BS SCHEME OF STUDIES

Eligibility Criteria

BS Mathematics: F. Sc. (Pre-Engineering)/FCS/FA (Statistics, Maths, Economics) or equivalent at least 2nd Division (45% Marks)

Semester-wise break up

First Year

Semester-I			
S. No	**Course code**	**Course title**	**Credit hours**
1	MATH-311	Calculus I	3(3+0)
2	MATH-312	Elements of Set Theory and Mathematical Logic	3(3+0)
3	ELL-311	English I: Functional English	3(3+0)
4	PS-321	Pakistan Studies	3(3+0)
5	CS-311	QR-1 (Introduction to Computer)	3(3+0)
6		Natural Science-I	3(3+0)
Total Cr. Hrs			**18(18+0)**
Semester-II			
S. No	**Course code**	**Course title**	**Credit hours**
1	MATH-321	Calculus II	3(3+0)
2	MATH-322	Linear Algebra	3(3+0)
3	ELL-321	English II: Composition Writing	3(3+0)
4	IS-312	Islamic Studies	3(3+0)
5		Arts and Humanities-I (Languages)	3(3+0)
6	SOC -313	SS-1 (Citizenship Education and Community Engagement)	3(3+0)
Total Cr. Hrs			**18(18+0)**

Second Year

Semester-III			
S. No	**Course code**	**Course title**	**Credit hours**
1	MATH-411	Calculus III	3(3+0)
2	MATH-412	Algebra-I (Group Theory-I)	3(3+0)
3	MATH-413	Software Packages (Matlab/Maple/Mathematica)	3(1+2)
4	ELL-411	English III: Academic Reading and Writing	3(3+0)
5		Natural Science-II	3(3+0)
6	PHIL-302	QR-II (Logic and Quantitative Reasoning)	3(3+0)
Total Cr. Hrs			**18(16+2)**
Semester-IV			
S. No	**Course code**	**Course title**	**Credit hours**
1	MATH-421	Number Theory	3(3+0)
2	MATH-422	Ordinary Differential Equations	3(3+0)
3	MATH-423	Discrete Mathematics	3(3+0)
4		Arts and Humanities-II	3(3+0)
5		Social Sciences – II	3(3+0)
Total Cr. Hrs			**15(15+0)**

Third Year

Semester-V			
S. No	**Course code**	**Course title**	**Credit hours**
1	MATH-511	Set Topology	3(3+0)
2	MATH-512	Differential Geometry	3(3+0)
3	MATH-513	Real Analysis- I	3(3+0)
4	MATH-514	Algebra-II (Rings and Fields)	3(3+0)
5	MATH-515	Functional Analysis-I	3(3+0)
Total Cr. Hrs			**15(15+0)**
Semester-VI			
S. No	**Course code**	**Course title**	**Credit hours**
1	MATH-521	Classical Mechanics	3(3+0)
2	MATH-522	Partial Differential Equations	3(3+0)
3	MATH-523	Functional Analysis-II	3(3+0)
4	MATH-524	Complex Analysis	3(3+0)
5	MATH-525	Real Analysis-II	3(3+0)
6	MATH-526	Numerical Method	3(3+0)
Total Cr. Hrs			**18(18+0)**

Fourth Year

Semester-VII			
S. No	**Course code**	**Course title**	**Credit hours**
1	MATH-611	Numerical Analysis	3(3+0)
2	MATH-612	Affine and Euclidean Geometry	3(3+0)
3	MATH-613	Mathematical Methods	3(3+0)
4	MATH-	E-1	3(3+0)
5	MATH-	E-2	3(3+0)
Total Cr. Hrs			**15(15+0)**
Semester-VIII			
S. No	**Course code**	**Course title**	**Credit hours**
1	MATH-621	Probability Theory	3(3+0)
2	MATH-622	Integral Equations	3(3+0)
3	MATH-623	Project	3(3+0)
4	MATH-	E-3	3(3+0)
5	MATH-	E-4	3(3+0)
Total Cr. Hrs			**15(15+0)**

General Courses for BS Mathematics

Arts and Humanities

I. Pashto, Urdu, Arabic, Turkish, Chinese or any other language

II. Islamic History and Culture, Philosophy, History, Education, Home Economics or any other approved course of BKUC

Social science II

Political Science, Sociology, Psychology, Economics, Law, or any other approved Basic course of BKUC

Natural Sciences (any two subjects may be selected from the following disciplines)

Mathematics, Statistics, Botany, Zoology, Chemistry, Physics-I, Physics-II, Geography, GIS, Geology, Electronics, Geophysics, computer, (or any other approved Basic Course of BKUC)

Codes Distribution

The Mathematics codes consist of four alphabets (MATH) followed by three numeric values. Each numeric value from left to right has it's nomenclature as follows:

1. The first numeric value represents academic year after matriculation that is 3 represent third year after matriculation (BS first year) and in similar way 4, 5, 6 and 7 represent fourth, fifth, sixth and seventh year after matriculation, respectively.
2. The middle numeric value represents the semester if they are 1 or 2 of that academic year. Similarly if this value is 0 then it represent the course of other department and for values other than 0, 1 and 2, this value represent the course of this department.
3. The last numeric value represents the number of course of that specific semester if applicable.

Marks Distribution

Mid –term	=30%
Tests/assignment/quiz/attendance/presentation	=20%
Final examination	=50%

Course Contents for BS Mathematics

Semester-I			
S. No	**Course code**	**Course title**	**Credit hours**
1	MATH-311	Calculus I	3(3+0)
2	MATH-312	Elements of Set Theory and Mathematical Logic	3(3+0)
3	ELL-311	English I: Functional English	3(3+0)
4	PS-321	Pakistan Studies	3(3+0)
5	CS-311	QR-1 (Introduction to Computer)	3(3+0)
6		Natural Science-I	3(3+0)
Total Cr. Hrs			**18(18+0)**

MATH-311 Calculus-I Credit Hours: 3(3+0)

Objectives of course: Calculus serves as the foundation of advanced subjects in all areas of mathematics. This is the first course of Calculus. 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.

Course Outline:

Equations and inequalities: Solving linear and quadratic equations, linear inequalities. Division of polynomials, synthetic division. Roots of a polynomial, rational roots; Viete Relations. Descartes rule of signs. Solutions of equations with absolute value sign. Solution of linear and non-linear inequalities with absolute value sign.

Functions and graphs: Domain and range of a function. Examples: polynomial, rational, piecewise defined functions, absolute value functions, and evaluation of such functions. Operations with functions: sum, product, quotient and composition. Graphs of functions: linear, quadratic, piecewise defined functions.

Lines and systems of equations: Equation of a straight line, slope and intercept of a line, parallel and perpendicular lines. Systems of linear equations, solution of system of linear equations. Nonlinear systems: at least one quadratic equation.

Limits and continuity: Functions, limit of a function. Graphical approach. Properties of limits. Theorems of limits. Limits of polynomials, rational and transcendental functions. Limits at infinity, infinite limits, one-sided limits. Continuity.

Derivatives: Definition, techniques of differentiation. Derivatives of polynomials and rational, exponential, logarithmic and trigonometric functions. The chain rule. Implicit differentiation. Rates of change in natural and social sciences. Related rates. Linear approximations and differentials. Higher derivatives, Leibnitz's theorem.

Applications of derivatives: Increasing and decreasing functions. Relative extrema and optimization. First derivative test for relative extrema. Convexity and point of inflection. The second derivative test for extrema. Curve sketching. Mean value theorems. Indeterminate forms and L'Hopitals rule. Inverse functions and their derivatives.

Integration: Anti derivatives and integrals. Riemann sums and the definite integral. Properties of Integral. The fundamental theorem of calculus. The substitution rule.

Recommended Books:

1. Thomas, Calculus, 11th Edition. Addison Wesley Publishing Company, 2005
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 with Analytic Geometry, PWS Publishers, Boston, Massachusetts, 1983.
7. M. Liebeck, A Concise introduction to pure Mathematics, CRC Press, 2011.
8. A. Kaseberg, Intermediate Algebra, Thomson Brooks/cole, 2004.
9. Calculus by James Stewart

MATH-312 Elements of Set Theory and Mathematical Logic Credit Hours: 3(3+0)

Objectives of course: 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.

Course Outline:

Set theory: Sets, subsets, operations with sets: union, intersection, difference, symmetric difference, Cartesian product and disjoint union. Functions: graph of a function. Composition; injections, surjections, bijections, inverse function.

Computing cardinals: Cardinality of Cartesian product, union. Cardinality of all functions from a set to another set. Cardinality of all injective, surjective and bijective functions from a set to another set. Infinite sets, finite sets. Countable sets, properties, examples (Z, Q). R is not countable. R, RxR, RxRxR have the same cardinal. Operations with cardinal numbers. Cantor-Bernstein theorem.

Relations: Equivalence relations, partitions, quotient set; examples, parallelism, similarity of triangles. Order relations, min, max, inf, sup; linear order. Examples: N, Z, R, $P(A)$. Well ordered sets and induction.Inductively ordered sets and Zorn's lemma.

Mathematical logic:

Introduction to Logics, Propositional Calculus. Truth tables. Predicate Calculus. Quantifiers and introduction to proofs.

Recommended Books:

1. M. Liebeck, A Concise Introduction to Pure Mathematics, CRC Press, 2011.
2. N. L. Biggs, Discrete Mathematics, Oxford University Press, 2002.
3. R. Garnier, J. Taylor, Discrete Mathematics, Chapters 1,3,4,5, CRC Press, 2010.
4. A.A. Fraenkal, Abstract Set Theory, North-Holland Publishing Company, 1966.
5. P. Suppes, Axiomatic Set Theory, Dover Publication, 1972.
6. P.R. Halmos, Naive Set Theory, New York, Van Nostrand, 1950.
7. B. Rotman, G.T. Kneebone, The Theory of sets and Transfinite Numbers, Oldbourne London, 1968.
8. D. Smith, M. Eggen, R.St. Andre, A Transition to Advanced Mathematics, Brooks/Cole, 2001.

ELL-311 ENGLISH–I: FUNCTIONAL ENGLISH Credit Hours: 3(3+0)

Course Description

The subject aims to enhance the students' ability in the meaningful use of grammatical structures. Students will be able to use the targeted grammatical structures meaningfully and appropriately both in oral and written production.

Course Objectives

1. To enable students to identify main/topic sentences.
2. To teach them to use effective strategies while reading texts.
3. To acquaint them with cohesive devices and their function in the text.

Course Contents

- Vocabulary (Frequently confused / misused words, Phrases, synonyms, antonyms, idioms & General vocabulary),
- Practical Use of Grammar (Nouns, Pronouns, Verbs, Adjectives, Adverbs, Prepositions, Conjunctions, Articles, Interjections & Tenses),
- Transitive and Intransitive verbs
- Punctuations, 14 American English Punctuations.
- Sentences (Types of sentences, Parts of sentences, Direct and Indirect Speech, Active & Passive Voice & Conditional Sentences),
- Composition + Summarization (Describing, Narrating, Argumentation, Short / long Composition)
- Comprehension + Précis writing.
- Phrase, Types of Phrase
- Clause, Types of Clause

Recommended Books

- High School English Grammar & Composition by Wren and Martin.
- Practical English Grammar by A.J. Thomson & A.V. Martinet. Exercises 1 & 2. 3rd edition. Oxford University Press.
- Writing. Intermediate by Marie-Christine Boutin, Suzanne Brinand& Francoise Grellet. Oxford Supplementary Skills. 4th Impression 1993.
- Reading. Upper Intermediate. Brian Tomilson & Rod Ellis. Oxford Supplementary Skills. 3rd Impression 1992.

PS-311 PAKISTAN STUDIES Credit Hours: 3(3+0)

Course Objectives:

Develop vision of historical perspective, government, politics, contemporary Pakistan, ideological background of Pakistan and to Study the process of governance, national development, issues arising in the modern age and posing challenges to Pakistan.

Course Contents:

Historical Perspective

- Ideological rationale with special reference to Sir Syed Ahmed Khan, Allama Muhammad Iqbal and Quaid-i-Azam Muhammad Ali Jinnah.
- Factors leading to Muslim separatism
- People and Land
  i. Indus Civilization
  ii. Muslim advent
  iii. Location and geo-physical features.

Government and Politics in Pakistan

- Political and constitutional phases:
- 1947-58
- 1958-71
- 1971-77
- 1977-88
- 1988-99
- 1999 onward

Contemporary Pakistan

- Economic institutions and issues
- Society and social structure
- Ethnicity
- Foreign policy of Pakistan and challenges
- Futuristic outlook of Pakistan

COURSE RECOMMENDED BOOKS:

1. Amin, Tahir. (1999). Ethno-National Movement in Pakistan. Islamabad: Institute of Policy Studies, Islamabad.
2. Burke,S.M and Ziring,Lawrence. (1993). Pakistan's Foreign policy: An Historical analysis. Karachi: Oxford University Press,
3. Mehmood, Safdar. (2001). Pakistan Kayyun Toota. Lahore: Idara-e-Saqafat-e-Islamia. Club Road Press.
4. Mehmood, Safdar. (1994). Pakistan Political Roots & Development. Lahore.
5. Waseem ,Muhammad. (1987). Pakistan Under Martial Law. Lahore: Vanguard.
6. Zaidi,Akbar. S.(2000). Issue in Pakistan's Economy. Karachi: Oxford University Press.

CS-311 INTRODUCTION TO COMPUTER Credit Hours: 3(3+0)

Course Learning Outcomes (CLOs):		
At the end of the course the students will be able to:	**Domain**	**BT Level***
Understand basics of computing technology (Knowledge)	C	1
Have knowledge of types of software (Understand)	C	2
Have knowledge of computing related technologies	C	2
Have practical knowledge of use of computer and MS office.	C	3
* BT= Bloom's Taxonomy, C=Cognitive domain, P=Psychomotor domain, A= Affective domain		

Course Content:

Introduction:

Brief history of Computer, Basic Computer Elements and computer types (Super, Mainframe, Mini and Micro), Digital and Analogue Computer

Computer Hardware:

(Input Devices, processor, Output Devices)

Storage Devices:

(Register, Cache, RAM, ROM, HDD, optical Storage devices (CD, DVD, Blue rays), Cloud)

Computer Software:

System Software (Operating System, Device Drivers and Language processor) Application software

Computer Network:

Types of Computer Network (LAN, MAN, WAN), Topologies (Bus, Star, Ring Mesh), Clint, Server, Hub, Switch, Router

Internet and WWW:

Basic Structure of Internet, Web page, Website, Web application, Web Browser, Search engine, email, cyber security

MS Word

MS Power Point

MS Excel

Basics of program relevant tools

Teaching Methodology:

Lectures, Written Assignments, Practical labs, Semester Project, Presentations

Course Assessment:

Sessional Exam, Home Assignments, Quizzes, Project, Presentations, Final Exam

Reference Materials:

1. Charles S. Parker, Understanding Computers: Today and Tomorrow, Course Technology, 25 Thomson Place, Boston, Massachusetts 02210, USA
2. Livesley, Robert Kenneth. An introduction to automatic digital computers. Cambridge University Press, 2017.
3. Zawacki-Richter, Olaf, and Colin Latchem. "Exploring four decades of research in Computers & Education." Computers & Education 122 (2018): 136-152.
4. Sinha, Pradeep K., and Priti Sinha. Computer fundamentals. BPB publications, 2010.
5. Goel, Anita. Computer fundamentals. Pearson Education India, 2010.

Natural Sciences **(any two subjects may be selected from the following disciplines)**

Mathematics, Statistics, Botany, Zoology, Chemistry, Physics-I, Physics-II, Geography, GIS, Geology, Electronics, Geophysics, computer, (or any other approved Basic Course of BKUC)

Semester-II			
S. No	**Course code**	**Course title**	**Credit hours**
1	MATH-321	Calculus II	3(3+0)
2	MATH-322	Linear Algebra	3(3+0)
3	ELL-321	English II: Composition Writing	3(3+0)
4	IS-312	Islamic Studies	3(3+0)
5		Arts and Humanities-I (Languages)	3(3+0)
6	SOC -313	SS-1 (Citizenship Education and Community Engagement)	3(3+0)
Total Cr. Hrs			**18(18+0)**

MATH-321 Calculus II **Credit Hours: 3(3+0)**

Specific Objectives of course: This is 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.

Course Outline:

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

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 McLaurin 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.

Recommended Books:

1. Thomas, Calculus, 11th Edition. Addison Wesley Publishing Company, 2005
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 with Analytic Geometry, PWS Publishers, Boston, Massachusetts, 1983.
7. M. Liebeck, A Concise introduction to pure Mathematics, CRC Press, 2011.
8. A. Kaseberg, Intermediate Algebra, Thomson Brooks/COLE, 2004.
9. J. Stewart, Calculus early transcendental, 7th Edition, Brooks/COLE, 2008.

MATH-322 LINEAR ALGEBRA Credit Hours: 3(3+0)

Course Outline:

Algebra of matrices, Row and Column operations, rank, inverse of matrices, Transformation, Linear transformation, matrix of a linear transformation. group of matrices and Subgroups, orthogonal transformation, Linear operators. Canonical form of the matrix of a nilpotent operator. Polynomial algebra and canonical form of the matrix of an arbitrary operator.

Rings, field, finite and infinite fields (definition and examples), Homomorphism of fields, annihilators, vector spaces, subspaces, Linear combination, Linear dependence and independence, linear span of a subset of a vector space, bases and dimensions of a vector space, Null space, nullity, dimension, Relation of rank, dimension and nullity.

Eigen value, eigenvector, eigen value problem with physical Significance , Similar matrices with eigen values, Inner product spaces. System of differential equations in normal form. Homogeneous linear systems. Solution by diagonalisation. Non-homogeneous linear systems.

RECOMMENDED BOOKS:

1. D.T. Finkbeiner, Introduction to Matrices and Linear Transformations, 3rd. Ed., N.H. Freeman and company San Francisco, 1978.
2. D. C. Lay, Linear Algebra and Its Applications, Addison-Wesley, 3rdEdition, 2005.
3. A. M. Tropper,Linear Algebra, Thomas Nelson & Sons, 1973.
4. S. Lang, Linear Algebra, Addison-Wesley, 1970.
5. K. R. Hoffman and R. Kunze, Linear Algebra , Prentice Hall, 1971.
6. I. N. Herstein, Topics in Algebra, Addison-Wesley, 1980.
7. T. S. Blyth, E. F. Robertson, Essential student Algebra, Vol I-V, Chapman & Hall, 1986.
8. Anton H, *Linear Algebra with Applications* (8th edition), John Wiley, New York
9. Hill RO, *Elementary Linear Algebra with Application* (3rd edition), 1995,Brooks/Cole
10. Leon SJ, *Linear Algebra with Applications* (6th edition), 2002, Prentice Hall, Englewood Cliffs, NJ, USA
11. Nicholson WK, *Elementary Linear Algebra with Applications* (2nd edition), 1994, PWS Publishing Co.

ELL-321 ENGLISH-II: COMPOSITION WRITING Credit Hours: 3(3+0)

Course Description:

The course focuses on the basic strategies of composition and writing skills. Good writing skills not only help students obtain good grades but also optimize their chances to excel in professional life. The course includes modes of collecting information and arranging it in appropriate manner such as chronological order, cause and effect, compares and contrast, general to specific etc. It enables the students to write, edit, rewrite, redraft and proofread their own document for writing effective compositions. Because of the use of a significant amount of written communication on daily basis, sharp writing skills have always been valued highly in academic as well as professional spheres.

Course Objectives:

This course aims to:

1. Assist students identify the audience, message, and the purpose of writing
2. Develop rhetorical knowledge and critical thinking
3. Enable them express themselves in a variety of writing styles
4. Help students write well organized academic texts including examination answers with topic/thesis statement and supporting details.
5. Make students write argumentative essays and course assignments

6. Use different mechanics of writing to produce various types of compositions effectively keeping in view the purpose and the audience
7. Demonstrate rhetorical knowledge
8. Demonstrate critical thinking in well-organized forms of academic texts

Course Contents:

- Writing Process,
- Invention in writing Process or brainstorming
- Generating Ideas (collecting information in various forms such as mind maps, tables, lists, charts etc)
- Identifying Audience, Purpose, and Message,
- Ordering Information,
- Chronology for a narrative,
- Stages of a process,
- Deductive vs Inductive approach in writing
- Comparison and contrast,
- Problem solution pattern,
- Drafting,
- Free Writing,
- Revising, Editing, Paraphrasing,
- Cohesion and Coherence, Cohesive Devices,
- Paragraph unity, Summary and Précis Writing,
- Creative Writing, Essay Writing,
- Developing a thesis, writing effective introduction and conclusion
- Organizing an essay, different types of essays, use of various rhetorical modes including exposition, argumentation and analysis

Recommended Books

Critical Reading and Writing: An Introductory Course by Goatly, A. 2000. London: Taylor & Francis

A Writer's Reference by Hacker, D. 1992. 2nd ed. Boston: St. Martin's

Study writing: A course in written English for academic and professional purposes. by Hamp-Lyons, L. & Heasley, B. 1987. Cambridge: Cambridge University Press.

Oxford English for Undergraduates by Howe, D. H, Kirkpatrick, T. A. & Kirkpatrick, D. L. 2004. Karachi: Oxford University Press.

- Patterns for College Writing: Fourth Edition. Kirszner, L.G & Mandell, S.R. 1989 USA: St. Martin's Press, Inc.
- Write to be Read: Reading, Reflection and Writing by Smazler, W. R. 1996. Cambridge: Cambridge University Press.

IS-312: ISLAMIC STUDIES **Credit Hours: 03**

Course Objectives:

This course is aimed at:

1. To provide Basic information about Islamic Studies
2. To enhance understanding of the students regarding Islamic Civilization
3. To improve Students skill to perform prayers and other worships
4. To enhance the skill of the students for understanding of issues related to faith and religious life.

Course Contents:

Introduction to Quranic Studies

- Basic Concepts of Quran
- History of Quran
- Uloom-ul -Quran

Study of Selected Text of Holly Quran

- Verses of Surah Al-Baqra Related to Faith(Verse No-284-286)
- Verses of Surah Al-Hujrat Related to Adab Al-Nabi(Verse No-1-18)
- Verses of Surah Al-Mumanoon Related to Characteristics of faithful (Verse No-1-11)
- Verses of Surah al-Furqan Related to Social Ethics (Verse No.63-77)
- Verses of Surah Al-Inam Related to Ihkam(Verse No-152-154)

Study of Selected Text of Holly Quran

- Verses of Surah Al-Ihzab Related to Adab al-Nabi (Verse No.6,21,40,56,57,58.)
- Verses of Surah Al-Hashar (18,19,20) Related to thinking, Day of Judgment
- Verses of Surah Al-Saf Related to Tafakar,Tadabar (Verse No-1,14)

Seerat of Holy Prophet (S.A.W) I

- Life of Muhammad Bin Abdullah (Before Prophet Hood)
- Life of Holy Prophet (S.A.W) in Makkah
- Important Lessons Derived from the life of Holy Prophet in Makkah

Seerat of Holy Prophet (S.A.W) II

- Life of Holy Prophet (S.A.W) in Madina
- Important Events of Life Holy Prophet in Madina
- Important Lessons Derived from the life of Holy Prophet in Madina

Introduction ToSunnah

- Basic Concepts of Hadith
- History of Hadith
- Kinds of Hadith
- Uloom –ul-Hadith
- Sunnah& Hadith
- Legal Position of Sunnah

Introduction To Islamic Law & Jurisprudence

- Basic Concepts of Islamic Law & Jurisprudence
- History & Importance of Islamic Law & Jurisprudence
- Sources of Islamic Law & Jurisprudence
- Nature of Differences in Islamic Law
- Islam and Sectarianism

Islamic Culture & Civilization

- Basic Concepts of Islamic Culture & Civilization
- Historical Development of Islamic Culture & Civilization
- Characteristics of Islamic Culture & Civilization
- Islamic Culture & Civilization and Contemporary Issues

Islam & Science

- Basic Concepts of Islam & Science
- Contributions of Muslims in the Development of Science
- Quranic& Science

Islamic Economic System

- Basic Concepts of Islamic Economic System
- Means of Distribution of wealth in Islamic Economics

- Islamic Concept of Riba
- Islamic Ways of Trade & Commerce

Political System of Islam

- Basic Concepts of Islamic Political System
- Islamic Concept of Sovereignty
- Basic Institutions of Govt. in Islam

Islamic History

- Period of Khlaft-E-Rashida
- Period of Ummayyads
- Period of Abbasids

Social System of Islam

- Basic Concepts of Social System of Islam
- Elements of Family
- Ethical Values of Islam

COURSE RECOMMANDED BOOKS:

1. Bhatia, H.S. (1989). Studies in Islamic Law, Religion and Society. New Delhi: Deep & Deep Publications.
2. Hasan, Ahmad. (1993) .Principles of Islamic Jurisprudence. Islamabad: Islamic Research Institute, IIU.
3. Waliullah, Mir. (1982). Muslim Jrisprudence and the Quranic Law of Crimes. Lahore: Islamic Book Service.
4. Zia-ul-Haq, Muhammad. (2001). Introduction to Al Sharia Al Islamia. Islamabad: Allama Iqbal Open University.

SOC-313 Citizenship Education And Community Engagement Credit Hours: 3(3+0)

Course Objectives:

The overall objectives of this course are to:

- Teach students the importance and role of active citizenship in promoting a productive, harmonious and developed society/world
- Educate students about the importance of concepts, skills and philosophy of community linkages in developing a sustainable society
- Inculcate the importance of community involvement for ensuring an improved, tolerant and generative society/world
- Provide an opportunity to the students to develop their relationship with the community

Learning Outcomes:

The primary outcome is inclusive development through active citizenship locally and globally,. Moreover, the following are the detailed outcomes of the course based on the three domains of Bloom's Taxonomy i.e Affective, Psychomotor and Cognitive. The students will be able to:

- Understand the overall organization of the society
- Recognize and exercise their rights, responsibilities and the significance of active citizenship in positive societal development
- Identify and critically evaluate social issues and implement practicable community based solutions
- Understand the concept of human rights and its significance
- Appreciate diverse viewpoints and inter-cultural harmony

Course Outline:

Introduction to Citizenship Education and Community Engagement

- Meaning & History
- Attributes of Active Citizenship
- Different Approach
    i. Republican Approach
    ii. Liberal Approach
    iii. Cosmopolitan Approach
- Dimensions of Active Citizenship
    i. Rights
    ii. Membership
    iii. Participation
    iv. Identity

Identity, Culture, and Social Harmony

- Sociological Theories of Self Formation
    i. Sigmund Freud Theory
    ii. George Herbert Mead Theory
    iii. Charles Horton Cooley Theory
- Cultural & Religious Harmony
- Pluralism & Diversity
- Democracy & Democratic Norms
- Concept and Development of Identity
- Components of Cultural and Social Harmony

Inter-Cultural Dialogue (me versus you)

- Principles & Purpose
- Ability to Support, learn and share through dialogue
- Policy Dialogue (encourage young people to share their opinion and perspective with policy makers and opinion makers.

Local & Global Communities

- Concept of Community
- Needs, Issues & Conflicts
- Conflict Resolution
- Communication & Networking
- Social Cohesion
- Social Capital
- Social Networking
- Advocacy
- Social Entrepreneurship & Partnership

Social Action Planning

- Skills in Project Planning & Management
- Project Cycle
- Stakeholder Analysis
- Problem Identification
- Writing Project Plan
- Monitoring & Evaluation
- Risk Analysis

Population Dynamics in Pakistan

- Population Growth Pakistan
- Factors Behind High Fertility Rate
    i. Legislative Actions
    ii. Dearth of Medical Facilities

iii. Delayed VS Early Age Marriages
iv. Poverty
v. Women Empowerment
vi. Spreading Awareness
vii. Providing Incentives

- Population Theory
- How to Control Population Growth

Text and Reference Books:

Core Readings:

- Larsen, A. K., Sewpaul, V., & Hole, G. O. (Eds.). (2013). *Participation in community work: International perspectives*. Routledge.
- Alan, T. (2008). Community work, London: Palgrave Macmillan.
- British Council, (2017) *Active Citizen's Social Action Projects Guide* (Scotland: British Council.
- Kaye, C. B. (2004). *The complete guide to service learning: Proven, practical ways to engage students in civic responsibility, academic curriculum, & social action*. Free Spirit Publishing.
- Hans, R. (1993). Population Studies, Indian Council of Social Science Research, New Delhi.
- Demeny, P., McNicoll, G., & Hodgson, D. (2003). *Encyclopedia of population*. Hodgson, Dennis (2003). Contemporary Population Thought.
- Peterson, W. (1975). Population, New York, Macmillan.
- Srinivasan, K. (1998). *Basic demographic techniques and applications*. SAGE Publications Pvt. Limited.
- Todaro, M. P. (1977). *Economic Development in the Third World: An introduction to problems and policies in a global perspective*. Pearson Education.
- United Nations Economic Commission for Europe – Official Web site
- UNO (2000). Population Trends, World Population Monitoring, Population growth Structure and Distribution 1999. Department of Economics and Social Affairs, Population Division, UNO.
- Weeks, J. R. (1992). Population: An Introduction to Concepts and Issues, Belmart California, Wadsworth Publishing Company.

Arts and Humanities

I. Pashto, Urdu, Arabic, Turkish, Chinese or any other language

II. Islamic History and Culture, Philosophy, History, Education, Home Economics or any other approved course of BKUC

Semester-III			
S. No	**Course code**	**Course title**	**Credit hours**
1	MATH-411	Calculus III	3(3+0)
2	MATH-412	Algebra-I (Group Theory-I)	3(3+0)
3	MATH-413	Software Packages (Matlab/Maple/Mathematica)	3(1+2)
4	ELL-411	English III: Academic Reading and Writing	3(3+0)
5		Natural Science-II	3(3+0)
6	PHIL-302	QR-II (Logic and Quantitative Reasoning)	3(3+0)
Total Cr. Hrs			**18(16+2)**

MATH-411 Calculus III **Credit Hours: 3(3+0)**

Objectives of course: This is 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.

Course Outline:

Vectors and analytic geometry in space: Coordinate system. Rectangular, cylindrical and spherical coordinates. The dot product, the cross product. Equations of lines and planes. Quadric surfaces.

Vector-valued functions: Vector-valued functions and space curves. Derivatives and integrals of vector valued functions. Arc length. Curvature, normal and binormal vectors.

Multivariable functions and partial derivatives: Functions of several variables. Limits and Continuity. Partial derivatives, Composition and chain rule. Directional derivatives and the gradient vector. Implicit function theorem for several variables. Maximum and minimum values. Optimization problems. Lagrange Multipliers.

Multiple integrals: Double integrals over rectangular domains and iterated integrals. Non-rectangular domains. Double integrals in polar coordinates. Triple integrals in rectangular, cylindrical and spherical coordinates. Applications of double and triple integrals. Change of variables in multiple integrals.

Vector calculus: Vector fields. Line integrals. Green's theorem. Curl and divergence. Surface integrals over scalar and vector fields. Divergence theorem. Stokes' theorem.

Recommended Books:

1. Thomas, Calculus, 11th Edition. Addison Wesley Publishing Company, 2005
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 with Analytic Geometry, PWS Publishers, Boston, Massachusetts, 1983.
7. M. Liebeck, A Concise introduction to pure Mathematics, CRC Press, 2011.
8. A. Kaseberg, Intermediate Algebra, Thomson Brooks/COLE, 2004.
9. J. Stewart, Calculus early transcendentals, 7th Edition, Brooks/COLE, 2008

MATH-412 Algebra-I (Group Theory-I) Credit Hours: 3(3+0)

Contents: Definition of a group, subgroup, subgroup generated by a set. The cyclic groups, cosets and Lagrange's theorem. Normalizer centralizer. The center of a group. Equivalence relation in a group,conjugacy classes. Normal subgroups, quotient group.

Group homomorphisms: Homomorphisms and isomorphism andAutomorphism. Kernel and image of homomorphism. Isomorphismtheorems. Permutation groups. The cyclic decomposition of apermutation group. Cayley's theorem. Direct product of two groupsand examples.**Recommended Books**

1. G. Nakose and D. Joyner: Linear Algebra with Applications, (1998).
2. W. Keith Nicholson: *Elementary linear algebra with applications*, (1994)
3. Richard O. Hill: Elementary linear algebra with applications, *3rd edition*, (1995)
3. Steven J. Leon: Linear algebra with applications, *6th edition, (2002).*
4. Shifrin T. and Adams R. M.: Linear Algebra, A Geometric Approach, (2002).
5. J. R. Durbin: Modern Agebra: An Introduction, 3rd Edition, (1992).

ELL-411 ENGLISH III: Academic Reading & Writing Credit Hours: 3(3+0)

Course Description

This course aims at inculcating proficiency in academic writing through research. It guides students to develop a well-argued and well documented academic paper with a clear thesis statement, critical thinking, argumentation and synthesis of information. This course also teaches students how to use different systems of citations and bibliography. It allows students to become independent and efficient readers armed with appropriate skills and strategies for reading and

Comprehending texts at undergraduate level.

Course Objectives

To enable the students to:

1. Improve literal understanding, interpretation & general assimilation, and integration of knowledge
2. Write well organized academic texts including examination answers with topic/thesis statement and supporting details.
3. Write argumentative essays and course assignments

Course Contents:

Reading and Critical Thinking

- Read academic texts effectively by
- Using appropriate strategies for extracting information and salient points according to a given purpose
- Identifying the main points supporting details, conclusions in a text of intermediate level
- Identifying the writer's intent such as cause and effect, reasons, comparison and contrast, and exemplification
- Interpreting charts and diagrams
- Making appropriate notes using strategies such as mind maps, tables, lists, graphs.
- Reading and carrying out instructions for tasks, assignments and examination questions
- Enhance academic vocabulary using skills learnt in Compulsory English I course
- Acquire efficient dictionary skills such as locating guide words, entry words, choosing appropriate definition, and identifying pronunciation through pronunciation key, identifying part of speech, identifying syllable division and stress patterns

- Writing Academic Texts

Organization and development of effective compositions

- employ appropriate strategies for prewriting, drafting, revising, and editing as part of the writing process
- compose coherent paragraphs, supporting central ideas with specific details
- Compose organized essays with genre-specific structure including thesis, introduction, body, and conclusion.
- demonstrate control of key conventions of standard written English
- summarize a text objectively
- respond to a text subjectively
- analyze, synthesize, interpret, and evaluate information from multiple texts
- apply active reading strategies such as skimming, scanning, questioning, and annotating
- develop vocabulary; choose correctly among different forms of related words; evaluate differences in diction

Recommended Books:

- English Practice Grammar (New edition with tests and answers) by Eastwood, J. 2004. Karachi: Oxford University Press.
- Fisher, A. 2001. Critical Thinking. C UP
- Critical Reading and Writing: An Introductory Course. By Goatly, A. 2000. London: Taylor & Francis
- A Writer's Reference. 2nd Ed. By Hacker, D. 1992. Boston: St. Martin's
- Study writing: A course in written English for academic and professional purposes. By Hamp-Lyons, L. & Heasley, B. 1987. Cambridge: Cambridge University Press.
- Oxford English for Undergraduates. By Howe, D. H, Kirkpatrick, T. A., & Kirkpatrick, D. L. 2004. Karachi: Oxford University Press.
- Grammar in Use. By Murphy, R. 2003. Cambridge: Cambridge University Press.
- Write to be Read: Reading, Reflection and Writing. By Smazler, W. R. 1996. Cambridge: Cambridge University Press.
- Study Skills. By Wallace, M. 1992. Cambridge: Cambridge University Press.
- Primary Texts: The Norton Field Guide to Writing, by Richard Bullock; or The St. Martin’s Guide to Writing, by Rise Axelrod and Charles Cooper; or The Allyn and Bacon Guide to Writing, by John Ramage and John Bean; or The Call to Write, by John Trimbu

PHIL-302 Logic and Quantitative Reasoning Credit Hours: 3(3+0)

Course contents:

Basic Logical Concepts:

- Definition of Logic.
- Logic as a Science and Art
- The scope of Logic
- Propositions, Arguments
- Conclusion-indicators and Premise-indicators
- The Laws of Thought
- Characteristics of Induction and Deduction

The Uses of Language:

- The basic uses of language

- Discourse serving multiple functions
- The forms of discourse
- Kinds of agreement and disagreement

Fallacies:

- The classification of Fallacies
- Fallacy of Relevance
- Fallacy of Ambiguity

Categorical Propositions:

- The theory of Deduction
- Classes and Categorical Propositions
- The four kinds of Categorical Proposition
- Quality, Quantity and Distribution
- The traditional square of opposition
- Obversion, Contraposition
- Symbolism and Diagrams of Categorical Proposition

Categorical Syllogism:

- Standard form of Categorical Syllogism
- The formal nature of Syllogistic arguments
- Venn diagram technique for testing Syllogism
- Syllogistic Rules and Fallacies
- Exposition of the 15 Valid forms of Categorical Syllogism

Syllogism in ordinary Language:

- Syllogistic Arguments
- Dilemma
- Disjunctive and Hypothetical Syllogism

Symbolic Logic:

- Modern Logic and Symbolic Language
- The symbols for Conjunction, Negation, and Disjunction
- The precise meaning of Valid and Invalid
- Testing arguments on Truth Table

Science and Hypothesis:

- Hypothesis
- Scientific explanation and Unscientific explanation

COURSE RECOMMENDED BOOKS:

1. Stewart, David and Blocker, Gene. H. (2006). Fundamentals of Philosophy. New Delhi: Pearson Education.
2. Copi, Iring. M. And Cohen, Carl. (2009). Introduction to Logic. New Delhi: Pearson Education.
3. Copi, Iring. M. , Cohen, Carl., Jetli, Priyadarshi. and Prabhakar, Monica. (2009).Introduction to Logic. New Delhi: Dorling Kindersley Pvt, Ltd.

Natural Sciences **(any two subjects may be selected from the following disciplines)**

Mathematics, Statistics, Botany, Zoology, Chemistry, Physics-I, Physics-II, Geography, GIS, Geology, Electronics, Geophysics, computer, (or any other approved Basic Course of BKUC)

Semester-IV			
S. No	**Course code**	**Course title**	**Credit hours**
1	MATH-421	Number Theory	3(3+0)
2	MATH-422	Ordinary Differential Equations	3(3+0)
3	MATH-423	Discrete Mathematics	3(3+0)
4		Arts and Humanities-II	3(3+0)
5		Social Sciences - II	3(3+0)
Total Cr. Hrs			**15(15+0)**

MATH-421 Number Theory — Credit Hours: 3(3+0)

Objectives of course: 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 and their distributions, Diophantine equations, and the theory of congruencies.

Course Outline:

Preliminaries: Well-ordering principle. Principle of finite induction.

Divisibility theory: The division algorithms. Basis representation theorem. Prime and composite numbers. Canonical decomposition. The greatest common divisor. The Euclidean algorithm. The fundamental theorem of arithmetic. Least common multiple.

Linear Diophantine equations: Congruences. Linear congruences. System of linear congruences. The Chinese remainder theorem. Divisibility tests. Solving polynomial congruences. Fermat's and Euler's theorems. Wilson's theorem.

Arithmetic functions: Euler's phi-function. The functions of J and sigma. The Mobius function. The sieve of Eratosthenes. Perfect numbers. Fermat and Mersenne primes.

Primitive Roots and Indices: The order of an integer mod n. Primitive roots for primes. Composite numbers having primitive roots.

Quadratic residues: Legendre symbols and its properties. The quadratic reciprocity law. Quadratic congruencies with composite moduli. Pythagorean triples. Representing numbers as sum of two squares.

Recommended Books:

1. D.M. Burton, Elementary Number Theory, McGraw-Hill, 2007.
2. W.J. Leveque, Topics in Number Theory, vols. I and II, Addison- Wesley, 1956.
3. S.B. Malik , Basic Number Theory, Vikas Publishing house, 1995.
4. K.H. Rosen, Elementary Number Theory and its Applications, 5th edition, Addison-Wesley, 2005.
5. I. Niven, H.S. Zuckerman, H.L. Montgomery, An Introduction to the theory of Numbers, John Wiley and Sons, 1991.
6. A. Adler, J.E. Coury, The Theory of Numbers, Jones and Bartlett Publishers, 1995.

MATH-422 Ordinary Differential Equations — Credit Hours: 3(3+0)

Objectives of course: To introduce students to the formulation, classification of differential equations and existence and uniqueness of solutions. To provide skill in solving initial value

and boundary value problems. To develop understanding and skill in solving first and second order linear homogeneous and non-homogeneous differential equations and solving differential equations using power series methods.

Course Outline:

Preliminaries: Introduction and formulation, classification of differential equations, existence and uniqueness of solutions, introduction of initial value and boundary value problems.

First order ordinary differential equations: Basic concepts, formation and solution of differential equations. Separable variables, Exact Equations, Homogeneous Equations, Linear equations, integrating factors. Some nonlinear first order equations with known solution, differential equations of Bernoulli and Richati type, Clairaut equation, modeling with first-order ODEs, Basic theory of systems of first order linear equations, Homogeneous linear system with constant coefficients, Non homogeneous linear system

Second and higher order linear differential equations: Initial value and boundary value problems, Homogeneous and non-homogeneous equations, Superposition principle, homogeneous equations with constant coefficients, Linear independence and Wronskian, Non-homogeneous equations, undetermined coefficients method, variation of parameters, Cauchy-Euler equation, Modelling.

Sturm-Liouville problems: Introduction to eigen value problem, adjoint and self adjoint operators, self adjoint differential equations, eigen values and eigen functions, Sturm-Liouville (S-L) boundary value problems, regular and singular S-L problems, properties of regular S-L problems

Series Solutions: Power series, ordinary and singular points, Existence of power series solutions, power series solutions, types of singular points, Frobenius theorem, Existence of Frobenius series solutions, solutions about singular points, The Bessel, modified Bessel Legendre and Hermite equations and their solutions.

Recommended Books:

1. Dennis G. Zill and Michael R., Differential equations with boundary-value problems by Cullin 5th Edition Brooks/Cole, 1997.
2. William E. Boyce and Richard C. Diprima, Elementary differential equations and boundary value problems, Seventh Edition John Wiley & Sons, Inc
3. V. I. Arnold, Ordinary Differential Equations, Springer, 1991.
4. T. Apostol, Multi Variable Calculus and Linear Algebra, 2nd ed., John Wiley and sons, 1997.

MATH-423 Discrete Mathematics Credit Hours: 3(3+0)

Objectives: Introduces the foundations of discrete mathematics as they apply to Computer Science, focusing on providing a solid theoretical foundation for further work. Further, this course aims to develop understanding and appreciation of the finite nature inherent in most Computer Science problems and structures through study of combinatorial reasoning, abstract algebra, iterative procedures, predicate calculus, tree and graph structures. In this course more emphasis shall be given to statistical and probabilistic formulation with respect to computing aspects.

Course Outline: Introduction to logic and proofs: Direct proofs; proof by contradiction, Sets, Combinatorics, Sequences, Formal logic, Prepositional and predicate calculus, Methods of

Proof, Mathematical Induction and Recursion, loop invariants, Relations and functions, Pigeonwhole principle, Trees and Graphs, Elementary number theory, Optimization and matching. Fundamental structures: Functions; relations (more specifically recursions); pigeonhole principle; cardinality and countability, probabilistic methods.

Counting methods: Basic methods: product, inclusion-exclusion formulae. Permutations and combinations. Recurrence relations and their solutions. Generating functions. Double counting. Applications. Pigeonhole principle, applications.

Relations: Binary relations, n-ary Relations. Closures of relations. Composition of relations, inverse relation.

Graphs: Graph terminology. Representation of graphs. Graphs isomorphism. Algebraic methods: the incidence matrix. Connectivity, Eulerian and Hamiltonian paths. Shortest path problem. Trees and spanning trees. Complete graphs and bivalent graphs.

Reference Material:

1. Kenneth H. Rosen, Discrete Mathematics and Its Applications, 6TH edition, 2006, Mcgraw Hill Book Co.
2. Richard Johnsonbaugh, Discrete Mathematics, 7TH edition, 2008, Prentice Hall Publishers.
3. Kolman, Busby & Ross, Discrete Mathematical Structures, 4th edition, 2000, Prentice-Hall Publishers.
4. Ralph P. Grimaldi, Discrete and Combinatorial Mathematics: An Applied Introduction, Addison-Wesley Pub. Co., 1985.

Arts and Humanities II

I. Pashto, Urdu, Arabic, Turkish, Chinese or any other language

II. Islamic History and Culture, Philosophy, History, Education, Home Economics or any other approved course of BKUC

Social science II

Political Science, Sociology, Psychology, Economics, Law, or any other approved Basic course of BKUC

Semester-V			
#	**Course code**	**Course title**	**Credit hours**
1	MATH-511	Set Topology	3(3+0)
2	MATH-512	Differential Geometry	3(3+0)
3	MATH-513	Real Analysis- I	3(3+0)
4	MATH-514	Algebra-II (Rings and Fields)	3(3+0)
5	MATH-515	Functional Analysis-I	3(3+0)
Total Cr. Hrs			**15(15+0)**

MATH-511 Set Topology — Credit Hours: 3(3+0)

Contents: Motivation and introduction, sets and their operations, countable and uncountable sets, cardinal and transfinite numbers. Topological spaces, open and closed sets, interior, closure and boundary of a set, neighborhoods and neighborhood systems, isolated points, some topological theorems, topology in terms of closed sets, limit points, the derived and perfect sets, dense sets and separable spaces, topological bases, criteria for topological bases, local bases, first and second countable spaces, relationship between separability and second countablity, relative or induced topologies, necessary and sufficient condition for a subset of a subspace to be open in the original space, induced bases. Metric spaces, topology induced by a metric, equivalent topologies, formulation with closed sets, Cauchy sequence, complete metric spaces, characterization of completeness, Cantor's intersection theorem, the completion of metric space, metrizable spaces.

Recommended Books:

1. J. R. Munkres: Topology A First Course, (1975).
2. G. F. Simon: Introduction to Topology and Modern Analysis, (1963).
3. W. J. Pervin: Foundation of General Topology, (1965).

MATH-512 Differential Geometry — Credit Hours: 3(3+0)

Objectives of course: After having completed this course, the students would be expected to understand classical concepts in the local theory of curves and surfaces including normal, principal, mean, curvature, and geodesics. They will also learn about tensors of different ranks.

Course Outline:

Theory of Space Curves: Introduction, index notation and summation convention. Space curves, arc length, tangent, normal and binormal. Osculating, normal and rectifying planes. Curvature and torsion. The Frenet-Serret theorem. Natural equation of a curve. Involutes and evolutes, helices. Fundamental existence theorem of space curves.

Theory of Surfaces: Coordinate transformation. Tangent plane and surface normal. The first fundamental form and the metric tensor. The second fundamental form. Principal, Gaussian, mean, geodesic and normal curvatures. Gauss and Weingarten equations. Gauss and Codazzi equations. Tensor Analysis: Einstein summation convention. Tensors of different ranks. Contravariant, covariant and mixed tensors. Addition, subtraction, inner and outer products of tensors. Contraction theorem, quotient law. The line element and metric tensor. Christoffel symbols.

Recommended Books:

1. R. S. Millman and G. D. Parker, Elements of Differential Geometry, Prentice-Hall, New Jersey, 1977.
2. A. Goetz, Introduction to Differential Geometry, Addison- Wesley, 1970.
3. E. Kreyzig, Differential Geometry, Dover, 1991.
4. M. M. Lipschutz, Schaum's Outline of Differential Geometry, McGraw Hill, 1969.
5. D. Somasundaram, Differential Geometry, Narosa Publishing House, New Delhi. 2005.
6. M. R. Spiegel, Vector Analysis, McGraw Hill Book Company, Singapore, 1981.
7. A. W. Joshi, Matrices and Tensors in Physics, Wiley Eastern Limited, 1991.
8 F. Chorlton, Vector and Tensor Methods, Ellis Horwood Publisher, U.K., 1977.

MATH-513 Real Analysis-I **Credit Hours: 3(3+0)**

Objectives of course: At the end of this course the students will be able to understand the basic set theoretic statements and emphasize the proofs' development of various statements by induction. Define the limit of, a function at a value, a sequence and the Cauchy criterion. Prove various theorems about limits of sequences and functions and emphasize the proofs' development. Define continuity of a function and uniform continuity of a function, prove various theorems about continuous functions and emphasize the proofs' development. Define the derivative of a function of one variable, prove various theorems about the derivatives of functions and emphasize the proofs' development. Define a cluster point and an accumulation point, prove, Rolles's Theorem, extreme value theorem, boundedness theorem and the Mean Value theorem and emphasize the proofs' development.

Course Outline:

Number Systems: Ordered fields. Rational, real and complex numbers. Archimedean property, supremum, infimum and completeness.

Sequences and Series of Real Numbers: Limits of sequences, The extended real number system. Euclidean space, Numerical sequences, Limits superior and inferior, Subsequences, algebra of limits. Bolzano Weierstrass Theorem. Cauchy sequences, liminf, limsup. Limits of series, convergences tests, absolute and conditional convergence. Power series.

Continuity: Functions, continuity and compactness, existence of minimizers and maximizers, uniform continuity. Continuity and connectedness, Intermediate mean Value Theorem. Monotone functions and discontinuities.

Differentiation: Mean Value Theorem, L'Hopital's Rule, Taylor's Theorem.

Recommended Books:

1. S. Lang, Analysis I, Addison-Wesley Publ. Co., Reading, Massachusetts, 1968.
2. W. Rudin, Principles of Mathematical Analysis, 3rd ed., Mc.Graw15 Hill, 1976.
3. B. S. Thomson, J. B. Bruckner and A. M. Bruckner, Elementary Real Analysis, 2nd Ed. 2008.
4. G. Boros, V. Moll, Irresistible Integrals: Symbolics, Analysis an Experiments in the Evaluation of Integrals, Cambridge University Press, 2004.
5. J. Borwein, D. Bailey, R. Girgenson, Experimentation in Mathematics: Computational Paths to discovery, Wellesley, MA, A.K. Peters, 2004.
6. G. Bartle , R. Sherbert , Introduction to Real Analysis, 3rd edition, John Wiley, New York, 1999.

MATH- 514 Algebra-II (Rings and Fields) Credit Hours: 3(3+0)

Contents: Rings, Subrings, Ideals, Factor ring, Definitions and basic concepts, Homomorphisms, Homomorphism theorems, Polynomial rings, Unique factorization domain, Factorization theory, Euclidean domains, Arithmetic in Euclidean domains, Extension fields, Algebraic and transcendental elements, Simple extension, Introduction to Galois theory, Examples of finite fields, application of vector spaces to binary linear codes and Markov (chain) Process, Application in Economics. Findings finite agebras through GAP.

Recommended Books:

1. S. J. Axler: Linear Algebra Done Right (1996).
2. B. Kolman and D. R. Hill: Introductory Linear Algebra with Applications, (2001).
3. D. S. Dummit and R.M. Foote: Abstract Algebra, (2002).
4. K. Nomizu: Fundamentals of Linear Algebra, (1966).

MATH-515 Functional Analysis-I Credit Hours: 3(3+0)

Objectives of course: 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.

Course Outline:

Metric Space: Review of metric spaces, Convergence in metric spaces, Complete metric spaces, Dense sets and separable spaces, No-where dense sets, Baire category theorem.

Normed Spaces: Normed linear spaces, Banach spaces, Equivalent norms, Linear operator, Finite dimensional normed spaces, Continuous and bounded linear operators, Dual spaces.

Inner Product Spaces: Definition and examples, Orthonormal sets and bases, Annihilators, projections, Linear functionals on Hilbert spaces. Reflexivity of Hilbert spaces.

Recommended Books:

1. A. V. Balakrishnan, Applied Functional Analysis, 2^{nd} edition, Springer-Verlag, Berlin, 1981.
2. J. B. Conway, A Course in Functional Analysis, 2nd ed., Springer-Verlag,Berlin,1997.
3. K. Yosida, Functional Analysis, 5th ed., Springer-Verlag, Berlin, 1995.
4. E. Kreyszig, Introduction to Functional Analysis with Applications, John Wiley and Sons, 2004.

Semester-VI			
#	**Course code**	**Course title**	**Credit hours**
1	MATH-521	Classical Mechanics	3(3+0)
2	MATH-522	Partial Differential Equations	3(3+0)
3	MATH-523	Functional Analysis-II	3(3+0)
4	MATH-524	Complex Analysis	3(3+0)
5	MATH-525	Real Analysis-II	3(3+0)
6	MATH-526	Numerical Methods	3(3+0)
Total Cr. Hrs			**18(18+0)**

MATH-521 Classical Mechanics **Credit Hours: 3(3+0)**

Objectives of course: To provide solid understanding of classical mechanics and enable the students to use this understanding while studying courses on quantum mechanics, statistical mechanics, electromagnetism, fluid dynamics, space-flight dynamics, astrodynamics and continuum mechanics.

Course Outline:

Kinematics: Rectilinear motion of particles. Uniform rectilinear motion, uniformly accelerated rectilinear motion. Curvilinear motion of particle, rectangular components of velocity and acceleration. Tangential and normal components. Radial and transverse components. Projectile motion.

Kinetics: Work, power, kinetic energy, conservative force fields. Conservation of energy, impulse, torque. Conservation of linear and angular momentum. Non-conservative forces.

Simple Harmonic Motion: The simple harmonic oscillator, period, frequency. Resonance and energy. The damped harmonic oscillator, over damped, critically damped and under damped. Motion, forces and vibrations.

Central Forces and Planetary Motion: Central force fields, equations of motion, potential energy, orbits. Kepler's law of planetary motion. Apsides and apsidal angles for nearly circular orbits. Motion in an inverse square field.

Planer Motion of Rigid Bodies: Introduction to rigid and elastic bodies, degree of freedom, translations, rotations, instantaneous axis and center of rotation, motion of the center of mass. Euler's theorem and Chasles' theorem. Rotation of a rigid body about a fixed axis, moments and products of inertia. Parallel and perpendicular axis theorem.

Motion of Rigid Bodies in Three Dimensions: General motion of rigid bodies in space. The momental ellipsoid and equimomental systems. Angular momentum vector and rotational kinetic energy. Principal axes and principal moments of inertia. Determination of principal axes by diagonalizing the inertia matrix.

Euler Equations of Motion of a Rigid Body: Force free motion. Free rotation of a rigid body with an axis of symmetry. Free rotation of a rigid body with three different principal moments. The Eulerian angles, angular velocity and kinetic energy in terms of Euler angles. Motion of a spinning top and gyroscopes-steady precession, sleeping top.

Recommended Books:

1. E. DiBenedetto, Classical Mechanics. Theory and Mathematical Modeling, ISBN: 978-0-8176-4526-7, Birkhauser Boston, 2011.

2. John R. Taylor, Classical Mechanics, ISBN: 978-1-891389- 22-1, University of Colorado, 2005.

3. H. Goldstein, Classical Mechanics, Addison-Wesley Publishing Co., 1980.
4. C. F. Chorlton, Text Book of Dynamics, Ellis Horwood, 1983.
5. M. R. Spiegel, Theoretical Mechanics, 3rd Edition, Addison-Wesley Publishing Company, 2004.
6. G. R. Fowles and G. L. Cassiday, Analytical Mechanics, 7th edition, Thomson Brooks/COLE, USA, 2005.

MATH-522 Partial Differential Equations Credit Hours: 3(3+0)

Specific Objectives of course: Partial Differential Equations (PDEs) are at the heart of applied mathematics and many other scientific disciplines. The course aims at developing understanding about fundamental concepts of PDEs theory, identification and classification of their different types, how they arise in applications, and analytical methods for solving them. Special emphasis would be on wave, heat and Laplace equations.

Course Outline:

First order PDEs: Introduction, formation of PDEs, solutions of PDEs of first order, The Cauchy's problem for quasilinear first order PDEs, First order nonlinear equations, Special types of first order equations

Second order PDEs: Basic concepts and definitions, Mathematical problems, Linear operators, Superposition, Mathematical models: The classical equations, the vibrating string, the vibrating membrane, conduction of heat solids, canonical forms and variable, PDEs of second order in two independent variables with constant and variable coefficients, Cauchy's problem for second order PDEs in two independent variables

Methods of separation of variables: Solutions of elliptic, parabolic and hyperbolic PDEs in Cartesian and cylindrical coordinates

Laplace transform: Introduction and properties of Laplace transform, transforms of elementary functions, periodic functions, error function and Dirac delta function, inverse Laplace transform, convolution theorem, solution of PDEs by Laplace transform, Diffusion and wave equations

Fourier transforms: Fourier integral representation, Fourier sine and cosine representation, Fourier transform pair, transform of elementary functions and Dirac delta function, finite Fourier transforms, solutions of heat, wave and Laplace equations by Fourier transforms.

Recommended Books:

1. Myint UT, Partial Differential Equations for Scientists and Engineers, 3rdedition, North Holland, Amsterdam, 1987.
2. Dennis G. Zill, Michael R. Cullen, Differential equations with boundary value problems, Brooks Cole, 2008.
3. John Polking, Al Boggess, Differential Equations with Boundary Value Problems, 2nd Edition, Pearson,July 28, 2005.
4. J. Wloka, Partial Differential Equations, Cambridge University press, 1987.

MATH- 523 Functional Analysis-II Credit Hours: 3(3+0)

Course Outline:

The Hahn-Banach theorem, principle of uniform boundedness, open mapping theorem, closed graph theorem, Weak topologies and the Banach-Alouglu theorem, extreme points and

theKlein-Milmantheorem.
The dual and bi-dual spaces, reflexive spaces, compact operators, Spectrum and eigenvalues of an operator, elementary spectral theory.

Recommended Books:

1. Kreyszing, E., Introductory Functional Analysis and Applications, John Wiley, 1973.
2. Taylor, A.E., and Lay, D.C., Introduction of Functional Analysis, John Wiley, 1979.
3. Heuser, H.G., Functional Analysis, John Wiley, 1982.
4. Groetsch, C.W., Elements of Applicable Functional Analysis, Marcel Dekker, 1980.

MATH- 524 Complex Analysis Credit Hours: 3(3+0)

Objectives of course: This is an introductory course incomplex analysis, giving the basics of the theory along with applications, with an emphasis on applications of complex analysis and especially conformal mappings. Students should have a background in real analysis (as in the course Real Analysis I), including the ability to write a simple proof in an analysis context.

Course Outline:

Introduction: The algebra of complex numbers, Geometric representation of complex numbers, Powers and roots of complex numbers.

Functions of Complex Variables: Definition, limit and continuity, Branches of functions, Differentiable and analytic functions. The Cauchy-Riemann equations, Entire functions, Harmonic functions, Elementary functions: The exponential, Trigonometric, Hyperbolic, Logarithmic and Inverse elementary functions, Open mapping theorem. Maximum modulus theorem.

Complex Integrals: Contours and contour integrals, Cauchy-Goursat theorem, Cauchy integral formula, Lioville's theorem, Morerea's theorem.

Series: Power series, Radius of convergence and analyticity, Taylor's and Laurent's series, Integration and differentiation of power series. Singularities, Poles and residues: Zero, singularities, Poles and Residues, Types of singular points, Calculus of residues, contour integration, Cauchy's residue theorem with applications. Mobius transforms, Conformal mappings and transformations.

Recommended Books:

1. R. V. Churchill, J. W. Brown, Complex Variables and Applications , 5th edition, McGraw Hill, New York, 1989.
2. J. H. Mathews and R. W. Howell, Complex Analysis for Mathematics and Engineering, 2006.
3. S. Lang, Complex Analysis, Springer-Verlag, 1999.
4. R. Remmert, Theory of Complex Functions, Springer-Verlag, 1991.
5. W. Rudin, Real and Complex Analysis, McGraw-Hill, 1987.

MATH-525 Real Analysis II Credit Hours: 3(3+0)

Specific Objectives of course: A continuation of Real Analysis I, this course will continue to cover the fundamentals of real analysis, concentrating on the Riemann-Stieltjes integrals, Functions of Bounded Variation, Improper Integrals, and convergence of series. Emphasis would be on proofs of main results.

Course Outline:

The Riemann-Stieltjes Integrals: Definition and existence of integrals. Properties of integrals. Fundamental theorem of calculus and its applications. Change of variable theorem. Integration by parts.

Functions of Bounded Variation: Definition and examples. Properties of functions of bounded variation.

Improper Integrals: Types of improper integrals, tests for convergence of improper integrals. Beta and gamma functions. Absolute and conditional convergence of improper integrals.

Sequences and Series of Functions: Power series, definition of point-wise and uniform convergence. Uniform convergence and continuity. Uniform convergence and differentiation. Examples of uniform convergence.

Fourier series; Orthogonal functions, Legendre, Hermite and Laguerre polynomials, Convergence in the mean. Fourier-Legendre and Fourier-Bessel series, Bessel inequality, Parseval equality. Convergence of the trigonometric Fourier series.

Recommended Books:

1. S. Lang, Analysis I, II, Addison-Wesley Publ. Co., Reading,Massachusetts,1968,1969.
2. W. Rudin, Principles of Mathematical Analysis, 3rd Ed., McGraw-Hill, 1976.
3. K. R. Davidson and A. P. Donsig, Real Analysis with Real Applications, Prentice Hall Inc., Upper Saddle River, 2002.
4. G. B. Folland, Real Analysis, 2nd Edition, John Wiley and Sons, New York, 1999.
5. E. Hewitt and K. Stromberg, Real and Abstract Analysis, Springer-Verlag, Berlin Heidelberg New York, 1965.
6. H. L. Royden, Real Analysis, 3rd Edition, Macmillan, New York, 1988.
7. G. Bartle , R. Sherbert , Introduction to Real Analysis, 3rd edition, John Wiley, New York, 1999.

MATH-526 Numerical Methods **Credit Hours: 3(3+0)**

Course Outline:

Numerical Solution of Non-linear Equations: The bisection method, the method of false position, the Newton-Raphson method, Rate of convergence of iterative methods.

Eigen value problems: Rutishauser method, the power and inverse power method, Jacobi's method, Given's method and House-holder's method. Numerical solutions of simultaneous linear algebraic equations: Solution by matrix inversion methods and Iterative methods (Jacobi, Gauss-Seidel, Successive over relaxation), convergence of iterative methods.

The error of interpolating polynomials. Finite difference operators (forward, backward, central, average and shift) and tables. Newton's forward and backward difference formulas.

Numerical integration: The Rectangular, Trapezoidal and Simpson rules. Romberg integration. Method of undetermined coefficients.

RECOMMENDED BOOKS:

1. W. A. Smith, Elementary Numerical Analysis, Harper &Row Pub. Int., 1979.
2.C. E. Froberg, Introduction to Numerical Analysis, Addsion-Wesley Co., 1974.
3.M. K. Jain, Numerical Methods for Scientific and Engineering Comp., Wiley E. Ltd, 1985.
4.R. L. Burden, J. D. Faires, Introduction to Numerical Analysis. 8th Ed, 2004.

Semester-VII			
#	**Course code**	**Course title**	**Credit hours**
1	MATH-611	Numerical Analysis	3(3+0)
2	MATH-612	Affine and Euclidean Geometry	3(3+0)
3	MATH-613	Mathematical Methods	3(3+0)
4	MATH-	E-1	3(3+0)
5	MATH-	E-2	3(3+0)
Total Cr. Hrs			**15(15+0)**

MATH-611 Numerical Analysis **Credit Hours: 3(3+0)**

Objectives of course: This course is designed to teach the students about numerical methods and their theoretical bases. The course aims at inculcating in the students the skill to apply various techniques in numerical analysis, understand and do calculations about errors that can occur in numerical methods and understand and be able to use the basics of matrix analysis.

Course Outline:

Error analysis: Floating point arithmetic, approximations and errors.

Interpolation and polynomial approximation: Lagrange interpolation, Newton's divided difference formula, forward, backward and centered difference formulae, interpolation with a cubic spline, Hermite interpolation, least squares approximation.

Numerical differentiation: Forward, backward and central difference formulae, Richardson's extrapolation.

Numerical integration: Rectangular rule, trapezoidal rule, Simpson's 1/3 and 3/8 rules, Boole's and Weddle's rules, Newton-Cotes formulae, Gaussian quadrature.

Difference Equations:

Numerical solutions of Differential equations: Numerical Solution of ODEs (Taylors' series methods, Euler and Modified Euler Methods, RK methods, Predictor Corrector Methods), Numerical Solutions of PDEs (Finite difference method)

Recommended Books:

1. C.F. Gerald and P.O. Wheatley, Applied Numerical Analysis, Pearson Education, Singapore, 2005.

2. R. L. Burden and J. D. Faires: Numerical Analysis, latest edition, PWS Pub. Co.

3. J.H. Mathews, Numerical Methods for Mathematics, latest Edition, Prentice Hall International.

4. S. C. Chapra and R. P. Canale: Numerical Methods for Engineers, 6th edition, McGraw Hill.

5. W. E. Boyce, R. C. DiPrima, Elementary Differential Equations and Boundary Value Problems, John Wiley \& Sons, Inc., 2001.

6. L. Debnath, Nonlinear Partial Differential Equations for Scientists and Engineers, Birkhauser-Boston, 2005.

7. Alexander Komech, Andrew Komech, Principles of Partial Differential Equations, Springer-New York, 2009.

8. H. Richard, Elementary Applied Partial Differential Equations, Prentice-Hall International, Inc., London 1987.

9. Weinberger, Hans F., A First Course in Partial Differential Equations with Complex Variables and Transform Methods, Dover Publications, Inc., 1995.

10. R. Kent Nagle, Edward B. Saff, Arthur David Snider, Fundamentals of Differential Equations, Addison Wesley Longman, Inc., 2000.

MATH-612 Affine and Euclidean Geometry **Credit Hours: 3(3+0)**

Objectives of course: To familiarize mathematics students with the axiomatic approach to geometry from a logical, historical, and pedagogical point of view and introduce them with the basic concepts of Affine Geometry, Affine spaces and Platonic Ployhedra.

Course Outline:

Vector spaces and affine geometry: Collinearity of three points, ratio AB/BC. Linear combinations and linear dependent set versus affine combinations and affine dependent sets. Classical theorems in affine geometry: Thales, Menelaus, Ceva, Desargues. Affine subspaces, affine maps. Dimension of a linear subspace and of an affine subspace.

Euclidean geometry: Scalar product, Cauchy-Schwartz inequality: norm of a vector, distance between two points, angles between two non-zero vectors. Pythagoras theorem, parallelogram law, cosine and sine rules. Elementary geometric loci.

Orthogonal transformations: Isometries of plane (four types), Isometries of space (six types). Orthogonal bases.

Platonic polyhedra: Euler theorem on finite planar graphs. Classification of regular polyhedra in space. Isometries of regular polygons and regular polyhedra

Recommended Books:

1. E. Rees, Notes on Geometry, Springer, 2004.
2. M. A. Armstrong, Groups and Symmetry, Springer, 1998.
3. H. Eves, Fundamentals of Modern Elementary Geometry, Jones and Bartlett Publishers International, 1992
4. S. Stahl, The Poincare Half-Plane A Gateway to Modern Geometry, Jones and Bartlett Publishers International, 1993.

MATH-613 Mathematical Methods **Credit Hours: 3(3+0)**

Objectives of course: The main objective of this course is to provide the students with a range of mathematical methods that are essential to the solution of advanced problems encountered in the fields of applied physics and engineering. In addition this course is intended to prepare the students with mathematical tools and techniques that are required in advanced courses offered in the applied physics and engineering programs.

Course Outline:

Fourier Methods: The Fourier transforms. Fourier analysis of the generalized functions. The Laplace transforms. Hankel transforms for the solution of PDEs and their application to boundary value problems.

Green's Functions and Transform Methods: Expansion for Green's functions. Transform methods. Closed form Green's functions.

Perturbation Techniques: Perturbation methods for algebraic equations. Perturbation methods for differential equations.

Variational Methods: Euler-Lagrange equations. Integrand involving one, two, three and n variables. Special cases of Euler-Lagrange's equations. Necessary conditions for existence of an extremum of a functional. Constrained maxima and minima.

Recommended Books:

1. D. L. Powers, Boundary Value Problems and Partial Differential Equations, 5th edition, Academic Press, 2005.
2. W. E. Boyce, Elementary Differential Equations, 8th edition, John Wiley and Sons, 2005.
3. M. L. Krasnov, G. I. Makarenko and A. I. Kiselev, Problems and Exercises in the Calculus of Variations, Imported Publications, Inc., 1985.
4. J. W. Brown and R. V. Churchil, Fourier Series and Boundary Value Problems, McGraw Hill, 2006.
5. A. D. Snider, Partial Differential Equations: Sources and Solutions, Prentice Hall Inc., 1

Semester-VIII			
#	**Course code**	**Course title**	**Credit hours**
1	MATH-621	Probability Theory	3(3+0)
2	MATH-622	Integral Equations	3(3+0)
3	MATH-623	Project	3(3+0)
4	MATH-	E-3	3(3+0)
5	MATH-	E-4	3(3+0)
Total Cr. Hrs			**15(15+0)**

MATH-621 Probability Theory **Credit Hours: 3(3+0)**

Objectives of course: 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 variables and random processes needed in applications.

Course Outline:

Finite probability spaces: Basic concept, probability and related frequency, combination of events, examples, Independence, Random variables, Expected value. Standard deviation and Chebyshev's inequality. Independence of random variables. Multiplicativity of the expected value. Additivity of the variance, Discrete probability distribution.

Probability as a continuous set function: sigma-algebras, examples. Continuous random variables, Expectation and variance. Normal random variables and continuous probability distribution.

Applications: de Moivre-Laplace limit theorem, weak and strong law of large numbers. The central limit theorem, Markov chains and continuous Markov process.

Recommended Books:

1. M. Capinski, E. Kopp, Measure, Integral and Probability, Springer-Verlag, 1998.
2. R. M. Dudley, Real Analysis and Probability, Cambridge University Press, 2004.
3. S. I. Resnick, A Probability Path, Birkhauser, 1999.
4. S. Ross, A first Course in Probability Theory, 5th ed., Prentice Hall, 1998.
5. Robert B. Ash, Basic Probability Theory, Dover. B, 2008.

MATH-622 Integral Equations **Credit Hours: 3(3+0)**

Objectives of course: Many physical problems that are usually solved by differential equation methods can be solved more effectively by integral equation methods. This course will help students gain insight into the application of advanced mathematics and guide them through derivation of appropriate integral equations governing the behavior of several standard physical problems.

Course Outline:

Linear integral equations of the first kind, Linear integral equations of the second kind. Relationship between differential equation and Volterra integral equation. Neumann series. Fredholm Integral equation of the second kind with separable Kernels. Eigenvalues and eigenvectors. Iterated functions. Quadrature methods. Least square methods. Homogeneous integral equations of the second kind. Fredholm integral equations of the first kind. Fredholm

integral equations of the second kind. Abel's integral equations. Hilbert Schmidt theory of integral equations with symmetric Kernels. Regularization and filtering techniques.

Recommended Books:

1. C. T. H. Baker, Integral Equations, Clarendon Press, 1977.
2. F. Smithies, Integral Equations, Cambridge University Press, 1989.
3. A. M. Wazwaz, A first Course in Integral Equations, World Scientific Pub., 1989.
4. W. V. Lovitt, Linear Integral Equations, Dover Publications, 2005.

Elective Courses for BS Mathematics

#	Course code	Course title	Credit hours
1	MATH-631	Measure Theory	3(3+0)
2	MATH-632	Rings and Modules	3(3+0)
3	MATH-633	Group Action	3(3+0)
4	MATH-634	Algebraic Topology	3(3+0)
5	MATH-635	Group Theory-II	3(3+0)
6	MATH-636	Graph Theory	3(3+0)
7	MATH-637	Galois Theory	3(3+0)
8	MATH-638	Riemannian Geometry	3(3+0)
9	MATH-639	Lie Algebra	3(3+0)
10	MATH-640	Fluid Mechanics	3(3+0)
11	MATH-641	General Relativity	3(3+0)
12	MATH-642	Special Relativity	3(3+0)
13	MATH-643	Electromagnetism	3(3+0)
14	MATH-644	Mathematical Modelling	3(3+0)
15	MATH-645	Optimization Theory	3(3+0)
16	MATH-646	Ring Theory	3(3+0)
17	MATH-647	Introduction to Algebraic geometry	3(3+0)
18	MATH-648	Continuous Groups	3(3+0)
19	MATH-649	Introduction to Combinotorics	3(3+0)
20	MATH-650	Introductions to Algebraic Systems (Optional)	3(3+0)
21	MATH-651	Simulation	3(3+0)
22	MATH-652	Dynamics	3(3+0)
23	MATH-653	Mathematical Physics	3(3+0)
24	MATH-654	Special Functions	3(3+0)
25	MATH-655	Computational Fluid Dynamics	3(3+0)
26	MATH-656	Quantum Mechanics	3(3+0)
27	MATH-657	History of Mathematics	3(3+0)
28	MATH-658	Axiomatic Set Theory	3(3+0)
29	MATH-659	Lie Groups	3(3+0)
30	MATH-660	Pointless Topology	3(3+0)
31	MATH-661	Category Theory	3(3+0)
32	MATH-662	Econometrics	3(3+0)
33	MATH-663	Statistical Inferences	3(3+0)
34	MATH-664	Convex Analysis	3(3+0)
33	MATH-665	Bio Mathematics	3(3+0)
34	MATH-666	Modules over PID	3(3+0)
35	MATH-667	Geometric Function Theory	3(3+0)
36	MATH-668	Optimization Theory	3(3+0)
38	MATH-669	Linear Dynamical System I	3(3+0)
39	MATH-670	Linear Dynamical System II	3(3+0)
40	MATH-671	Numerical Solution of Ordinary Differential Equations	3(3+0)

MATH-632 Rings and Modules **Credit Hours: 3(3+0)**

Course Outline:

Rings and modules, decomposition of modules, decomposition theorem, the primary decomposition theorem, The primary decomposition, Abelian groups as Z-modules, Abelian groups, Sylow's theorem, linear transformation and matries, invariants and the Jordan canonical form, the rational canonical form theorem - (linear transformation version), The Jordan canonical form theorem, conjugacy classes in general linear groups.

Recommended Books:

1. Blyth, T., Module theory, O.U.P., Oxford, 1977.
2. Hartley, B. and Hawkes, T., Rings, modules and linear algebra, Chapman, G., Lecture Nortes on Modules, Michigan University Press.

MATH-633 Group Action **Credit Hours: 3(3+0)**

Course Outline:

Actions of Groups, Permutation representation, Equivalence of actions, Regular representation, Cosets spaces, Linear groups and vector spaces. Affine group and affine spaces, Transitivity and orbits, Partition of G-spaces into orbits, Orbits as conjugacy class Computation of orbits, The classification of transitive G-spaces Catalogue of all transitive G-spaces up to G-isomorphism, One-one correspondence between the right coset of Ga and the G-orbit, G-isomorphism between coset spaces and conjugation in G. Simplicity of A5, Frobenius-Burnside lemma, Examples of morphisms, G-invariance, Relationship between morphisms and congruences, Order preserving one-one correspondences between congruences on Ω and subrroups H of G that contain the stabilizer Gα. The alternating groups, Linear groups, Projective groups, Mobius groups, Orthogonal groups, unitary groups, Cauchy's theorem, P-groups, Sylow P-subgroups, Sylow theorems, Simplicity of An when $n \geq 5$.

Recommended Books:

1. J.S. Rose, A Course on Group Theory, Cambridge University Press, 1978.
2. H. Wielandt, Finite Permutation Groups. Academic Press, 1964.
3. J.B. Fraleigh, A Course in Algebra, Addison-Wesley 1982.

MATH-635 Group Theory-II **Credit Hours: 3(3+0)**

Course Outline:

Group action, solvable and nilpotent groups, P-groups, upper and lower central series, finitely generated abelian groups,

T-groups, Dedekind groups, subnormal subgroups, characteristic groups, Wielandt subgroups, Wielandt theorem, Frattini subgroups, fitting subgroups, Socle subgroups, Endomorphism and Automorphism, power automorphism of groups, universal power automorphism, simple groups.(Definition and examples). Direct product of groups, Sylow groups and Sylow theorems, normal series of a group, refinement theorem, composition series and Jordan Holder theorem

RECOMMENDED BOOKS:

1. J. B. Fraleigh, A First Course in Algebra, Addison Wesley Co., 1976.
2. I. N. Herstein, Topics in Algebra, Ginn & Co.

3. P. M. Cohn, Algebra Vol. I & II, John Wiley & Sons.
4. A. Majeed, Theory of Groups, University Grant Commission.
5. T. S. Blyth, E. F. Robertson, Essential student Algebra, Vol I-V, Chapman & Hall, 1986.
6. T. S. Blyth, E. F. Robertson, Algebra Through Practice, Book I-VI, CUP, 1984.

MATH-636 Graph Theory **Credit Hours: 3(3+0)**

Course Outline:

Undirected graphs, Geometric graphs, Abstract graphs, Isomorphism, Edge progressions chains and circuits rank and nullity, Degrees, Trees. Bipartite graphs, Unicursal graphs, Hamiltonian Graphs. Directed graphs, Arc Progressions, paths progression and cycle progression.

Partition and distances in graphs, edge partitions, Arc partitions, Hamiltonian chains and circuits, vertex partitions, radius and diameter, minimal length problem. Foundation of electrical network theory. Matrix representation, the incidence matrix, the circuit matrix, the cut-set matrix, the vertex or adjacency matrix, the path matrix. Network Flows, network flow problems.

RECOMMENDED BOOKS:

1. R. G. Busacker, T. L. Seaty, Finite graphs and Networks', An introduction with applications', McGraw Hill Book Company.
2. R. J. Wilson, Introduction to Graph Theory, Longman Scientific and Technical, 1985. Wai-Kaichen,Applied graph Theory "graphs and electrical networks, North-Holland Pub., 1976. Bela Bollobas,Advances in Graph Theory.

MATH-637 Galois Theory **Credit Hours: 3(3+0)**

Course Outline:

Integral domains and Fields, Homomorphisms and ideals, Quotient Rings, Polynomial rings in one indeterminate over Fields, Prime ideals and Maximal ideals, irreducible Polynomials.

Algebraic and Transcendental field extensions, Simple Extensions, Composite Extensions, Splitting Fields, The Degree of an Extension, Ruler and Compass Constructions. Normality and Separability.

Circle Division, The Galois Group, Toots of Unity, Solvability by Radicals, Galois extensions, The Fundamental Theorem of Galois Theory, Galois's Great Theorem, Algebraically Closed Fields.

Recommended Books:

1. Joseph Rotman, "Galois Theory", Springer-Veriog, New York, Inc. (2005)
2. Lan Steward, "Galois Theory", Chapman & Hall, New York (2004)
3. David S. Dummit and Richard M. Foote, "Abstract Algebra", John Wiley & Sons, Inc, New York (2002).

MATH-640 Fluid Mechanics **Credit Hours: 3(3+0)**

Course Outline:

Viscous Fluids: Review of the basics of fluids, Two-dimensional motion, stream function, complex potential and some potential flows; sources, sinks and doublets; Circle theorem; Method of images; Blasius theorem; Aerofoil and the theorem of Kutta and Joukowski; Vortex motion; Karman's vortex street. Viscous Fluids, constitutive equations; Navier-

Stokes equations; Exact solutions of Navier-stokes equations, Steady unidirectional flow; Poiseuille flow, Couette flow, Unsteady Unidirectional flow; sudden motion of a plane boundary in a fluid at rest, flow due to an oscillatory boundary, Equations of motion relative to a rotating system, Ekman flow, Dynamical similarity and the Reynolds number, Boundary layer concept and its governing equations; Flow over a flat plate (Blasius solution); Reynolds equations of turbulent motion.

RECOMMENDED BOOKS:

1. I. G. Currie, Fundamental Mechanics of Fluids, McGraw-Hill Co., 1974.
2. Schlichting, Boundary Layer Theory, McGraw-Hill Co., 1979.
3. F. Chorltan, Fluids Dynamics, CBS Pub. & Dist., 1985.
4. F. M. White, Introduction to fluid mechanics.
5. Fox, McDonald, Introduction to fluid mechanics.

MATH-641 General Relativity **Credit Hours: 3(3+0)**

Course Outline:

The Einstein field equations. The principles of general relativity. The stress-energy momentum tensor. The vacuum Einstein equations and the Schwarzschild solution. The three classical tests of general relativity. The homogeneous sphere and the interior Schwarzschild solution. Birkhoff's theorem. The Reissner-Nordstrom solution and the generalised Birkhoff's theorem. The Kerr and Kerr-Newman solution. Essential and coordinate singularities. Event horizon and black holes. Eddington-Finkelstein. Kruskal-Szekres coordinates. Penrose diagrams for Schwarzschild, Reissner-Nordstrom solutions.

Recommended Books:

1.Wald, R.M., Introduction to General Relativity, University of Chicago Press, Chicago,1984.

2.Adler, R., Bazine, M., and Schiffer, M., Introduction to General Relativity, McGraw- Hill Inc.,1965.

3.Rindler, W., Essential Relativity, Springer Verlag 1977.

MATH- 642 Special Relativity **Credit Hours: 3(3+0)**

Course Outline:

Historical background and fundamental concepts of Special theory of Relativity. Lorentz transformations (for motion along one axis). Length contraction, Time dilation and simultaneity. Velocity addition formulae. 3-dimensional Lorentz transformations. Introduction to 4-vector formalism. Lorentz transformations in the 4-vector formalism. The Lorentz and Poincare groups. Introduction to classical Mechanics. Minkowski spacetime and null cone. 4-velocity, 4-momentum and 4-force. Application of Special Relativity to Doppler shift and Compton effect. Particle scattering. Binding energy, particle production and decay. Electromagnetism in Relativity. Electric current. Maxwell's equations and electromagnetic waves. The 4-vector formulation of Maxwell's equations. Special Relativity with small acceleration.

Recommended Books:

1. Qadir, A. Relativity, An Introduction to the Special Theory, World Scientific, 1989.
2. D' Inverno. R., Introducing Einstein's Relativity, Oxford University Press, 1992.

3. Goldstein, H., Classical Mechanics, Addison Wesley, New York, 1962.
4. Jackson, J.D., Classical Electrodynamics, John Wiley, New York, 1962.
5. Rindler, W., Essential Relativity, Springer-Verlag, 1977.

MATH-645 Optimization Theory Credit Hours: 3(3+0)

Course Outline:

Linear programming: simplex method, duality theory, dualand primal-dual simplex methods. Unconstrained optimization: optimality conditions, one-dimensional problems, multi-dimensional problems and the method of steepest descent. Constrained optimization with equality constraints: optimality conditions, Lagrange multipliers, Hessians and bordered Hessians. Inequality constraints and the Kuhn-Tucker Theorem. The calculus of variations, the Euler-Lagrange equations, functionals depending on several variables, variational problems in parametric form, transportation models and networks.

Recommended Books:

1. Elsgolts L, *Differential Equations and the Calculus of Variations*, 1970, Mir Publishers, Moscow
2. Gotfried BS, Weisman J, *Introduction to Optimization Theory*, 1973, Prentice Hall, Englewood Cliffs, NJ, USA
3. Luenberger DG, *Introduction to Linear and Non-Linear Programming*, 1973, Addision-Wesley, Reading, Ma, USA

MATH-646 Ring Theory Credit Hours: 3(3+0)

Course Outline:

Rings and Fields, Integral domains ,ideals, Operations on ideals, quotient rings and homomorphism of rings. Isomorphism, Isomorphism theorems, Embedability of an integral domain in a field, Field of quotients, Maximal and Prime ideals and their properties, Divisibility theory in integral domains, Polynomial rings, Division Algorithm, Remainder theorem, Field extensions.

RECOMMENDED BOOKS:

1. J. B. Fraleigh, A First Course in Algebra, Addison Wesley Co., 1976.
2. I. N. Herstein, Topic in Algebra, Ginn & Co.
3. P. M. Cohn, Algebra Vol. I & II, John Wiley & Sons.
4. Burton, A First Course in Rings & Ideals, Addison Wesley Co.
5. J. Lambek, Lectures on Rings & Modules, Blaisdel.
6. T. S. Blyth, E.F. Robertson, Essential student Algebra, Vol I-V, Chapman & Hall, 1986.
7. T. W. Hungerford, Abstract Algebra: An Introduction

MATH-647 Introduction to Algebraic geometry Credit Hours: 3(3+0)

Course Outline:

Algebraic varieties: Affine algebraic varieties, Hibert basis Theorem, Decomposition of variety into irreducible components, Hibert's Nulttstellensatz, The Sectrum of a Ring, Projective variety and the homogeneous Spectrum.

Functions and Morphisms: Some properties of Zariski topology, Rings and modules of functions and their properties, Coordinate ring and polynomial functions, Polynomial maps, Regular and rational functions, Morphisms, Rational maps.

Dimension: The Krull dimension of Topological Spaces and Rings, Prime Ideal Chain and Integral Extensions, The Dimension of Affine Algebras and Affine Algebraic Varieties, The Dimension of Projective Varieties.

Applications: The product of varieties, On dimension, Tangent space and smoothness, Completeness.

Recommended Books:

1. O. Zariski and P. Samual, Commutative Algebra, Vol. 1, Van Nostrand, Princeton, N. J., 1958.
2. M.F. Atiyah and I. G. Macdonald, Introduction to Commutative Algebra, Addison Wesley Pub. Co., 1969.
3. I.R. Shafarevich, Basic Algebraic Geometry, Springer Verlag, 1974.
4. R. Hartshorne, Algebraic Geometry, Springer Verlag, 1977.
5. E, Kunz, Introduction to Commutative Algebra and Algebraic Geometry, Boston; Basel; Stuttgrat: Birkhauser, 1985.

MATH-648 Continuous Groups **Credit Hours: 3(3+0)**

Course Outline:

Continuous Groups; Gl(n,R), Gl(n,C), So(p,q), Sp(2n); generalities on continuous groups; groups of isometries, classification of two and three dimensional Euclidean space according to their isometries; introduction to Lie groups with special emphasis on matrix Lie groups; relationship of isometries and Lie group; theorem of Cartan; correspondence of continuous groups with Lie algebras; classification of groups of low dimensions; homogeneous spaces and orbit types; curvature of invariant metrics on Lie groups and homogeneous spaces.

Recommended Books:

1. Bredon, G.E., Introduction to compact transformation groups, Academic Press, 1972.
2. Eisenhart, L.P., Continuous groups of transformations, Priceton U.P., 1933.
3.Pontrjagin, L.S., Topological groups, Princeton University Press, 1939.
4.Husain Taqdir., Introduction to Topological Groups, W.B. Saunder's Company,1966.
5.Miller Willard, Jr., Symmetry groups and their application, Academic Press New York and London 1972.

MATH-649 Introduction to Combinatorics **Credit Hours: 3(3+0)**

Course Outline:

To basic counting principles, Permutations, Combinations. The injective and bijective principles, Arrangements and selections with repetitions. Graphs in Combinatorics. The Binomial theorem, combinatorial identities. Properties of binomial coefficients, Multinomial coefficients, The multinomial theorem. The Pigeonhole principle, Examples, Ramsay numbers, The principle of inclusion and exclusion, Generalization. Integer solutions. Surjective mapping, Stirling numbers of the second kind, The Sieve of Eratostheries, Euler φ-function, The Probleme des Manages. Ordinary Generating Functions, Modelling problems. Partition of integers, Exponential generating functions. Linear homogeneous recurrence relations, Algebraic solutions of linear recurrence relations and constant functions, The method of generating functions, A non-linear recurrence relation and Catalpa numbers

Recommended Books:

1. A Tucker, Applied Combinatorics, John Wiley & Sons, New York, 2nd Edition, 1985.

2. C.C. Chen and K.M.Koh, Principles and Techniques in Combinatorics, World Scientific Pub. Co. Pte. Ltd, Singapore. 1992.
3. V.K.Balakrishnan, Theory and Problems of Combunatorics, Schaum's Outline Series, MeGraw-Hill International Edition, Singapore, 1995.
4. C.L.Liu, Introduction to Combinatorial Mathematics, McGraw-Hill, New York, 1968.
5. J.H.van Ling & R.M. Wilson, A course on Combinatorics, 2nd Edition, Cambridge University Press, Cambridge, 2001.

MATH- 650 Introductions to Algebraic Systems Credit Hours: 3(3+0)

Course Outline:

An introduction to the use of abstract methods in mathematics, using algebraic systems that play an important role in many applications of mathematics.

Abelian groups, Commutative rings with identity, fields, Ideals, Polynonial rings, Principal Ideal domains, arithmetic of integers mod n and finite fields. Vector spaces over arbitrary fields, Examples of Algebra of Polynomial rings over an arbitrary field, subspaces, bass, linear transformations. Eigenvalues, eigenvectors, eigenspaces, Characteristies, Polynomial, Minimal Polynomial, Linear Transformation as a matrix operator, geometric and algebraic multiplicity and diagonalisation. Groups: subgroups, cosets, Lagrange's theorem, homomorphisms.

Applications to coding theory will be chosen from: linear codes, encoding and decoding, the dual code, the parity check matrix, syndrome decoding, Hamming codes, perfect codes, cyclic codes, BCH codes.

Recommended Books:

1. Any book labeled "Abstract Algebra" or "An Introduction to Abstract Algebra". Call numbers are AQ 162 and QA266.

2. In addition. John B Fraleigh A First Course in Abstract Algebra, 5th edition, Addison-Wesley, 1994, AQ266.F7.

MATH-652 Dynamics Credit Hours: 3(3+0)

Course Outline:

Particle Dynamics: Projectile motion under gravity, constrained particle motion, angular momentum of a particle.

Orbital Motion: Motion of a particle under a central force, use of reciprocal polar co-ordinates, use of pedal co-ordinates and equations, Kepler's laws of planetary motion. Motion of a system of Particles: Linear momentum of a system of particles, angular momentum and rate of change of angular momentum of a system, use of centroid, moving origins, impulsive forces, elastic impact. Introduction to Rigid Body Dynamics: Moments and products of inertia, the theorems of parallel and perpendicular axes, angular momentum of a rigid body about a fixed point and about fixed axes, principal axes. Kinetic energy of a rigid body rotating about a fixed point, general motion of a rigid body, momental ellipsoid, equimomental system, coplanar distribution.

RECOMMENDED BOOKS:

1. F. Chorlton, Text book of Dynamics, Ellis Horwood Ltd., 1983.
2. L. A. Pars, Introduction to Dynamics, Cambridge Uni. Press, 1953.
3. A. S. Remsey, Dynamics Part-I, Cambridge Uni. Press, 1962.
4. J. L. Synge and B. A. Griffith, Principle of Mechanics, McGraw Hill Book Co., 1970.

MATH-654 Special Functions **Credit Hours: 3(3+0)**

Course Outline:

Definition and properties of Gamma function, Beta function, Incomplete Gamma function. Digama and Polygamma function. Definition and generating function of Legendre polynomials. Recurrence relation and Legendre polynomials. Recurrence relation and Legendre differential equation. Rodrigue's formula. An Integral representation of Legendre polynomials and orthogonality. Hermite polynomials. Differential equation solvable with Bessel functions. An Integral form of Bessel function and orthogonality. The Laplace transformation and application of differential equations.

RECOMMENDED BOOKS:

1. L. C. Andrews, Special functions for Engineers and applied mathematics, McMillan Publishing Company.
2. N.W. Lebedev, Special functions and their applications, Dover Publishing Inc., 1972.
3. B. Spain, M. G. Smith, Functions of Mathematical Physics, Van Nostrand Reinhold Comp., 1970.
4. W. E.Boyee, R. C.Dipri, Elementary differential equations and boundary value problems,John Wiley and Sons, 1986.
1. E.D. Rainvill, Special Functions, McGraw Hill, 1992

MATH-656 Quantum Mechanics **Credit Hours: 3(3+0)**

Course Outline:

Inadequacy of Classical Mechanics, Wave particle duality. Schrodinger's equation, Harmonic oscillator, One dimensional motion in a potential well. Reflection by and transmission across a potential barrier, Uncertainty principle, Dirac delta function, Operator formulism in Quantum Mechanics, Angular momentum. Pauli Exclusion Principle. Hydrogen atom.

RECOMMENDED BOOKS:

1. R.L.White, Basic Quantum Mechanics, McGraw Hill Book Co. NY, 1966.
2. L.I.Schiff, Quantum Mechanics, McGraw Hill Kogakusha Ltd., 1955.
3. P.T.Mathews, Introduction to Quantum Mechanics, McGraw Hill Book Co., 1974.
4. Dicke & Wittke, Introduction to Quantum Mechanics, Addison Wesley Pub. Co. Inc., 1966.
5.

MATH-667 Geometric Function Theory **Credit Hours: 3(3+0)**

Course Outline:

Basic of Geometrics Function Theories, Similarities, Normalization of Analytical function, Biberbak Theorem, Distortion theorem, Riemann mapping theorem, conformal mappings and their properties, univalent functions and their subclasses, Functions with positive real part, Herglotz Formula, Some basic properties of univalent and multivalent functions.

RECOMMENDED BOOKS

1. Geometric function theory and non-linear analysis by Tadeusz Iwaniec, Gaven Martin.
2. Topics in geometric function theory By Carl Hanson FitzGerald.
3. A. W. Goodman, Univalent Functions, Vol I & II.

MATH- 669 Linear Dynamical System-I Credit Hours: 3(3+0)

Course Outline:

Introduction to Dynamical system, Linear and nonlinear Dynamical systems, Autonomous and nonautonomous systems. First-Order Equations: The Simplest Examples, The Logistic Population Model, Constant Harvesting and Bifurcations, Periodic Harvesting and Periodic Solutions, Computing the Poincare Map. Planar Linear Systems: Second-Order Differential Equations, Planar Systems, Preliminaries from Algebra, Eigen values and Eigenvectors, Solving Linear Systems, The Linearity Principle. Phase Portraits for Planar Systems: Real Distinct Eigen values, Complex Eigen-values, Repeated Eigenvalue, Changing Coordinates. Classification of Planar Systems: The Trace-Determinant Plane, Dynamical Classification. Higher Dimensional Linear Systems: Distinct Eigen values,Harmonic Oscillators, Repeated Eigenvalues, The Exponential of a Matrix. Nonautonomous Linear Systems.

Recommended Books:

1. Differential Equations, Dynamical Systems and Introduction to Chaos by Morris W. Hirsch, Stephen Smale and Robert L. Devaney.
2. Nonlinear Dynamics and Chaos by Steven H. Strogatz.

MATH- 670 Linear Dynamical System-II Credit Hours: 3(3+0)

Course Outlines: Part I. One-Dimensional Flows:

Chaos, Fractals, and Dynamics, Capsule History of Dynamics, The Importance of Being Nonlinear, A Dynamical View of the World. Flows on the Line: Introduction A Geometric Way of Thinking, Fixed Points and Stability, Population Growth, Linear Stability Analysis, Existence and Uniqueness, Impossibility of Oscillations, Potential. Bifurcations: Introduction, Saddle-Node Bifurcation, Transcritical Bifurcation, Laser Threshold, Pitchfork Bifurcation, Over damped Bead on a Rotating Hoop, Imperfect Bifurcations and Catastrophes, Insect Outbreak. Flows on the Circle: Introduction, Examples and De_nitions, Uniform Oscillator, Nonuniform Oscillator, Overdamped Pendulum.

Part II. Two-Dimensional Flows:

Linear Systems, Definitions and Examples, Classification of Linear Systems, A simple model of Love Affairs. Phase Plane: Phase Portraits, Existence, Uniqueness, and Topological Consequences, Fixed Points and Linearization, Rabbits versus Sheep, Conservative Systems, Reversible Systems, Pendulum.

Limit Cycles: Introduction, Examples of limit Cycles, Ruling Out Closed Orbits, Poincare-Bendixson Theorem, Lienard Systems, Relaxation Oscillators, Weakly Nonlinear Oscillators.

Recomended Books:

1. Differential Equations, Dynamical Systems and Introduction to Chaos by Morris W. Hirsch, Stephen Smale and Robert L. Devaney.
2. Nonlinear Dynamics and Chaos by Steven H. Strogatz.

External Courses for BS/ M. Sc/ MS, M. Phil

External Courses for Mathematics

S. No	Course No.	Course Title	Credit Hours
1	MATH-301	Mathematics	3(3+0)
2	MATH-401	Advanced Mathematics	3(3+0)
3	MATH-304	Business Mathematics	3(3+0)
4	MATH-303	Mathematics-I	3(3+0)
5	MATH-403	Mathematics-II	3(3+0)
6	MATH-302	Mathematical Economics I	3(3+0)
7	MATH-402	Mathematical Economics II	3(3+0)
8	MATH-404	Discrete Structure	3(3+0)
9	MATH-305	Geomathematics/Mathematical Methods of Physics	3(3+0)
10	MATH-306	Calculus and Analytical Geometry	3(3+0)
11	MATH-405	Multivariate Calculus	3(3+0)
12	MATH-406	Linear Algebra & Differential Equations	3(3+0)
13	MATH-407	Numerical Computing	3(3+0)
14	STAT-401	Probability & Statistics	3(3+0)

Course Contents for external Courses of Mathematics

MATH-301 MATHEMATICS **Credit Hours: 3(3+0)**

Course Contents

Indices and logaroithum, and their application, the principles of algebra, solution of quadratic equation, solution of two simultaneous equations, both linear, one linear one quadratic, both quadratic, basic trigonometry definition, Trignometric ratios of general angle, Trignometric identities, Multiple angle and half angle formula, Sum and difference formula, Graph of trignometric functions, Inverse trignometric functions, Coordinate geometry, Coordinates, Change of coordinates, Graph-Log and exponential, The straight line, distance between two points, Circle, Parabola, Differential calculus, Limits, Definition and properties of limits, Continuity, Derivatives, Rules for differentiation (algebric, logarithmic, exponential, and inverse functions), Integration, Introduction, Integration of algebric, trignometric, exponential functions, and their combinations, Integration by substitution, Integration by parts, Differential equations, Definition and classification of differential equations of Ist order and Ist degree, Solution of ordinary differential equations and of second order equations with constant coefficients

BOOKS RECOMMENDED

1. Basic Concepts of Mathematics, by Elias Zakon, ISBN 1-931705-00-3, published by The Trillia Group, 2001.
2. New Mathematics and Applied Mathematics Books July - August 2000 HG6024.A3.W554 1995 - Wilmott, Paul. Mathematics of financial derivatives: a student introduction. Cambridge University Press, Oxford; New York S-BKS. Elementary Statistics, Ninth Edition by Mario.F 1995.
3. Mathematics by S. M. Yousaf.
4. Statistics by Bhattey

MATH- 401 ADVANCED MATHEMATICS Credit Hours: 3(3+0)

Course Contents

Permutations and Combinations, Permutations and Combinations Further Trigonometric Identities, Binomial Theorem, Differentiation, Rates of Change, Stationary Points, Derivatives of Trigonometric Functions, Derivatives of Exponential and Logarithmic Functions, Integration and Applications of Integration

Recommended Books

1. Advanced Mathematics for Engineering and Science By C F Chan Man Fong (Tulane University, USA) By D. De Kee (Tulane University, USA), By P N Kaloni

MATH-304 BUSINESS MATHEMATICS Credit Hours: 3(3+0)

Objectives of course:

This course is built upon the mathematical concepts, principles and techniques that are useful in business management. The main objectives of the course are to enhance students‟ competency in application of mathematical concepts in solving business management problems and to improve their level of quantitative approach.

Course Contents

Linear Equation involving one variable, Solution of Quadratic Equations, Applications of quadratic equation, Characteristics of Linear Equations Graphical Characteristics ,Writing of the Linear Equation ,Slope - Intercept Form ,Slope and Point formula, Two point formula ,Determining the Equation of a Straight Line Linear Equations involving more than two variables ,Introduction Two variables Systems of Equations. Elimination method ,Three variable system of Equations ,Elimination method ,Applications of Linear Equations and Systems of Equations ,Two variables Systems of Equations. Gauss – Jordan Elimination method, Three variable system of equations ,Gauss-Jordan Elimination method ,Applications of Linear Equations and Systems of Equations Two variables Systems of Equations. Gauss – Jordan Inversion method , Singularity ,Special Determinants ,Solution of Linear Equations by Determinants Charamer‟s Rule , Solution of Linear Equations by Determinants , Inverse Matrices Method

RECOMMENDED/REFERENCE BOOKS

1. Cheryl Cleaves, Business Maths, Pearson (Latest Edition)
2. Burton, Shelton, Business Maths using Excel, South-Western Cengage Learning
3. Budnick, Mathematics for Business Economics and Social Science

MATH-303 MATHEMATICS-I Credit Hours: 3(3+0)

Objectives:

This is the first course of the basic sequence, Calculus I-III, serving asthe foundation of advanced subjects in all areas of mathematics. The sequence, equally, emphasizes basic concepts and skills needed for mathematical manipulation. Calculus I & II focus on the study of functions of a single variable.

Course Detail:

- Limits and continuity.
- Derivative of a function and its applications.
- Optimization problems.
- Mean value theorem (Taylor’s theorem and the infinite Taylor series with applications) & curve sketching; anti-derivative &integral.

- Definite integral and applications.
- The fundamental theorem of Calculus.37
- Inverse functions (Chapters 1-6 of the text)

RECOMMENDED BOOKS:

1. Anton H, *Calculus: A New Horizon* (6th edition), 1999. John Wiley, New York.
2. Stewart J, *Calculus* (3rd edition), 1995, Brooks/Cole (suggested text)
3. Thomas G. B, Finney A. R., *Calculus* (10th edition), 2002.Addison-Wesley, Reading, Ma, U.S.A.
4. Anton, H., 1999. *Calculus: A New Horizon*, 6th Edition, John Wiley, New York.
5. Stewart J, 1995. *Calculus, 3rd* Edition, Brooks/Cole
6. Thomas, G. B. and Finney, A. R, 2002. *Calculus*

MATH-403 MATHEMATICS-II Credit Hours: 3(3+0)

Specific Objectives of the Course: To prepare the students, not majoring in mathematics, with the essential tools of calculus to apply the concepts and the techniques in their respective disciplines.

Course Outline:

Preliminaries: Real-number line, functions and their graphs, solution of equations involving absolute values, inequalities. Limits and Continuity: Limit of a function, left-hand and right-hand limits, continuity, continuous functions.

Derivatives and their Applications: Differentiable functions, differentiation of polynomial, rational and transcendental functions, derivatives.

Integration and Definite Integrals: Techniques of evaluating indefinite integrals, integration by substitution, integration by parts, change of variables in indefinite integrals.

Recommended Books:

- Anton H, Bevens I, Davis S, *Calculus: A New Horizon* (8^{th} edition), 2005, John Wiley, New York
- Stewart J, *Calculus* (3^{rd} edition), 1995, Brooks/Cole (suggested text) Swokowski EW, *Calculus and Analytic Geometry*, 1983, PWS-Kent Company, Boston
- Thomas GB, Finney AR, *Calculus* (11^{th} edition), 2005, Addison-Wesley, Reading, Ma, USA

MATH-302 MATHEMATICAL ECONOMICS I Credit Hours: 3(3+0)

Objectives

The course is designed to enable the students use mathematical tools in clarifying their economic concepts and solving problems. This is because economic analysis requires extensive use of mathematics in the present day world of complexity. Mere logical reasoning and diagrammatic approach is perhaps not sufficient. This is true for positive economics in particular. As such, the students of economics have to learn and apply mathematics along side their theoretical underpinnings.

Homework: The students may be given assignments and exercises from the texts and weekly or fortnight class tests including MCQ's and confronted to extensive practice.

Course Contents

The Nature of Mathematical Economics

Pure and applied mathematics, The use of mathematical tools in social sciences, particularly in economics, Economic theory (logical argument) as description of some kind of relationship between variables, Mathematical Support: Expression of theory in functional form, Explaining properties of economic parameters like elasticity, propensity to consume etc., Verification of hypotheses and the use of mathematical models, Parameters and variables (dependent and independent), Linear and non-linear functions: quadratic, polynomial, circular, Types of functions: constant, rational, non-algebraic, logarithms & exponential, Rules of logarithms and exponents, Functions of more than two
independent variables, Graphs of various functions, The importance and limitations of mathematical models.

Equilibrium Analysis

Equation of a straight line: Intercept and Slope parameters and their economic interpretation, Partial and general equilibrium analysis, Single and Simultaneous equation models, Examples from market models: Demand and supply equations, Determination of price and quantity, Calculation of elasticities at equilibrium, The effect of an excise tax on market equilibrium, National Income determination: Closed economy with goods and money markets.

Linear Models and Matrix Algebra

Simultaneous equations models and the use of matrices, Types of matrices: Square, identity, null, idempotent, diagonal, transpose and their properties, Laws of matrix operations: addition/subtraction, scalar and vector multiplication, Conditions for non singularity of a matrix, Determinant & its properties, Minors and cofactors, Ad-joint and inverse of a matrix, Properties of inverse of a matrix, Solution of linear equations: the Gaussian method, the Cramer's rule and Inverse matrix method, Economic applications: Solution of market models, national income models, and the normal equations of the Least-Squares econometric model via matrix approach.

Differentiation

The concept of derivations, Functions of one variable and rules of differentiation: Sum-difference, product and quotient rules, chain rule, power function rule, inverse function rule, Implicit functions rule, Combinations of rules, differentiation of logarithmic & exponential functions, Higher order derivatives, Concept of maxima & minima, First and second derivative tests, point of inflection, Free and Constrained optimization, Partial differentiation & its rules, Hessian and Jacobian determinants, Higher order & cross partial derivatives (Young's theorem), Total differentials & total derivatives, Optimizing cubic functions.

Economic Applications of Differential Calculus

Analysis of Utility, Demand, Production, Cost and Supply functions, Lagrange function: Profit maximization and cost minimization under perfect competition and monopoly, Maximizing excise tax revenue in monopolistic competitive market, Comparative static analysis: Partial equilibrium market model, National Income model, Partial and Substitution elasticities, Optimization of unconstrained functions and their economic applications, Profit maximization by a multi-product and multi-plant firms, Price discrimination and monopoly, Optimization by using
Cobb- Douglas, CES and Translog functions with interpretation of the results.

Linear Programming

Ingredients of linear Programming, Graphical approach, Simplex method, Economic application of linear programming, Concept of primal & dual, Duality theorems, Solving of

Primal via dual, Economic interpretation of a dual.

Recommended Books

- Chiang, A. C. - Fundamental Methods of Mathematical Economics – 3rd Edition (1984) - McGraw Hill Publishing Company.
- Frank, Budnick - Applied Mathematics for Business, Economics and Social Sciences- 4th Edition (1993) or latest – McGraw Hill Publishing Company.
- Dowling E. T.- Mathematics for Economists, Schaum's Outline Series- 3rd Edition
- (2001) – McGraw Hill Publishing Company.
- George, Alvery et al – Essentials of Mathematics with Business Applications-
- 5th Edition (1995) - McGraw Hill Publishing Company.
- Weber E. Jean - Mathematical Analysis: Business and Economic Applications- (Latest Edition) -Harper and Row Publishers, New York.
- Colin, Glass – An Introduction to Mathematical Methods in Economics- (Latest Edition) - McGraw Hill Publishing Company.

MATH-402 MATHEMATICAL ECONOMICS II Credit Hours: 3(3+0)

Objectives

Objectives: The course is designed for senior undergraduates more interested in quantitative economics. The objective is to confront the students to advanced mathematical techniques so as to enable them handle economic models, interpret the results and solve complex problems. The students may be given assignments and exercises from the texts and weekly or fortnight class tests and quizzes including MCQ's.

Course Contents

Complex Number and Circular Functions

Imaginary and Complex Numbers, Complex Roots, Circular Functions, Properties of Sine & Cosine functions, Eular and Maclaurin series, Alternative representation of Complex Numbers.

Integral Calculus

Comparative Dynamics and Integration, The Nature of Indefinite Integrals, Rules of Integrations and Operation: Substitution Rule, Integration by parts. Definite integrals and their properties, Definite Integrals and Area under a curve, Improper integrals, Economic Applications of Integrals: Finding total functions from marginal functions, Investment & capital formation, Present value of cash flow, P.V. of a Perpetual Flow, The Domar growth model.

Differential Equations

(i) First Order Linear Differential Equations

Meaning and Definition; Homogenous & non-Homogenous cases, Solution of first order linear differential equations: with constant coefficient & constant term, with variable coefficient and variable terms, Qualitative approach: Concept of phase diagrams, types of time paths and the dynamic stability of equilibrium, Exact differential equations: Solution and Verification, Non-linear differential equations of the first order and first degree, Bernoulli Equation,

Separable Variables, Economic Application: Dynamics of market models, Solow growth model.

(ii) Higher Order Differential Equations

Solution and Verification of second order linear differential equations with constant coefficients and constant terms, Real and imaginary roots, Distinct, repeated roots and complex roots, Dynamic stability of equilibrium, Economic applications: Market models with price expectations, The Interaction of inflation and unemployment in continuous time, Higher order differential equations, Convergence and the Routh theorem, Solution of simultaneous difference equations.

Difference Equations

(i) First Order Difference Equations

Meaning and definition, First order linear difference equations: Solution and verification of results, Conditions for dynamic stability of equilibrium, Types of time paths, Economic applications: The Cobweb model, Market model with inventory, Model with price ceiling, Nonlinear difference equations, The qualitative/graphic approach and phase diagrams.

(ii) Higher Order Difference Equations

Solution and verification of second-order linear difference equations with constant coefficients and constant terms, Real and imaginary roots, Distinct, repeated and complex roots, The convergence and divergence of the time paths. Economic applications: Models of business cycles, The Multiplier-Acceleration interaction model, inflation-unemployment model in discrete time, Higher order difference equations and their solutions, Convergence and the Schur's theorem, Solution of simultaneous difference equations.

Non-Linear Programming

The nature of non-linear programming, Non-linearities in Economics, Kuhn-Tucker conditions and their interpretation, The Kuhn-Tucker Sufficiency theorem: Concave programming, The Arrow-Enthoven Sufficiency theorem: Quasi-concave programming, Economic applications: Utility maximization, Least-cost combination,

Recommended Books

- Chiang A.C and Kevin Wainwright - Fundamental Methods of Mathematical Economics- 4th Edition (2005) McGraw Hill Publishing Company.
- Gandalfo, G – Economic Dynamics: Methods and Models – (1983 or Latest Edition)
- North Holland Publishing Company
- Dowling Edward T. -Mathematics for Economics: Schaum Series – (1981).
- Weber E. Jean, Mathematical Analysis, Business and Economic Application (latest edition), Harper and Row Publishers, Netherlands.
- Hoy M., Livermois J, Rees R, Stengos T. - Mathematic for Economics – (1996) - Addison & Wesley Publishers.
- Shone, R – Economic Dynamics: Phase Diagrams and their Economic Applications- (1997)- Cambridge University Press.

MATH-404 Discrete Structures **Credit Hours: 3(3+0)**

Objectives: Introduces the foundations of discrete mathematics as they apply to Computer Science, focusing on providing a solid theoretical foundation for further work. Further, this course aims to develop understanding and appreciation of the finite nature inherent in most Computer Science problems and structures through study of combinatorial reasoning, abstract algebra, iterative procedures, predicate calculus, tree and graph structures. In this course more emphasis shall be given to statistical and probabilistic formulation with respect to computing aspects.

Course Outline: Introduction to logic and proofs: Direct proofs; proof by contradiction, Sets, Combinatorics, Sequences, Formal logic, Prepositional and predicate calculus, Methods of Proof, Mathematical Induction and Recursion, loop invariants, Relations and functions, Pigeonwhole principle, Trees and Graphs, Elementary number theory, Optimization and matching. Fundamental structures: Functions; relations (more specifically recursions); pigeonhole principle; cardinality and countability, probabilistic methods.

Reference Material:

1. Kenneth H. Rosen, Discrete Mathematics and Its Applications, 6TH edition, 2006, Mcgraw Hill Book Co.
2. Richard Johnsonbaugh, Discrete Mathematics, 7TH edition, 2008, Prentice Hall Publishers.
3. Kolman, Busby & Ross, Discrete Mathematical Structures, 4th edition, 2000, Prentice-Hall Publishers.
4. Ralph P. Grimaldi, Discrete and Combinatorial Mathematics: An Applied Introduction, Addison-Wesley Pub. Co., 1985.

MATH-305 Geomathematics/Mathematical Methods of Physics

Credit Hours: 3(3+0)

Course Outline

Vector and Tensor analysis, Curvilinear Coordinates and multiple integrals, Fourier and Lap lace transforms, Matrices and Eigenvalue problems, complex variable and their applications, Legendre Polynomials and Bessel functions, solution of Lap lace equation in various coordinates boundary values.

Recommended Books:

1. Bourne DE, Kendall PC, *Vector Analysis and Cartesian Tensors* (2nd edition),
2. Thomas Nelson
3. Shah NA, *Vector and Tensor Analysis*, 2005, A-One Publishers, Lahore
4. Smith GD, *Vector Analysis*, Oxford University Press, Oxford
5. Spiegel MR, *Vector Analysis*, 1974, McGraw Hill, New York

MATH-306 Calculus and Analytical Geometry **Credit Hours: 3(3+0)**

Objectives: To provide foundation and basic ground for calculus and analytical geometry background.

Course Outline: Complex Numbers, DeMoivre's Theorem and its Applications, Simple Cartesian Curves, Functions and Graphs, Symmetrical Properties, Curve Tracing, Limit and Continuity, Differentiation of Functions. Derivative as Slope of Tangent to a Curve and as Rate of Change, Application to Tangent and Normal, Linearization, Maxima/Minima and

Point of Inflexion, Taylor and Maclaurin Expansions and their convergence. Integral as Anti-derivative, Indefinite Integration of Simple Functions. Methods of Integration: Integration by Substitution, by Parts, and by Partial Fractions, Definite Integral as Limit of a Sum, Application to Area, Arc Length, Volume and Surface of Revolution.

Recommended Books:

1. Swokowski, Olinick and Pence, Calculus and Analytical Geometry, 6th edition, 1994, Brooks/Cole Publishers.
2. Howard Anton, Calculus, 7th edition. 2002, John Wiley and Sons (WIE).
3. William E. Boyce Richard C. Diprima, Calculus, John Wiley & Sons, ISBN: 0471093335.
4. Thomas Finny, Calculus and Analytical Geometry, 10th edition, John Wiley and Sons.
5. Erwin Kreyzig, Advanced Engineering Mathematics, 7th edition, 1993, John Wiley & Sons Inc.

MATH-405 Multivariable Calculus Credit Hours: 3(3+0)

Objectives: The goals are to develop the skills to have ground knowledge of multivariate calculus and appreciation for their further computer science courses.

Course Outline: Functions of Several Variables and Partial Differentiation. Multiple Integrals, Line and Surface Integrals. Green's and Stoke's Theorem. Fourier Series: periodic functions, Functions of any period P-2L, Even & odd functions, Half Range expansions, Fourier Transform. Laplace Transform, Z-Transform.

Recommended Books:

1. James Stewart, Multivariable Calculus, 6th edition, 2007, Cengage Learning publishers.
2. Swokowski, Olinick and Pence, Calculus and Analytical Geometry, 6th edition, 1994, Thomson Learning EMEA, Ltd.
3. Bernard Kolman, William F. Trench, Elementary Multivariable Calculus, 1971, Academic Press.
4. Howard Anton, Albert Herr, Multivariable Calculus, 5th edition, 1995, John Wiley

MATH-406 Linear Algebra & Differential Equations Credit Hours: 3(3+0)

Objectives: To provide fundamentals of solution for system of linear equations, operations on system of equations, matrix properties, solutions and study of their properties.

Course Outline: Vectors, Vector Spaces, Matrices & Determinants, Cofactor and Inverse, Rank, Linear Independence, Solution of system of linear systems, Positive Definite matrix, Linear Transformations, Operations on matrices, Inner products, orthogonality and least squares, Eigenvalue & Eigenvectors. Applications to Systems of Equations and to Geometry, Singular Value Decomposition.

Recommended Books:

1. Bernard Kolman, David Hill, Elementary Linear Algebra with Applications, 9th edition, Prentice Hall PTR, 2007.
2. Gilbert Strang, Strang, Brett Coonley, Andy Bulman-Fleming, Andrew Bulman-Fleming, Strang's Linear Algebra And Its Applications, 4th edition, Brooks/Cole, 2005

3. Howard Anton, Chris Rorres, Elementary Linear Algebra: Applications Version, 9th edition, Wiley, 2005.
4. David C. Lay, Linear Algebra and Its Applications, 2nd edition, Addison-Wesley, 2000.

MATH-407 Numerical Computing Credit Hours: 3(3+0)

Objectives: On completion of this unit, students will be able to demonstrate programming proficiency using structured programming techniques to implement numerical methods for solutions using computer-based programming techniques .using Matlab for all methods. The course must serve the purpose of scientific software development for science and engineering problems.

Course Outline: The concepts of efficiency, reliability and accuracy of a method. Minimising computational errors. Theory of Differences, Difference Operators, Difference Tables, Forward Differences, Backward Differences and Central Differences. Mathematical Preliminaries, Solution of Equations in one variable, Interpolation and Polynomial Approximation, Numerical Differentiation and Numerical Integration, Initial Value Problems for Ordinary Differential Equations, Direct Methods for Solving Linear Systems, Iterative Techniques in Matrix Algebra, Solution of non-linear equations.

Recommended Books:

1. Numerical Methods in Scientific Computing Germund Dahlquist and Åke Björck .
2. Numerical Methods for Scientific Computing : J.H. Heinbockel
3. Numerical Analysis: I.A. Khubaza
4. Numerical Analysis and Programming : Shan S Kuo
5. Numerical Analysis by Berden Fairs
6. Numerical Analysis by Gerald

STAT- 401 Probability and Statistics Credit Hours: 3(3+0)

Objective: The subject of statistics is very important in many areas including computer science. The main objective of this course is that a student should know the basics of statistics and he/she should be able to do statistical analysis independently in his/her research work.

Course Outlines:

Basic Univariate Statistical Methods:

Review of basic concepts, summary measures, introduction to hypothesis testing, t-test for one and two samples, Analysis of Variance (ANOVA), Chi-squared test for count data, Regression and Correlation

Multivariate Statistical Methods:

Introduction to Multivariate Analysis, Principal Component Analysis (PCA), Factor Analysis (FA), Discriminant Analysis (DA), Cluster Analysis (CA), Multidimensional Scaling (MDS).

Special topics (with applications in Corpus Linguistics):

Hidden Markov Models (HMM), Log-linear models, Bayesian Statistics

All the techniques would be learned through a computer-integrated approach. The analysis would be carried out by using SPSS and/or Minitab (or any other special-purpose statistical software).

Recommended Books:

1. Oakes, M.P. (1998, 2005). Statistics for Corpus Linguistics. Edinburgh Textbooks in Empirical Linguistics. Edinburgh University Press, Edinburgh.Walpole, R.E. (1982).
2. Introduction to Statistics. 3rd Edition, Macmillan Publishing Co. Inc., New York. Johnson, R.A., Wichern, D.W. (2002).
3. Applied Multivariate Statistical Analysis. 5th Edition, Prentice Hall, New Jersey.