. Subgame perfect equilibrium. Finding subgame perfect equilibria of finite horizon games: backward Induction.
Coalitional Games and the Core: Coalitional games, The core.

Text Book: Martin J. Osborne, An Introduction to Game Theory, Oxford University Press; Int edition (January 28, 2009)

Reference Book: Julio González-Díaz, Ignacio García-Jurado, M. Gloria Fiestras-Janeiro An Introductory Course on Mathematical Game Theory, 2010.

Weekly Breakdown		
Week	***Section***	***Topics***
1	1.1-1.3	Introduction to game theory: The theory of rational choice, Coming attractions.
2	2.1-2.3	Nash Equilibrium (Theory): Strategic games, the Prisoner's Dilemma, Bach or Stravinsky
3	2.4, 2.5	Matching Pennies, the Stag Hunt.
4	2.6, 2.7	Nash equilibrium, Examples of Nash equilibrium
5	2.8, 2.9	Best response functions, Dominated actions
6	2.10	Equilibrium in a single population: symmetric games and symmetric equilibria
7	3.1	Nash Equilibrium (Illustrations): Cournot's model of oligopoly.
8	3.2, 3.3	Bertrand's model of oligopoly, Electoral competition

9	**Mid Semester Exam**	
10	3.4	The War of Attrition
11	4.1-4.3	Mixed Strategy Equilibrium: Strategic games in which players may randomize, Mixed strategy Nash equilibrium,
12	4.4-4.5	Dominated actions, Pure equilibria when randomization is allowed.
13	5.1-5.4	Extensive Games with Perfect Information (Theory): Strategies and outcomes, Nash equilibrium.
14	5.5	Subgame perfect equilibrium.
15	5.6	Finding subgame perfect equilibria of finite horizon games: backward Induction.
16	8.1, 8.2	Coalitional Games and the Core: Coalitional games, The core
17		Revision
18	**End Semester Exam**	

MATH-480 Tensor Calculus

Credit Hours: 3-0
Prerequisite: None
Course Objectives: The purpose of this course is to introduce the basic definitions and techniques arising in tensor calculus, differential geometry and continuum mechanics. In particular, this course is aimed to (i) develop a physical understanding of the mathematical concepts associated with tensor calculus and (ii) develop the basic equations of tensor calculus, differential geometry and continuum mechanics which arise in applications.
Core Contents: Index notation, Transformation equations, Contravariant components, Special tensors: Metric tensor, Derivative of a tensor, Differential geometry and relativity, Tensor notation for scalar and vector quantities, Basic equations of continuum mechanics.
Detailed Course Contents: Index notation: Symmetric and skew-symmetric systems, Summation convention, Addition, multiplication and contraction, The e-permutation symbol and Kronecker delta, The e-delta Identity, Generalized Kronecker delta, Additional applications ofthe indicial notation.
Transformation equations, Calculation of derivatives, Vector identities in Cartesian coordinates, Indicial Form of Integral Theorems, Determinants, Cofactors
Tensor concepts and transformations: Reciprocal Basis, Coordinate Transformations, Scalars, Vectors and Tensors, Cartesian Coordinates, Scalar functions and invariance, Vector Transformation, Contravariant components, Covariant components, Higher order tensors, Dyads and polyads, Operations using tensors(Addition and Subtraction, Outer Product, Contraction, Inner product, Quotient law)
Special tensors: Metric tensor, Conjugate metric tensor, Associated tensors, Riemann space, Epsilon Permutation Symbol, Cartesian
Tensors, Physical Components, Physical Components For Orthogonal Coordinates, Higher ordertensors, Physical components in general, Tensors and multilinear forms, Dual Tensors, Derivative of a tensor: Christoffel Symbols, Covariant differentiation, Covariant derivative ofcontravariant tensor, Rules for covariant differentiation, Riemann Christoffel tensor, Physical Interpretation of Covariant Di_erentiation, Ricci's theorem, Intrinsic or absolute differentiation,Parallel vector fields,
Differential geometry and relativity: Surfaces and Curvature, Normal Curvature, The equations of Gauss. Weingarten and Codazzi, Geodesic Curvature, Tensor derivatives, Geodesic Coordinates, Riemann Christoffel tensor. Surface Curvature.
Tensor notation for scalar and vector quantities: Gradient, Divergence, Laplacian, Eigenvalues and Eigenvectors of Symmetric Tensors. Dynamics: Particle Movement, Frenet-Serret formulas, Work and Potential Energy, Conservative systems. Lagrange's equations of motion, Euler- Lagrange equations of motion, Action Integral, Dynamics of Rigid Body Motion, Relative motion and angular velocity, Euler's equations of motion.
Basic equations of continuum mechanics: Introduction to elasticity, Normal and shearing stresses, The stress tensor, Cauchy stress law. Conservation of linear momentum, Conservation of angular momentum, Strain in Two Dimensions. Transformation of an arbitrary element, Cartesian tensor derivation of strain. Lagrangian and Eulerian Systems, General tensor derivation
of strain, Compressible and incompressible material, Conservation of mass.
Course Outcomes: The students are expected to:

- Develop a physical understanding of the mathematical concepts associated with tensor calculus and.
- Develop the basic equations of tensor calculus, differential geometry and continuum mechanics

which arise in applications.

Text Books: J. H. Heinbockel, Introduction to Tensor Calculus and Continuum Mechanics,Trafford Publishing (2001)

Reference Books:

1. Mikhail Itskov, Tensor algebra and tensor analysis for engineers with applications to continuum mechanics, Springer Berlin Heidelberg (2009).
2. Theodore Frankel, The Geometry of Physics, An Introduction (3rd Ed.), Cambridge (1997).

Weekly Breakdown		
Week	***Section***	***Topics***
1	1.1	Index notation: Symmetric and skew-symmetric systems, Summation convention, Addition, multiplication and contraction, The e-permutation symbol and Kronecker delta, The e-delta Identity, Generalized Kronecker delta, Additional applications of the indicial notation.
2	1.1 (cont.)	Transformation equations, Calculation of derivatives, Vector identities in Cartesian coordinates, Indicial Form of Integral Theorems, Determinants, Cofactors
3	1.2	Tensor concepts and transformations: Reciprocal Basis, Coordinate Transformations, Scalars, Vectors and Tensors, Cartesian Coordinates, Scalar functions and invariance, Vector transformation,
4	1.2 (cont.)	Contravariant components, Covariant components, Higher order tensors, Dyads and polyads, Operations using tensors (Addition and Subtraction, Outer Product, Contraction, Inner product, Quotient law).
5	1.3	Special tensors: Metric tensor, Conjugate metric tensor, Associated tensors, Riemann space, Epsilon Permutation Symbol, Cartesian.
6	1.3 cont.	Tensors, Physical Components, Physical Components For Orthogonal Coordinates, Higher order tensors, Physical components in general, Tensors and multilinear forms, Dual Tensors.
7	1.4	Derivative of a tensor: Christoffel Symbols, Covariant differentiation, Covariant derivative of contravariant tensor, Rules for covariant differentiation, Riemann Christoffel tensor, Physical Interpretation of Covariant Differentiation, Ricci's theorem, Intrinsic or absolute differentiation, Parallel vector fields.
8	1.5	Differential geometry and relativity: Surfaces and Curvature, Normal Curvature, The equations of Gauss.
9	**Mid Semester Exam**	
10	1.5 cont.	Weingarten and Codazzi, Geodesic Curvature, Tensor derivatives, Geodesic Coordinates, Riemann Christoffel tensor.
11	1.5 Cont.2.1	Surface Curvature, Tensor notation for scalar and vector quantities: Gradient, Divergence, Laplacian, Eigenvalues and Eigenvectors of Symmetric Tensors.
12	2.2	Dynamics: Particle Movement, Frenet-Serret formulas, Work and Potential Energy, Conservative systems.
13	2.3	Basic equations of continuum mechanics: Introduction to elasticity, Normal and shearing stresses, The stress tensor, Cauchy stress law.
14	2.3 cont.	Conservation of linear momentum, Conservation of angular momentum, Strain in Two Dimensions.
15	2.3 cont.	Transformation of an arbitrary element, Cartesian tensor derivation of strain.
16	2.3 cont.	Lagrangian and Eulerian Systems, General tensor derivation of strain, Compressible and incompressible material, Conservation of mass.
17		Revision
18	**End Semester Exam**	

MATH-491 Fluid Mechanics

Credit Hours: 3-0
Pre-requisite: None

Course Objectives: Fluid mechanics deals with the fluids in a static or in a dynamic state. Most of the phenomena occurring in human lives are mostly fall in this subject. Either we study the flow of air around an aeroplane or study the air flow around a vehicle on the road we must understand the laws of fluid mechanics. The key topics in this subject includes real and ideal fluids, steady and unsteady flows, velocity potential, Bernoulli's equations, incompressible fluid, streamlines, streaklines and pathlines, Reynold transport theorem, Navier-Stokes equations, potential flows, boundary layer equations, vorticity and rotation, viscous stresses and rotation, dimensional analysis.

Core Contents: Introduction, Pressure Distribution in a Fluid, Integral Relations for a Control Volume, Differential Relations for a Fluid Particle, Dimensional Analysis and Similarity

Detailed Contents:
Preliminary Remarks: Introduction.
The Concept of a Fluid: The Concept of a Fluid
The Fluid as a Continuum: The Fluid as a Continuum
Dimension and Units: Primary Dimension, Consistent Units
Properties of the Velocity Field: Eulerian and Lagrangian Description,The Velocity Field
Thermodynamic Properties of a Fluid: Pressure, Temperature, Density, Specific Weight, Specific Gravity, Potential and Kinetic Energies, State Relations for Gases, State Relations for Liquids
Viscosity and Other Secondary Properties: Viscosity, The Reynolds Number, Flow Between Plates, Variation of Viscosity with Temperature, Thermal Conductivity, Non-Newtonian Fluids, Vapor Pressure, No Slip and No Temperature Jump Conditions, Speed of Sound
Basic Flow Analysis Techniques: Basic Flows Analysis Technique
Flow P atterns: Streamlines, Streaklines an d Pathlines: Flow Patterns: Streamlines, Streaklines a nd Pathlines
Pressure and Pressure Gradient: Pressure Force on a Fluid Element
Equilibrium of a Fluid Element: Equilibrium of a Fluid Element, Gage Pressure and Vacuum Pressure: Relative Terms
Hydrostatic Pressure Distribution: Hydrostatic Pressure Distribution, Hydrostatic Pressure in Liquid, Hydrostatic Pressure in Gases
Pressure Measurement: Pressure Measurement
Basic Physical Laws of Fluid Mechanics: Basic Physical Laws of Fluid Mechanics, System versus Control Volume, Volume and Mass Rate of Flow
The Reynolds Transport Theorem: The Reynolds Transport Theorem, One Dimensional Fixed Control Volume, Arbitrary Fixed Control Volume
Conservation of Mass: Conservation of Mass, Incompressible Flow
The Linear Momentum Equation: The Linear Momentum Equation, One Dimensional Momentum Flux, Net Pressure on a Closed Control Surface
The Angular Momentum Theorem: The Angular Momentum Theorem
The Energy Equation: The Energy Equation, One Dimensional Energy F lux T erm, The Steady F low Energy Equation,
Frictionless Flow: The Bernoulli Equation: Frictionless Flow: The Bernoulli Equation, Relation Between the Bernoulli and Steady Flow Energy Equations
The Acceleration Field of a Fluid: The Acceleration Field of a Fluid
The Differential Equation of Mass Conservation: The Differential Equation of Mass Conservation,

Cylindrical Polar Coordinates, Steady Compressible Flow, Incompressible Flow
The Differential Equation of Linear Momentum: The Differential Equation of Linear Momentum,Inviscid Flow: Euler Equation, Newtonian Fluid: Navier-Stokes Equations
The Differential Equation of Energy: The Differential Equation of Energy
Boundary Conditions for the Basic Equations: Boundary Conditions for the Basic Equation, Simplified Free Surface Conditions, Incompressible Flow with Constant Properties, Inviscid Flow, Approximation.
The Stream Function: The Stream Function, Geometric Interpretation of ψ, Steady Plane Compressible Flows, Incompressible Plane Flow in Polar Coordinates, Incompressible Axisymmetric Flows
Vorticity and Irrotationality: Vorticity and Irrotationality
Frictionless Irrotational Flows: Frictionless Irrotational Flows, Velocity Potential, Orthogonality of Streamlines and Potential Lines, Generation of Rotationality
Some Illustrative Incompressible Viscous Flows: Couette Flow between a Fixed and a Moving Plate, Flow Due to Pressure Gradient between Two Fixed Plates
Introduction: Introduction
The Principle of Dimensional Homogeneity: The Principle of Dimensional Homogeneity, Ambiguity: The Choice of Variables and Scaling Parameters, Some Peculiar Engineering Equation
Learning Outcome: On successful completion of this course, students will be able to:
understand the governing laws for fluid flows which will be helpful in understanding physicalphenomena.
model and solve the fluid flow problems.
differentiate between different types of flows e.g. steady or unsteady flows etc.

Textbook:

Frank M. White , Fluid Mechanics, 8th Edition, McGraw-Hill Higher Education, 2017.

Recommended Books

1. Fluid Mechanics: Fundamentals and Applications by Yunus A Çengel and John M Cimbala, 3rd Edition, McGraw-Hill Science/Engineering/Math, 2013.
2. Fluid Mechanics by Pijush K. Kundu and Ira M. Cohen and David. R. Dowling, 5th Edition, Academic Press , 2011.

Weekly Breakdown		
Week	***Section***	**Topics**
1	1.1-1.3	**Preliminary Remarks:** Introduction **The Concept of a Fluid:** The Concept of a Fluid **The Fluid as a Continuum:** The Fluid as a Continuum
2	1.4-1.6	**Dimension and Units:** Primary Dimension, Consistent Units **Properties of the Velocity Field**: Eulerian and Lagrangian Description,The VelocityField **Thermodynamic Properties of a Fluid:** Pressure, Temperature, Density, Specific Weight, Specific Gravity, Potential and Kinetic Energies, State Relations for Gases, State Relations for Liquids
3	1.7	**Viscosity and Other Secondary Properties:** Viscosity, The Reynolds Number, FlowBetween Plates, Variation of Viscosity with Temperature, Thermal Conductivity, Non-Newtonian Fluids, VaporPressure, No Slip and No Temperature Jump Conditions, Speed of Sound
4	1.8-1.9	**Basic Flow Analysis Techniques:** Basic Flows Analysis Technique **Flow Patterns: Streamlines, Streaklines and Pathlines:** Flow Patterns: Streamlines,Streaklines and Pathlines

5	2.1-2.2	**Pressure and Pressure Gradient:** Pressure Force on a Fluid Element **Equilibrium of a Fluid Element:** Equilibrium of a Fluid Element, Gage Pressure andVacuum Pressure: Relative Terms
6	2.3	**Hydrostatic Pressure Distribution:** Hydrostatic Pressure Distribution, HydrostaticPressure in Liquid, Hydrostatic Pressure in Gases
7	3.1	**Basic Physical Laws of Fluid Mechanics:** Basic Physical Laws of Fluid Mechanics,System versus Control Volume, Volume and Mass Rate of Flow
8	3.2-3.4	**The Reynolds Transport Theorem:** The Reynolds Transport Theorem, OneDimensional Fixed Control Volume, Arbitrary Fixed Control Volume **Conservation of Mass:** Conservation of Mass, Incompressible Flow **The Linear Momentum Equation:** The Linear Momentum Equation, One DimensionalMomentum Flux, Net Pressure on a Closed Control Surface
9	**Midterm**	
10	3.5, 3.7	**Frictionless Flow: The Bernoulli Equation:** Frictionless Flow: The Bernoulli Equation**,** Relation Between the Bernoulli and Steady Flow Energy Equations **The Energy Equation:** The Energy Equation, One Dimensional Energy Flux Term, TheSteady Flow Energy Equation,
11	4.1-4.3	**The Acceleration Field of a Fluid**: The Acceleration Field of a Fluid **The Differential Equation of Mass Conservation:** The Differential Equation of Mass Conservation, Cylindrical Polar Coordinates, Steady Compressible Flow, IncompressibleFlow **The Differential Equation of Linear Momentum:** The Differential Equation of LinearMomentum, Inviscid Flow: Euler Equation, Newtonian Fluid: Navier-Stokes Equation
12	4.5 4.6	**The Differential Equation of Energy:** The Differential Equation of Energy **Boundary Conditions for the Basic Equations:** Boundary Conditions for the BasicEquation, Simplified Free Surface Conditions, Incompressible Flow with Constant Properties, Inviscid Flow Approximation
13	4.7-4.8	**The Stream Function:** The Stream Function, Geometric Interpretation of $\psi\psi$, SteadyPlane Compressible Flows, Incompressible Plane Flow in Polar Coordinates, Incompressible Axisymmetric Flows **Vorticity and Irrotationality:** Vorticity and Irrotationality
14	4.9	**Frictionless Irrotational Flows:** Frictionless Irrotational Flows, Velocity Potential, Orthogonality of Streamlines and Potential Lines, Generation of Rotationality
15	4.10	**Some Illustrative Incompressible Viscous Flows:** Couette Flow between a Fixed anda Moving Plate, Flow Due to Pressure Gradient between Two Fixed Plates
16	5.1-5.2	**Inroduction**: Introduction **The Principle of Dimensional Homogeneity**: The Principle of Dimensional Homogeneity, Ambiguity: The Choice of Variables and Scaling Parameters, SomePeculiar Engineering Equation
17	**5.3**	**The Pi Theorem**
18		**End semester Exam**

MATH-492 Computational Fluid Dynamics

Credit Hours: 3-0
Prerequisite: MATH-491 Fluid Mechanics

Course Objectives: This course provides an in depth introduction to the method and analysis techniques used in computational solutions of fluid mechanics problems. Modeled problems are used to study the interaction of physical processes and numerical techniques. Contemporary methods for boundary layers, incompressible viscous flows and inviscid compressible flows are studied. Finite difference and finite volume techniques are emphasized.

Core Contents: Discretization methods; Numerical methods for some modeled equations; Approximations to the governing equations in fluid dynamics; Numerical methods for inviscid and viscous flow problems; Numerical solutions of the Navier-Stokes equations.

Detailed Course Contents: Basics of Discretization Methods: Finite volume method,Introduction to the use of irregular meshes, Stability considerations.

Application of Numerical Methods to Selected Model Equations: Burgers equation (inviscid), Burgers equation (viscous).

Governing Equations of Fluid Mechanics: Averaged equations for turbulent flows, Boundary layer equations, Introduction to turbulence modeling, Euler equation, Transformation of the governing equations, Finite-volume formulation.

Numerical Methods for Inviscid Flow Equations: Introduction to numerical methods for inviscid flow equations, Method of characteristics, Classical shock capturing methods, Flux-splitting schemes, Flux-difference splitting schemes, Multi-dimensional case in a general coordinatesystem, Boundary conditions for the Euler equations, Methods for solving the potential equation,Transonic small disturbance equations, Methods for solving Laplace equation.

Numerical Methods for Boundary-Layer Type Equations: Introduction, Brief comparison of prediction methods, Finite difference method for two-dimensional or axisymmetric externalflows, Inverse method, Separated flows and viscous-inviscid interactions, Methods for internal flows, Application to free-shear flows, Three-dimensional boundary layers, Unsteady boundary layers.

Numerical Methods for the Parabolized Navier-Stokes Equations: Introduction, Thin layer Navier-Stokes equations, Parabolized Navier-Stokes equation, Parabolized and partial parabolized Navier-Stokes procedures for subsonic flows, viscous shock layer equations, “Conical” Navier-Stokes equations.

Numerical Methods for the Navier-Stokes Equations: Introduction, Compressible Navier-Stokes equations, Incompressible Navier-Stokes equations.

Course Outcomes:

- To develop an understanding for: the major approaches and methodologies used in CFD, the interplay of physics and numeric, the methods and results of numerical analysis
- To gain experience in: the actual implementation of methods, the little stuff that is not always clear from theory (e.g. boundary conditions, etc.)

- Increase skills in: implementing and using basic CFD methods computer use and programming.

Text Book: R. H. Pletcher, J. C. Tennehill and D. Andersson, Computational Fluid Mechanicsand Heat Transfer, 3rd Edition, Taylor & Francis, ISBN-10: 1591690374

Reference Books:

1. S. Chapra and R. Canale, Numerical Methods for Engineers, (6th Ed.) McGraw-Hill Higher Education, 2009.
2. J. Ferziger and M. Peric, Computational Methods for Fluid Dynamics. (3rd Ed.) Springer, 2001.

Weekly Breakdown		
Week	***Section***	***Topics***
1	3.5, 3.6,3.7	Finite volume method, Introduction to the use of irregular meshes, Stability considerations.
2	4.4, 4.5	Burgers equation (inviscid), Burgers equation (viscous).
3	5.2, 5.3	Averaged equations for turbulent flows, boundary layer equations.
4	5.4, 5.5	Introduction to turbulence modeling, Euler equation.
5	5.6, 5.7	Transformation of governing equations, Finite-volume formulation.
6	6.1, 6.2, 6,3	Introduction to numerical methods for inviscid flow equations, Method of characteristics, Classical shock capturing methods.
7	6.4, 6.5, 6.6, 6.7	Flux-splitting schemes, Flux-difference splitting schemes, Multi-dimensional case in a general coordinate system, Boundary conditions for the Euler equations.
8	6.8, 6.9, 6.10	Methods for solving the potential equation, Transonic small disturbance equations, Methods for solving Laplace equation.
9	**Mid Semester Exam**	
10	7.1, 7.2, 7.3	Introduction to numerical methods for boundary layer type equations, Brief comparison of prediction methods, Finite difference method for two-dimensional or axisymmetric external flows.
11	7.4, 7.5	Inverse method, Separated flows and viscous-inviscid interactions, Methods for internal flows.
12	7.6, 7.7, 7.8	Application to free-shear flows, Three-dimensional boundary layers, Unsteady boundary layers.
13	8.1, 8.2,	Introduction to numerical methods for “parabolized” Navier-Stokes equation, Thin layer Navier-Stokes equations, Parabolized Navier-Stokes equations
14	8.4, 8.5	Parabolized and partial parabolized Navier-Stokes procedures for subsonic flows, viscous shock layer equations, “Conical” Navier-Stokes equations.
15	9.1, 9.2	Introduction to Numerical methods for the Navier-Stokes equations, Compressible Navier-Stokes equations.
16	9.3, 10.1	Incompressible Navier-Stokes equations, Introduction to grid generation.
17		Revision
18	**End Semester Exam**	

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DS-201 Introduction to Data Science

Credit Hours: 2-1
Prerequisite: None

Course Objectives: At the conclusion of the course, students should learn the skill sets required to be a data scientist. Basic statistical concepts such as probability distributions, statistical inference etc. will be covered during the course. Python language will be utilized to carry out basic statistical modeling and analysis. Significance of exploratory data analysis (EDA) in data science will be explored together with basic tools (plots, graphs, summary statistics).

Course Contents: Introduction: What is data science? Big data and data science hype - and getting past the hype, skill sets needed, statistical inference, populations and samples, statistical modelling, probability distributions, fitting a model, exploratory data Analysis and the data science process, basic tools of EDA and introductory concepts involved in machine learning.

Course Outcomes: Upon completion of this course, the student should be able to:

- Describe data science
- Explain statistical inference in basic terms
- Explain the significance of exploratory data analysis (EDA) in data science

Text Book: Cathy O'Neil and Rachel Schutt. Doing Data Science, Straight Talk From The Frontline. O'Reilly, 2014.

Reference Books:

1. Van Der Aalst, Wil. Process mining: data science in action. Vol. 2. Heidelberg: Springer, 2016.
2. De Brouwer, Philippe JS. The Big R-Book: From Data Science to Learning Machines and Big Data. John Wiley & Sons, 2020.

Weekly Breakdown		
Week	***Section***	***Topics***
1	Chap 1	Introduction: What is Data Science? Big Data and Data Science hype - and getting past the hype Skill sets needed
2	2.1	Statistical Inference Populations and samples Statistical modelling, probability distributions, fitting a model
3	2.2	Exploratory Data Analysis and the Data Science Process Basic tools (plots, graphs and summary statistics) of EDA
4	2.3	Philosophy of EDA, The Data Science Process
5	2.4	SQL and Enterprise Data Management
6	3.1	Three Basic Machine Learning Algorithms, Linear Regression
7	3.2-3.3	k-Nearest Neighbours (k-NN) and k-means
8	4.1,4.6-4.7	Data Wrangling: APIs and other tools for scrapping the Web
9	**Mid Semester Exam**	
10	7.4	Feature Generation and Feature Selection (Extracting Meaning From Data)
11	7.5-7.8	Mining Social-Network Graphs
12	7.9-7.10	Social networks as graph
13	9.1-9.3	Data Visualization, Basic principles, ideas and tools for data visualization
14	9.4-9.6	Data Science and Ethical Issues,
15	16.1-16.3	Next-generation data scientists
16	16.4-16.5	Next-generation data scientists
17		Review
18	**End Semester Exam**	

DS-302 Machine Learning for Data Analysis

Credit Hours: 3-1
Prerequisite: None

Course Objectives: This course introduces students to the broad field of artificial intelligence (AI) with focus on machine learning (ML) algorithms for data analysis. The students will learn basic principles and techniques used in ML. They will also be able to apply ML techniques to solve real-world data analysis problems.

Course Contents: Machine Learning Overview, Supervised Learning, Linear Regression, Artificial Neural Networks, Deep Learning, Support Vector Machines and Applications, Unsupervised Learning, K-Means Clustering, Dimensionality Reduction, Recurrent Neural Networks, Visual Perception.

Course Outcomes: Upon completion of this course, the student should be able to learn:

- Machine learning
- Regression
- Clustering
- Classification

Text Book: Bishop, Christopher M., and Nasser M. Nasrabadi. Pattern recognition and machine learning. Vol. 4. No. 4. New York: springer, 2006.

Reference Books:

1. Hastie, Trevor, et al. The elements of statistical learning: data mining, inference, and prediction. Vol. 2. New York: Springer, 2009.
2. Hart, Peter E., David G. Stork, and Richard O. Duda. Pattern Classification. Hoboken: Wiley, 2000.
3. Goodfellow, Ian, Yoshua Bengio, and Aaron Courville. Deep learning. MIT press, 2016.

Weekly Breakdown		
Week	***Section***	***Topics***
1	2.1-2.4	Machine Learning Overview, Linear Regression
2	2.5	Visual Recognition, Nearest Neighbor Classifier
3	3.1	Regularization
4	4.3	Logistic Regression
5	4.5	Naïve Bayes Classifier
6	5.1-5.2	Artificial Neural Networks
7	5.3-5.4	Training Neural Networks with Backpropagation
8	5.5	Convolutional Neural Networks
9	**Mid Semester Exam**	
10	6.2-6.3	Kernel Methods
11	7.1	Support Vector Machines

12	9.1-9.2	Unsupervised Learning: Cluster Analysis, K-Means
13	9.3-9.4	Unsupervised Learning: Distribution Based Clustering, Validation
14	12.1-12.3	Latent Variables Based Learning
15		Project Presentations
16		Project Presentations
17		Review
18	**End Semester Exam**	

DS-403 Data Mining

Credit Hours: 3-0
Prerequisite: None

Course Objectives: Students will learn to understand the underlying concepts and the theory behind the different algorithms and have a detailed understanding of data mining etc.

Course Contents: Introduction to data mining and basic concepts, Pre-Processing Techniques & Summary Statistics, Topological Attributes , Centrality Analysis, Graph Models Kernel Matrix, Vector Kernels, Basic Kernel Operations in Feature Space, Kernels for Complex Objects High-dimensional Objects, High-dimensional Volumes, Hypersphere Inscribed within Hypercube Diagonals in Hyperspace, Density of the Multivariate Normal Principal Component Analysis, Kernel Principal Component Analysis Frequent Pattern Trees Mid Term Association Rule mining using Apriori Algorithm. Generating Association Rules Maximal and Closed Frequent Itemsets, Mining Maximal Frequent Itemsets: GenMax Algorithm Frequent Sequences, Mining Frequent Sequences Substring Mining via Suffix Trees Rule and Pattern Assessment Measures, Significance Testing and Confidence Interval Implementing concepts using Python.

Course Outcomes: After completion of the course, the students shall be able to:

- Understand the underlying concepts and the theory behind the different data mining algorithms
- Use python and the associated libraries for implementation of data mining algorithms.

Text Book: Zaki, Mohammed J., Wagner Meira Jr, and Wagner Meira. Data mining and analysis: fundamental concepts and algorithms. Cambridge University Press, 2014.

Reference Books:

1. Han, Jiawei, Micheline Kamber, and Jian Pei. "Data mining: concepts and." Techniques (3rd ed), Morgan Kauffman (2011).
2. Tan, Pang-Ning, Michael Steinbach, and Vipin Kumar. Introduction to data mining. Pearson Education India, 2016.
3. Aggarwal, Charu C. Data mining: the textbook. Vol. 1. New York: springer, 2015.

Weekly Breakdown		
Week	***Section***	***Topics***
1	Chapter 1	Introduction to data mining and basic concepts
2	Chapter 2 and 3	Pre-Processing Techniques & Summary Statistics
3	4.2-4.4	Topological Attributes , Centrality Analysis, Graph Models
4	5.1-5.4	Kernel Matrix, Vector Kernels, Basic Kernel Operations in Feature Space, Kernels for Complex Objects
5	6.1-6.3	High-dimensional Objects, High-dimensional Volumes, Hypersphere Inscribed within Hypercube
6	6.5-6.6	Diagonals in Hyperspace, Density of the Multivariate Normal
7	7.2-7.3	Principal Component Analysis, Kernel Principal Component Analysis
8	8.1	Frequent Pattern Trees
9	**Mid Semester Exam**	
10	8.2	Association Rule mining using Apriori Algorithm.
11	8.3-8.4	Generating Association Rules
12	9.1	Maximal and Closed Frequent Itemsets,
13	9.2	Mining Maximal Frequent Itemsets: GenMax Algorithm
14	10.1-10.2	Frequent Sequences, Mining Frequent Sequences
15	10.3	Substring Mining via Suffix Trees
16	12.1-12.2	Rule and Pattern Assessment Measures, Significance Testing and Confidence Interval
17		Revision
18	**End Semester Exam**	

DS-404 Artificial Neural networks

Credit Hours: 3-1
Prerequisite: DS-302 Machine Learning for Data Analysis

Course Objectives: This course aims to understand, design the structure of deep neural networks and implement a number of industry-standard architectures in a wide range of application areas.

Course Contents: Introduction and history of neural networks, Basic architecture of neural networks, Perceptron and Adaline (Minimum Error Learning) for classification, Gradient descent (Delta) rule, Hebbian, Neo-Hebbian and Differential Hebbian Learning, Drive Reinforcement Theory, Kohonen Self Organizing Maps, Associative memory, Bi-directional associative memory (BAM), Energy surfaces, The Boltzmann machines, Backpropagation Networks, Feedforward Networks; Introduction to Deep learning and its architecture.

Course Outcomes: After completion of the course, the students shall be able to:

1. Understand and design the structure of deep neural networks.
2. Understand the different layers and their operations as well as backpropagation.
3. Design a neural network for a given data set
4. Develop a deep understanding of PyTorch and its use in designing one's own deep architectures.

Text Book: Aggarwal, Charu C. Neural networks and deep learning (10th Edition). Springer, 2018

Reference Materials:

1. Gurney, Kevin. An introduction to neural networks. CRC press, 2018. Vol-1.
2. Goodfellow, Ian, Yoshua Bengio, and Aaron Courville. Deep learning. MIT press, 2016.

Weekly Breakdown		
Week	***Section***	***Topics***
1	1.1	Introduction and history of neural networks
2	1.2	Basic architecture of neural networks, perceptron and adaline
3	1.3-1.4	Training neural networks with backpropagation and gradient descent and practical issue
4	2.2	Neural networks for binary classification
5	2.3	Neural networks for multiclass classification
6	2.4-2.5	Feature selection, and matrix factorization
7	3.2-3.3	Backpropagation
8	3.5	Gradient-Descent Strategies
9	**Mid Semester Exam**	
10	3.6	Batch normalization
11	5.1-5.2	Radial basis function networks
12	6.3-6.4	Restricted Boltzmann machines

13	7.1-7.2	Recurrent neural networks
14	8.1-8.3	Convolutional neural networks
15	9.1-9.3	Deep reinforcement learning
16	9.4-9.5	Deep learning methods
17		Revision
18	**End Semester Exam**	

DS 405 Experimental Design for Data Science

Credit Hours 3-0

Pre-requisites: MATH-264 Introduction to Statistics

Objectives: Data Science project exists the planning, design and execution of experiments. Experimental design is the process of carrying out research in an objective and controlled fashion so that precision is maximized and specific conclusions can be drawn regarding a hypothesis statement. Generally, the purpose is to establish the effect that a factor or independent variable has on a dependent variable

Course Contents

Principles of experimental design, Layout analysis and related efficiency of completely randomized, randomized complete block, Latin square, Cross-over and Greco Latin square designs, Estimation of missing observations in three basic designs, Fixed, random and mixed effect models in the basic designs, Factorial experiments , Multiple comparisons, Effect of violation of assumptions underlying ANOVA and transformation of data, Analysis of covariance up to two covariates.Practically structuring lay-out plan of basic experiments techniques, collection of data, estimation of parameters and statistical analysis on collected data. Response surface methodology and its optimization

Outcomes: At the end of the course, attendees should be able to:

- Describe some of the factors affecting reproducibility and external validity.
- Conduct the different types of formal experimental design
- Optimize the experimental design.

Textbook Montgomery, Douglas C. *Design and analysis of experiments*. John wiley & sons, 2017.

Reference Books:

1. Quinn, Gerry P., and Michael J. Keough. *Experimental design and data analysis for biologists*. Cambridge university press, 2002.
2. Gonzalez, Richard. *Data analysis for experimental design*. Guilford Press, 2009.
3. Diamond, William J. *Practical experiment designs: for engineers and scientists*. John Wiley & Sons, 2001.

Weekly Breakdown		
Week	***Section***	***Topics***
1	1.1-1.4	Introduction and basic strategies
2	3.2-3.3, 3.3.1	The Analysis of Variance, Analysis of the Fixed Effects Model Decomposition of the Total Sum of Squares
3	3.3.3, 3.4	Estimation of the Model Parameters, Unbalanced Data, Model Adequacy Checking
4	4.1-4.2	The Randomized Complete Block Design, The Latin Square Design
5	5.1-5.2	Factorial Designs,Basic Definitions and Principles, The Advantage of Factorials
6	5.3	The Two-Factor Factorial Design
7	5.4	The General Factorial Design
8	5.5	Fitting Response Curves and Surfaces
9	**Mid Semester Exam**	
10	5.6	Blocking in a Factorial Design
11	6.1-6.2	2^2 Design
12	6.3	2^3 Design
13	6.4-6.5	General 2k Design, A Single Replicate of the 2k Design
14	6.7	2^k Designs are Optimal Designs
15	11.1-11.2	Introduction to Response Surface Methodology. The Method of Steepest Ascent
16	11.3-11.4	Analysis of a Second-Order Response Surface, Location of the Stationary Point
17		Revision
18	**End Semester Exam**	

DS 406   Time Series Analysis and Forecasting

Credit Hours: 3-0
Pre-requisites: MATH-264 Introduction to Statistics

Objectives: There are two main goals of time series analysis: identifying the nature of the phenomenon represented by the sequence of observations, and forecasting (predicting future values of the time series variable).

Course Contents: Stochastic Process, Stationery time-Series: auto-correlation and auto-covariance, estimates functions and standard error of the auto-correlation function (ACF), Spectral Analysis: Periodogram, spectral density functions, comparison with ACF, Linear stationery models: Auto-regressive, Moving average and mixed models, Non-stationery models, general ARIMA notation and models, Introduction to forecasting, important considerations for forecasting: objective, cost function, model specification, forecast construction using ARMA models, forecasting trend, other types of forecast: exponential smoothing, Forecast Evaluation: recursive estimation, model specification, model comparison and testing. Spurious Regressions, introduction to cointegration, Error correction representation, Granger representation theorem.

Outcomes: At the end of the course, attendees should be able to:

- define time series components.
- construct stationary time series model.
- construct nonlinear stochastic models.
- evaluate stationary in time series.
- construct and evaluate time series models.

Textbook(s) Box, George EP, et al. *Time series analysis: forecasting and control*. John Wiley & Sons, 2015.

Reference Materials:

1. Chatfield, Chris. The analysis of time series: an introduction. Chapman and hall/CRC, 2003.

2. Chatfield, Christopher. The analysis of time series: theory and practice. Springer, 2013.

3. Brockwell, Peter J., and Richard A. Davis. Time series: theory and methods. Springer science & business media, 2009.

Weekly Breakdown		
Week	***Section***	***Topics***
1	Chap 1	Introduction to Time Series
2	Chap 2	Autocorrelation Function and Spectrum of Stationary Processes
3	Chap 3	Linear Stationary Models, General Linear Process, Autoregressive Processes, Moving Average Processes, Mixed Autoregressive
4	Chap 4	Autoregressive Integrated Moving Averag, ARIMA
5	5.1-5.2	Forecasting , Minimum Mean Square Error Forecasts and Their Properties, Calculating Forecasts and Probability Limits
6	5.3-5.5	Forecast Function and Forecast Weights, Examples of Forecast Functions and Their Updating, Use of State-Space Model Formulation for Exact Forecasting
7	6.1-6.2	Model Identification, Objectives of Identification, Identification Techniques
8	6.3-6.4	Initial Estimates for the Parameters, Model Multiplicity
9	**Mid Semester Exam**	
10	7.1	Study of the Likelihood and Sum-of-Squares Functions
11	7.2, 7.5	Nonlinear Estimation, Estimation Using Bayes' Theorem
12	9.1-9.2	Parsimonious Models for Seasonal Time Series, Representation of the Airline Data by a Multiplicative
13	10.1-10.2	Tests for Unit Roots in ARIMA Models, Conditional Heteroscedastic Models
14	14.1-14.2	Stationary Multivariate Time Series, Vector Autoregressive Models
15	14.3-14.4	Vector Moving Average Models, Vector Autoregressive--Moving Average Models
16	14.5-14.6	Forecasting for Vector Autoregressive--Moving Average Processes, State-Space Form of the VARMA Model 536
17	14.8	Nonstationarity and Cointegration
18	**End Semester Exam**	

DS 407 Artificial Intelligence

Credit Hours: 3-1
Pre-requisites: None

Objectives This course aims to understand the notions of rational behavior, intelligent agents and general understanding of major concepts and approaches in knowledge representation, planning, learning, robotics and other AI areas.

Course Contents: An Introduction to Artificial Intelligence and its applications towards Knowledge Based Systems. Search algorithm, Uniform search strategies, Breadth-first search, Dijkstra's algorithm or uniform-cost search, Depth-first search and the problem of memory, Depth-limited and iterative deepening search Informed (Heuristic) Search Strategies, Greedy best-first search , A* search, Search contours, Satisficing search: Inadmissible heuristics and weighted Heuristic Functions, the effect of heuristic accuracy on performance, Generating heuristics from relaxed problems Local Search and Optimization Problems Search with Nondeterministic Actions. Search in Partially Observable Environments. Game Theory, Two-player zero-sum games, Optimal Decisions in Games Heuristic Alpha--Beta Tree Search, Monte Carlo search Stochastic Games, Evaluation functions for games of chance, Partially Observable Games , Limitations of Game Search Algorithm Defining Constraint Satisfaction, Constraint Propagation: Inference in CSPs Propositional vs. First-Order Inference, Unification and First-Order Inference, Unification ,Forward Chaining Backward Chaining Resolution.

Outcomes: After completion of the course, the students shall be able to:

- Understand the notions of rational behavior and intelligent agents.
- Develop a general appreciation of the goals, subareas, achievements and difficulties of AI.
- Knowledge of methods of blind as well as informed search and ability to practically apply the corresponding techniques.
- General understanding of major concepts and approaches in knowledge representation, planning, learning, robotics and other AI areas.
- Developing programming skills for AI applications.

Textbook: Artificial Intelligence: A Modern Approach, 3rd ed. S. Russell and P. Norvig, Prentice Hall, 2010.

Reference Materials:

1. Artificial Intelligence: Structures and Strategies for Complex Problem Solving, 6th ed. G. Luger, Addison Wesley, 200
2. AI Algorithms, Data Structures, and Idioms in Prolog, Lisp and Java, G. Luger and W. Stubblefield, Addison Wesley, 2009.
3. Artificial Intelligence: A Systems Approach. M. Tim Jones, Infinity Science Press, 2008 Supporting website: http://aima.cs.berkeley.edu

Weekly Breakdown		
Week	***Section***	***Topics***
1	1.1, 1.4-1.5	Introduction, applications, The State of the Art, Risks and Benefits of AI
2	2.3-2.4	Nature and structure of agent
3	3.3	Search algorithm, Best-first search , Search data structures , Redundant paths, Measuring problem-solving performance .
4	3.4	Uniform search strategies, Breadth-first search, Dijkstra's algorithm or uniform-cost search, Depth-first search and the problem of memory, Depth-limited and iterative deepening search
5	3.5	Informed (Heuristic) Search Strategies, Greedy best-first search , A* search, Search contours, Satisficing search: Inadmissible heuristics and weighted
6	3.6	Heuristic Functions, the effect of heuristic accuracy on performance, Generating heuristics from relaxed problems
7	4.1	Local Search and Optimization Problems
8	4.3-4.4	Search with Nondeterministic Actions. Search in Partially Observable Environments.
9	**Mid Semester Exam**	
10	5.1-5.2	Game Theory, Two-player zero-sum games, Optimal Decisions in Games
11	5.3-5.4	Heuristic Alpha--Beta Tree Search, Monte Carlo search
12	5.5-5.7	Stochastic Games, Evaluation functions for games of chance, Partially Observable Games , Limitations of Game Search Algorithm
13	6.1-6.2	Defining Constraint Satisfaction, Constraint Propagation: Inference in CSPs
14	9.1-9.3	Propositional vs. First-Order Inference, Unification and First-Order Inference, Unification ,Forward Chaining
15	9.4	Backward Chaining
16	9.5	Resolution
17		Revision
18	**End Semester Exam**	

FL-100 Foreign Language (Chinese-I)

Credit Hours: 3-0
Prerequisite: None

STANDARD COURSE						
HSK						
1 Workbook						
S #	**Lesson**	**Page#**		**Note**	**Pinyin**	**Characters**
1	Hello	Page 2			Initial and Finals of Chinese Pinyin (1); b.p.m,f,d,t,n,l,g,k,h,j,q ,x, s.er,a,la,ua,o,uo,e,ue,a l,ual,el,uel(ul),ao,bco, Tones (Four Tones), Chinese Syllables, Tone Sandhi;3rd tone	Strokes of Chinese Characters (1). 2. Single Component Characters
2	Thank you	Page 8			Initial and Finals of Chinese Pinyin (II); ou, ch,sh,r,z,c,s, ou,lou (iu), an,ian,uan,en,in,uen,(un), un, ong, lang, uang,eng,ing,ueng,on g,long, The Neutral Tone, Rules of Pinyin (1): Tone Marking and Abbreviation	1. (2): Strokes of Chinese Characters 2. Single Component Characters
3	What is your name	Page 14		1. The Interogative Pronoun. 2. The Sentence. 3. Interrogative Sentences	j, q,x,z,c,s Differentiation:pronu nciation of the finals I,u,o Tone Sandhi of , Rules of Pinyin (2): U or Finals led by u with j,q,x	1. (3); Strokes of Chinese Characters (3); 2. Single Component Characters. 3. Stroke Order (1): horizontal preceding vertical and left falling preceding right falling

4	She is my Chinese teacher	Page 22		1. The Interogative Pronoun and. 2. The Structural Partical (i)3.The Interrogative Partical	1. zh, ch,sh,r: Differentiation:pronunication of the initials zh,ch,sh,r 2. Differentiation pronunciation of the alveolar nasal n and the velar nasal ng. 3. Tone Sandhi of (yi), 4. (3): y,w Rules of Pinyin (3): use of y and w	1. Strokes of Chinese Characters (4); 2. Single Component Character. 3. Stroke Order (2); top preceding bottom and left preceding right
5	Her daughter is 20 years old this year	Page 30		1. The Interrogative Prounce. 2. Numbers below 100. 3. Indicating a Charge. 4. The Interrogative Phases	1. Differentiation:pronunication of the finals I,u,o. 2. Differentiation pronunciation of the alveolar nasal n and the velar nasal ng. 3. Tone Sandhi of (3) y, w, Rules of Pinyin (4): Syllabe dividing mark	1. (5): 2. Single component Characters. 3. Stroke Order (3): outside preceding inside and middle preceding sides
6	I can speak Chinese	Page 40		1. The Modal Verb, 2. Sentence with Predicate. 3. The Interrogative	1. Time Collocation in Disyllabic Words (2) 2. Tone +3rd/4th tone	1. Single Component Character; 2. Structure of Chinese Characters (2): left-right and left-middle-right. 3. Chinese Radicals: "and".
7	What's the date today	Page 48		1. Expression of date, day and month date,. 2. Nominal Preducate. 3. Sentences Verb Constructon	Time collocation in Disyllabic Words (2) tone + tone	1. Single Component Character . 2. Structure of Chines Characters (2) left +right and lift middle -right

8	I'd like some tea	Page 56		1. The Modal verb, 2. The Interogative Annul money, 3. The interrogative prime. 4. Expression of annual Money	Time collocation in Disyllabic Words (3) tone + tone	1. Single Component Character . 2. Structure of Chines Course Characters (3) top-bottom and top middle bottom
9	**Mid Semester Exam**					
10	Where does your son work	Page 64		The verb, 2. The Interrogative Pronoun. 3. The prepostion. 4. The Interrogative parctice	Time collocation in Disyllabic words (4) 4th tone +2,3,4 tone	1. Single component Characters: 2. Structure of Chinese Character (4) half enclosure. 3. Chinese Radicals and
11	Can I sit here	Page 72		The Sentence Existence, 2. The Conjunction. 3. The modal Verb, imperative sentences with	Pronunciation of Neutral Tone Syllables, Pronunciation of Reduplicated Syllables, Pronunciation of Words with the Suffix	1. Single component Character. 2. Structure of Chines Characters (5): enclosure Chines Radicals and
12	What's the time now	Page 82		Expression of Time. 2. Time Word Used as an . 3.The Noun	Function of Neutral Tone Syllables	1. Single component Character. 2. Chines Radicals and
13	What will the weather be like tomorrow	Page 90		1. The Interrogative Prounce. 2. Sentences with a subject phrase as the predicate. 3. Adverb. 4. The Modal Verb	Time collocation in Trisyllabic words (2) words starting with tone syllable	1. Single component characters. 2. Chines Radicals and

14	He is learning to cook Chines food	Page 98		The Interjection. 2. Used to indicate action in progress. 3. Expression of Telphone . 4. The__particle	Time collocation in Trisyllabic words (3) words starting with tone syllable	1. Single compnent Characters. 2. Chinese Radicals and
15	She has bought quite a few clothes	Page 104		Indicating Occurrence Completion. 2. The Noun. 3. The Modal Particle . 4. The Adverb	Time collocation in Trisyllabic words (3) words starting with three tone syllable	1. Single compnent Characters. 2. Chinese Radicals and
16	I came here by air	Page 112		The Structure used to emphasize time phases manner. 2. Expression of a date, months, day of the week	Time Collocation in Trisyllabic Words (4) words starting with a fourth tone syllble	1. Single component Character. 2. Chines Radicals and
17	**Review**					
18	**Final Exam**					

FL-101 Foreign Language (Turkish)

Credit Hours: 3-0
Prerequisite: None
Course Objectives: This basic course covers A1 level of Turkish language and provides a base to understand a basic grammatical structure of Turkish Language which includes Reading, writing, listening, and speaking modules.
Course Contents (in Turkish): Tanışma, selamlaşma, dilekler, Alfabe, Bu ne? O kim?, Okulda, Sayılar, Şehirde, Neredesin? Bir günüm, Ne yapıyorsun?, Benim dünyam, ailem, arkdaşlarım, ailemden uzakta, saatler, Bayramlar, Özel günler, Ne zaman? Akrabalarım, Benim mahallem, Eczanede, Gezi planı, Hastane diyalogu
Course Outcomes: Upon completion of this course, Students are expected to understand:

- Turkish Alphabetics, Introductions, Greetings, Wishes
- Names of places, days, months, counting
- This, That, These, Those, singular, plural.
- Daily conversations
- Where, when, what, who etc.
- Time, Body parts, names of relatives

Text Book: Fatma BÖLÜKBAŞ, Funda KESKİN, Enver GEDİK and Fazilet ÖZENÇ, "Istanbul Turkish for Foreigners A1", Kültür Sanat Basımevi, (2012).
Reference Books: "Yeni Hetit Yabancılar için Türkçe Ders Kitabı A1", Ankara Tömer, (2015).

Weekly Breakdown		
Week	***Section***	***Topics***
1	1	Merhaba; Tanışma
2	1	Dilekler, Alfabe
3	1-2	Bu ne? O kim? Okulda?
4	2	Sayılar, kaç? Ev
5	2-3	Şehirde? Bir günüm
6	3	Boş Zamanlarım, Sosyal Gruplar,
7	3	Haftasonu ne yapıyorsun?
8	4	Benim ailem, arkadaşlarım
9	**Mid Semester Exam**	
10	4	Benim sınıfım, sevgili ailem
11	4-5	Saatler, bayramlar
12	5	Ne zaman?
13	5	Özel Günlerde ne yapıyorsun?
14	5-6	Plan yapma, Akrabalarım
15	6	Gezi planı, Eczanede
16	6	Hastane diyalogu
17		Revizyon
18	End Semester Exam	

FL-400 Foreign Language (Chinese -II)

Credit Hours: 3 - 0
Pre-requisite: FL-100 Foreign Language (Chinese -I)

Course Objectives: Learners can master the language knowledge and use some basic grammar and sentence patterns in communication, learn to express personal feelings and attitudes in Chinese, and can complete communicative functions such as gratitude, apology, introduction and farewell, and begin to understand Chinese cultural knowledge and cultivate interest in learning. Through this course, learners can systematically learn the language knowledge at this stage and cope with general communication, and can communicate on familiar topics and meet the basic communication needs of daily life and study, and gradually understand and be familiar with Chinese communication etiquette, cultural customs, etc.

Course Outcomes: Following are basic objectives:

- Learning Chinese can connect students with worlds large population.
- Students can get opportunity to serve in CPEC.
- Students can get extra skill which in beneficial in their career growth.
- Students can get to know about Chinese Culture.

Learning Outcome:

On successful completion of this course, the students should be able to:

- Attain all features of the 2 Levels of the Common European Framework of Reference for Languages
- Develop speaking and listening vocabulary of 300 most frequently used Chinese words and relevant grammar
- Develop a written vocabulary of 300 characters
- Would be able to communicate effectively in everyday routine tasks requiring simple and direct exchange (e.g) ask for information on locations and directions and how to respond; ask questions about travelling and shopping; ask time-related questions; communicate daily conversations about food, families etc.)

Reference Books: Jiang Liping , Standard HSK level 2 (Hanban) Beijing, 2014.

Course Outline:

Chapter Contents	**Content Introduction**
第 1课 Lesson 1 7点我还在睡觉 呢 I was still sleeping at 7 o'clock	本课介绍 "还"语法点，使学生正确理解与 语法点， 使学生正确理解与 "还"有关 句意，并能正确使用该 型进行交际。 This lesson introduces the grammatical points of "still", so that students can correctly understand the meaning of sentences related to "still" and use this sentence pattern correctly for communication.
第2 课 Lesson 2 明天是阴天 It will be cloudy tomorrow	通过介绍几座中国城市的天气，讲解如何使用温度 回答天气问题。 By introducing the weather in several Chinese cities, explain how to use temperature to answer weather questions.
第3 课 Lesson 3 那件比这件便宜 五百块 That one is five hundred dollars cheaper than this one	本课讲解比较句，在价格、身高、温度等方面对比， 让学生对比较句理解透彻。 This lesson explains comparative sentences, and compares them in terms of price, height and temperature, so that students can understand comparative sentences thoroughly.
第4 课 Lesson 4 这是一张全家福 This is a family photo	通过外貌、服饰、职业等方面细致介绍家庭成员， 使学生掌握更细致的描述方法。 This lesson introduces family members in detail through appearance, clothing and occupation, so that students can master more detailed description methods.
第5 课 Lesson 5 这里禁止拍照 It is forbidden to take pictures here	本课带领学生认识表示命令的相关知识点，如禁 止、不可以、使学生在日常生活中能够正确理解言 语意思。 This lesson leads students to understand the relevant knowledge points of expressing commands, such as forbidden and forbidden, so that students can correctly understand the meaning of words in daily life.
第 6课 Lesson 6 我有个东西找不 我有个东西找不 我有个东西找不 我有个东西找不 我有个东西找不 我有个东西找不 我有个东西找不 到了 I can't find something	本课介绍 "V+得+结果补语"语言点的使 用方法，语言点的使 用方法，学生在交际中能够正确运用相关句型。 This lesson introduces the use of language points in "V + should + result complement", so that students can correctly use relevant sentence patterns in communication.
第 7课 Lesson 7	本课通过 "v+过"介绍中国的文化，如长城、 故宫国宝等，使学生在交际中正确用该句型。

我去过四川， 我去过四川，我去过四川， 我去过四川，我去过四川， 我去过四川，看 过大熊猫 I have been to Sichuan and seen pandas	This lesson introduces Chinese culture through "V + have been to", such as the Great Wall, the Forbidden City, national treasures, etc., so that students can use this sentence pattern correctly in communication.
第 8课 Lesson 8 希望你们能来参 希望你们能来参 希望你们能来参 希望你们能来参 希望你们能来参 希望你们能来参 希望你们能来参 加我的婚礼 I hope you can come to my wedding	本课通过介绍中国婚礼，使学生掌握宴会邀请、节 本课通过介绍中国婚礼，使学生掌握宴会邀请、节 本课通过介绍中国婚礼，使学生掌握宴会邀请、节 日祝福、情感表达委婉拒绝等言语用法。 By introducing Chinese weddings, this lesson enables students to master the verbal usage of banquet invitation, holiday blessing, emotional expression and euphemistic refusal.
Mid Semester Exam	
第 9课 Lesson 9 生病了，要多休 生病了，要多休 生病了，要多休 生病了，要多休 生病了，要多休 生病了，要多休 生病了，要多休 息 Be ill, take more rest	介绍生病相关词汇以及医用药建议等，使学在 介绍生病相关词汇以及医用药建议等，使学在 看病过程中能够正确描述并理解医生意思。 This lesson introduces the vocabulary related to illness and the doctor's medication advice, so that students can correctly describe and understand the doctor's meaning in the process of seeing a doctor.
第 10课 Lesson 10 车站就在马路对 车站就在马路对 车站就在马路对 车站就在马路对 车站就在马路对 车站就在马路对 车站就在马路对 面 The station is just across the road	本课通过问路介绍了地点的询方式以及回答，帮 本课通过问路介绍了地点的询方式以及回答，帮 助学生能够使用相关句型进行实际交的问答。 This lesson introduces the way of asking places and answers by asking directions, which helps students to use relevant sentence patterns for practical communication questions and answers.
第 11课 Lesson 11 她唱歌得很好 She sings very well	本课围绕兴趣爱好，介绍了关联词在句子中的正确 本课围绕兴趣爱好，介绍了关联词在句子中的正确 使用方式。 This lesson focuses on hobbies and introduces the correct use of related words in sentences.
第 12课 Lesson 12 你考得好 不Did you do well in the exam	通过描述考试的程及答题情况，使学生正确理解 通过描述考试的程及答题情况，使学生正确理解 考场指令、题型分配试卷问析 By describing the examination process and the situation of answering questions, students can correctly understand the instructions of the examination room, the distribution of questions and the analysis of test

	paper problems.
第 13课 Lesson 13 买两盒 送一 Buy two and get one free	介绍了超市的商品名称，以及常见促销活动、折 介绍了超市的商品名称，以及常见促销活动、折 介绍了超市的商品名称，以及常见促销活动、折 扣、减价等用语。 This lesson introduces the commodity names of supermarkets, as well as common terms such as promotional activities, discounts and price reductions.
第 14课 Lesson 14 我们是新开的饭 我们是新开的饭 我们是新开的饭 我们是新开的饭 我们是新开的饭 我们是新开的饭 我们是新开的饭 店 We're a new restaurant	本课帮助学生理解如何听懂服务员的推荐菜，以及 本课帮助学生理解如何听懂服务员的推荐菜，以及 提出菜品要求进行点餐。 This lesson helps students understand how to understand the waiter's recommendation and put forward the food requirements for ordering.
第 15课 Lesson 15 这个女孩穿着白 这个女孩穿着白 这个女孩穿着白 这个女孩穿着白 这个女孩穿着白 这个女孩穿着白 这个女孩穿着白 衣服 The girl is dressed in white clothes	通过 “v+着”介绍他人穿着，如何运用语法点描述某 介绍他人穿着，如何运用语法点描述某 个事物的状态。 This lesson introduces others' clothes and how to use grammar points to describe the state of something through "V + be dressed in".
第 16课 Lesson 16 下个星期就可以 下个星期就可以 下个星期就可以 下个星期就可以 下个星期就可以 下个星期就可以 下个星期就可以 出院了 You can be discharged from hospital next week	本课介绍了住院、探病出等多种方式的表达，使学生理解医院场景用语，加强多情沟通能 使学生理解医院场景用语，加强多情沟通能 力。 This lesson introduces a variety of expressions, such as hospitalization, visiting patients and discharge, so that students can understand the language of hospital scenes and strengthen their multi-scene communication ability.
End Semester Exam	