WORKING PAPER

2ND MEETING

OF

THE BOARD OF STUDIES OF MATHEMATICS

August 9, 2018

Department of Mathematics

Shaheed Benazir Bhutto University Sheringal,

Dir Upper, Khyper Pakhtunkhwa

Pakistan

2018

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Annexure A

Item One: Bachelor of Science in Mathematics

Degree Awarded: BS Mathematics

Entrance Requirements: HSSC with Mathematics or equivalent with at least 45% marks

Duration of the Program: 4 years (8 Semesters)

Maximum duration allowed-six academic years

Total Credit Hours: 136
Total Marks: 4500

Marks Breakdown for Courses

Item	Maximum Marks for Courses (without Laboratory)	Maximum Marks for Courses with Laboratory (2 + 1)
Mid-Term Examination	30%	15%
Internal Marks (Assignments, Quizzes, Presentations)	20%	20%
Laboratory	----	15%
Semester Examination	50%	50%
Total	100%	100%

The BS Scheme of Studies: Main Structure

S. No.	Categories	Number of Courses	Credit Hours
1	Compulsory Requirements	09	25
2	General Courses	08	24
3	Discipline Specific Foundation Courses	10	33
4	Major Courses including Research Project	13+Project	42
5	Elective Courses within the Major	04	12
Total		**44+Project**	**136**

The BS Mathematics Scheme of Studies: Layout/ Framework

Compulsory Requirements		**General Courses**	
9 courses		**8 courses**	
25 Credit hours		**24 Credit hours**	
Title	**Credit hours**	**Title**	**Credit hours**
1. Islamic Studies	**2**	**1.** Physics-I	**3**
2. Pakistan Studies	**2**	**2.** Physics-II	**3**
3. Functional English	**3**	**3.** Physics-III	**3**
4. Communication Skills	**3**	**4.** Physics-IV	**3**
5. Technical Writing and Presentation Skills	**3**	**5.** Economics	**3**
6. Introduction to Computers	**3**	**6.** Statistics	**3**
7. Elements of Set theory and Mathematical Logic	**3**	**7.** Accounting	**3**
8. Software Packages	**3**	**8.** Computer Programming	**3**
9. Discrete Mathematics	**3**		
Total	**25**	**Total**	**24**

Disciplines Specific Foundation Courses		Major Courses including Research Project		Electives Courses + Project	
10 Courses		**13 Courses**		**04 Courses**	
33 Credit hours		**42 Credit hours**		**12 Credit hours**	
Title	**Credit hours**	**Title**	**Credit hours**	**Title**	**Credit hours**
1. Calculus-I	**4**	**1.** Number Theory	**3**	**1.** Elective-I	**3**
2. Calculus-II	**3**	**2.** Real Analysis-I	**3**	**2.** Elective-II	**3**
3. Calculus-III	**4**	**3.** Real Analysis-II	**3**	**3.** Elective-III	**3**
4. Algebra-I	**3**	**4.** Mathematical Methods	**3**	**4.** Elective-IV	**3**
5. Algebra-II	**3**	**5.** Topology	**3**		
6. Linear Algebra	**3**	**6.** Differential Geometry	**3**		
7. Complex Analysis	**3**	**7.** Classical Mechanics	**3**		
8. Ordinary Differential Equations	**3**	**8.** Partial Differential Equations	**3**		
9. Integral Equations	**3**	**9.** Functional Analysis	**3**		
10. Affine and Euclidean Geometry	**3**	**10.** Numerical Analysis	**4**		
		11. Probability Theory	**3**		
		12. General Topology	**3**		
		13. Vector and Tensor Analysis	**3**		
		14. Project	**3**		
Total	**32**	**Total**	**43**	**Total**	**12**

SECHEME OF STUDIES

(Semester-Wise Breakdown)

1st Semester

S. No.	Course Code	Course Title	Marks	Credit Hours
1	PS-311	Pakistan Studies	50	2(2-0)
2	ENG-312	Functional English	100	3(3-0)
3	MGC-313	Physics-I	100	3(3-0)
4	BCS-314	Introduction to Computers	100	3(3-0)
5	MCC-315	Discreet Mathematics	100	3(3-0)
6	MCC-316	Elements of Set Theory and Mathematical Logic	100	3(3-0)
Total			**550**	**17**

2nd Semester

S. No.	Course Code	Course Title	Marks	Credit Hours
7	ISL-321	Islamic Studies/Ethics	50	2(2-0)
8	BCS-322	Software Packages	100	3(2-1)
9	MGC-323	Physics-II	100	3(3-0)
10	MGC-324	Statistics	100	3(3-0)
11	MFC-325	Calculus-I	100	4(4-0)
12	ENG-326	Communication Skills	100	3(3-0)
Total			**550**	**18**

3rd Semester

S. No.	Course Code	Course Title	Marks	Credit Hours
13	ENG-431	Technical Writing and Presentations Skills	100	3(3-0)
14	BCS-432	Computer Programming	100	3(2-1)
15	MFC-433	Algebra-I	100	3(3-0)
17	MGC-434	Physics-III	100	3(3-0)
18	MFC-435	Calculus-II	100	3(3-0)
Total			**600**	**15**

4th Semester

S. No.	Course Code	Course Title	Marks	Credit Hours
19	MFC-441	Affine Euclidean Geometry	100	3(3-0)
20	MGC-442	Accounting	100	3(3-0)
21	MGC-443	Physics-IV	100	3(3-0)
22	MFC-444	Linear Algebra	100	3(3-0)
23	MFC-445	Calculus-III	100	4(4-0)
24	MGC-446	Economics	100	3(3-0)
Total			**600**	**19**

5^{th} Semester

S. No.	Course Code	Course Title	Marks	Credit Hours
25	MFC-551	Algebra-II (Rings and Fields)	100	3(3-0)
26	MMC-552	Real Analysis-I	100	3(3-0)
27	MFC-553	Ordinary Differential Equations	100	3(3-0)
28	MMC-554	Vector and Tensor Analysis	100	3(3-0)
29	MMC-555	Differential Geometry	100	3(3-0)
30	MMC-556	Topology	100	3(3-0)
Total			**600**	**18**

6^{th} Semester

S. No.	Course Code	Course Title	Marks	Credit Hours
31	MMC-561	Number Theory	100	3(3-0)
32	MMC-562	General Topology	100	3(3-0)
33	MFC-563	Complex Analysis	100	3(3-0)
34	MMC-564	Classical Mechanics	100	3(3-0)
35	MMC-565	Partial Differential Equations	100	3(3-0)
36	MMC-566	Real Analysis-II	100	3(3-0)
Total			**600**	**18**

7^{th} Semester

S. No.	Course Code	Course Title	Marks	Credit Hours
37	MMC-671	Functional Analysis	100	3(3-0)
38	MMC-672	Numerical Analysis	100	4(3+1)
39	MMC-673	Mathematical Methods	100	3(3-0)
40	----	Elective-I	100	3(3-0)
41	----	Elective-II	100	3(3-0)
Total			**500**	**16**

8^{th} Semester

S. No.	Course Code	Course Title	Marks	Credit Hours
42	MMC-681	Probability Theory	100	3(3-0)
43	MFC-682	Integral Equation	100	3(3-0)
44	----	Elective-III	100	3(3-0)
45	----	Elective-IV	100	3(3-0)
46	----	Project	100	3(3-0)
Total			**500**	**15**

NOTE:
MCC means Mathematics Compulsory Course
MGC means Mathematics General Course
MFC means Mathematics Foundation Course
MMC means Mathematics Major Course
MEC means Mathematics Elective Course

ELECTIVE COURSES

S. No	Course Code	Course Name	Credit hours
1	MEC-674	Mathematical Modeling	03
2	MEC-675	Advanced Group Theory	03
3	MEC-676	Optimization Theory	03
4	MEC-677	Measure Theory	03
5	MEC-678	Fluid Mechanics	03
6	MEC-679	Stochastic Processes	03
7	MEC-683	Quantum Mechanics	03
8	MEC-684	Heat and Mass Transfer	03
9	MEC-685	Advanced Number Theory	03
10	MEC-686	Analytical Dynamics	03
11	MEC-687	Difference Equations	03
12	MEC-688	Convex Analysis	03
13	MEC-689	Econometrics	03

COURSE CONTENTS

1st SEMESTER

PS-311 Pakistan Studies
Prerequisite: None
Credit Hours: 2+0
Specific Objectives of the Course:
To develop the 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 Outline:
Pakistan Studies; An Introduction, Ideology of Pakistan; Meaning, Evolution and importance of the Ideology of Pakistan, Reformation Movements and Educational Institutions; Shah Wali Ullah and his Successors, Sir Syed Ahmad Khan and the Aligarh Movement, Dar-ul-Ulam of Deoband, Nadwat-Ul-Ulama, Lucknow, Islamia College Peshawar, Freedom/ Pakistan Movement; Partition of Bengal, Foundation of All India Muslim League (1906), Separate Electorates, Minto-Morley Reforms (1909), Lucknow Pact (1916), Government of India Act (1919), Delhi Proposals (1927), Simon Commission (1927), Nehru Report (1928), Jinnah's Fourteen Points, Allama Muhammad Iqbal and his Allahabad Address (1930), Round Table Conferences (1930-1932), Government of India Act (1935), The General Elections of 1937 and the Congress Ministries, The Lahore Resolution (1940), The Cripps Mission (1942), The General Elections of 1946 and the Transfer of Power, The Cabinet Mission Plan (1946), The Third June Plan and the establishment of Pakistan, Constitutional History of Pakistan; Early Constitution Making Problems, The Objective Resolution (1949), Initials Steps taken for the introduction of Shariah in Pakistan, Geography of Pakistan; Geographical locations of Pakistan; Its importance, Natural Resources of Pakistan, Pakistan and International Community; Foreign Policy of Pakistan, Pakistan and the Muslim World, Kashmir Problem.
Recommended Books:

- S. J. Burki, *State and Society in Pakistan*, The Macmillan Press Ltd, 1980
- Akbar S. Zaidi, *Issue in Pakistan's Economy*, Oxford University Press, 2000
- M. Safdar, *Pakistan Kayyun Toota*, Idara-e-Saqafat-e-Islamia, Club Road, Lahore
- A. Tahir, *Ethno-National Movement in Pakistan*, Institute of Policy Studies, Islamabad
- K. B. Sayeed, *The Political System of Pakistan*, Houghton Mifflin, Boston, 1967
- L. Ziring, *Enigma of Political Development*, WmDawson and Sons Ltd, England, 1980
- Noor-Ul-Haq, *Making of Pakistan, The Military Perspective*, National Commission on Historical and Cultural Research, 1993
- S. M. Burke and L. Ziring, *Pakistan Foerign Policy: An Historical analysis,* Oxford University Press, 1993

ENG-312 Functional English
Prerequisite(s): None
Credit Hours: 3 + 0
Specific Objectives of the Course:
The course aims at enhancing the language skills and developing critical thinking of the students.
Course Outline:
Basics of Grammar, parts of speech and use of articles, sentence structure, active and passive voice, direct and indirect narrations, practice in unified sentence, analysis of phrase, clause, and sentence structure, transitive and intransitive verbs, the use of punctuation marks on and spellings, Comprehension (answering questions on a given text), Discussion (about General and academic topics), Listening (To be improved by showing documentaries/films carefully selected by subject teachers, Translational skills (Urdu to English).
Recommended Books:

- A. J. Thomson and A.V. Martinet, *Practical English Grammar*, 3rd edition, Oxford University Press, 1997
- P. C. Wren and Martin, *English Grammar and Composition*
- M. C. Boutin, S. Brinand, F. Grellet, *Writing: Intermediate, Oxford Supplementary Skills*
- B. Tomlinson, R. Ellis, *Reading: Upper Intermediate*, *Oxford Supplementary Skills*

MGC-313 Physics-I
Prerequisite(s): None
Credit Hours: 3 + 0
Course Outline:
Harmonic Oscillations: Simple harmonic motion (SHM), Obtaining and solving the basic equations of motions, Longitudinal and transverse Oscillations, Energy consideration in SHM. Applications of SHM, Torsional oscillator, Physical Pendulum, Simple Pendulum, SHM and uniform circular motion, Combination of harmonic motions, Lissajous patterns, Damped harmonic motion, Equation of Damped Harmonic motion, Quality factor, discussion of its solution, Forced oscillations and Resonances, Equation of forced oscillation, discussion of its solution, Natural frequency, Resonance, Examples of resonance, Waves in physical Media: Mechanical waves, traveling waves, phase velocity of traveling waves, Sinusoidal waves, Group speed and dispersion, Waves speed, Mechanical analysis, Wave equation, Discussion of solution, Power and intensity in wave motion, Derivation & discussion, Principle of Superposition(basic ideas), Interference of Waves, Standing Waves, Interference: Coherence of sources, Double slit Interference, Analytical treatment, Adding of electromagnetic waves using phasors, Interference from thin films, Newton's ring(analytical treatment), Diffraction: Diffraction at single slit, intensity in single slit diffraction using phasor treatment and analytical treatment using addition of waves, Double slit Interference & diffraction combined, Diffraction at a circular aperture, Diffraction from multiple slits, Discussion to include width of the maxima, Polarization: Basic definition, Production of Polarization by polarizing sheets, by reflection, by double refraction and double scattering, Description of polarization states, Linear, Circular, elliptical Polarization.
Recommended Book:

- Halliday, D. Resnick, Krane, *Physics*, Vol. I & II, John Wiley, 5th edition, 1999
- Halliday, D. Resnick, Krane, and Walker, *Fundamental of Physics*, Extended ed. John Wiley, 5th edition
- Ritz and Milford, *Introduction to Electromagnetic Field and Waves*

BCS-314 Introduction to Computer
Prerequisite(s): None
Credit Hours: 2 + 1
Specific Objectives of the Course:
This course focuses on a breadth-first coverage of computer science discipline, introducing computing environments, general applications, basic computing hardware and software, operating systems, desktop publishing, Internet, software applications, tools and computer usage concepts. The main objective of this course is to enable the students to practically use computer for learning and apply their computing skills in the field of mathematics.
Course Outline:
Brief history of computers, major hardware components of a computer, software and its types, operating system, computer security threats and solutions, general applications of computers, network, Internet and its applications, search engines and effective searching, Office automation tools; Word processing, Graphic packages, Databases and Spreadsheets, Current trends, research and future prospects, Number Systems, Binary numbers, Boolean logic, Algorithms, programming, and software development cycle for non-technical users, Social and legal issues.
Recommended Books:

- B. Williams, S. Sawyer, *Using Information Technology*
- L. Long and N. Long, Computers: *Information Technology in Perspective,* 12/e:
- Sherer, Computer Science: *An Overview of Computer Science*
- A. S. Ali, A Nudrat, *Fundamentals Concepts of Computer System*, Aays Desktop Publishing

MCC-315 Discrete Mathematics
Pre-requisite(s): Mathematics at intermediate level
Credit Hours: 3+0
Specific Objectives of the Course:
This course shall assume background in number theory. It lays a strong emphasis on understanding and utilizing various strategies for composing mathematical proof.
Course outline: Basic methods: product, inclusion-exclusion formulae. Permutations and combinations. Recurrence relations and their solutions. Generating functions. Double counting and applications. Pigeonhole principle and applications. Binary relations, n-ary Relations. Closures of relations. Composition of relations, inverse relation. 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. Boolean algebra: Introduction to gates and its types, combinatorial circuit of graphs, Boolean expression, Boolean function and its representation. Graph theory: order and types. Matrix representation of a graph, Graph isomorphism.
Recommended Books:

- S. E. Susana, Discrete Mathematics with applications
- D. P. Acharjya, Sreckummar, Discrete Mathematics
- K. H. Rossen, Discrete Mathematics and its applications
- J. Gersting, Mathematical Structures for Computer Sciences

MCC-316 Elements of Set Theory and Mathematical Logic
Prerequisite(s): Mathematics at Intermediate level
Credit Hours: 3 + 0
Specific 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.

Mathematical Logic: Introduction, statements, negation, logical connectives, truth table, conjunction, disjunction, conditional and Bi-conditional statements, and converse, inverse and contrapositive statements, Tautology and contradiction, Predicates and quantifiers, Cardinality of all injective, surjective and bijective functions from a set to another set. Infinite sets, finite sets. Countable sets, introduction to first and second countable, properties, examples (Z, Q). R is not countable. ($R, R\times R, R\times R\times R$), 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. Propositional Calculus. Truth tables. Predicate Calculus.

Recommended Books:

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

2nd SEMESTER

ISL-321 Islamic Studies
Prerequisite: None
Credit Hours: 2+0

کورس کے خصوصی مقاصد

اس کورس کا مقصد اسلامیات کے متعلق بنیاد ی معلومات مہیا کرنا، اسلامی تہذیب کے متعلق ان کی معلومات بڑھانا،طلباء کی مہارتوں کو پروان چڑھانا تا کہ وہ نمازیں اور دوسری عبادات بخوبی ادا کر سکیں ۔ایمان اور مذہبی زندگی کے ساتھ متعلقہ مسائل کو سمجھنے کے لئے طلباء کی مہارتوں کو بڑھانا ہے۔

کورس کاخاکہ:

قرآنی مطالعہ کا تعارف:قرآن اور عقیدہ توحید کے بنیادی عقائد،قرآن کی تاریخ،علوم القرآن ،قرآن مجید کے منتخب آیات کا مطالعہ:سورۃ بقرۃ کی آیات(284- 286)ایمان سے متعلق،سورۃ الحجرات کی آیات (1- 18) آدابِ نبویﷺ سے متعلق،سورۃ محمد کی آیات (1-11) ایمان کے اخلاقیات سے متعلق،سورۃ الفرقان کی آیات 63(-77) سماجی اخلاقیات سے متعلق،سورۃ الانعام کی آیات (152-154) احکام سے متعلق،سورۃ احزاب کی آیات(6،21،40،56،57،58)آدابِ نبویﷺ سے متعلق،سورۃ الحشر کی آیات(18،19،20) انصاف کے دن سوچنے کے متعلق،سورۃ الصف کی آیات (1-14) تفکر،تدبرسے متعلق۔حضور ﷺ کی سیرت: محمد ﷺ کی مکی زندگی و مدنی زندگی(کے بڑے بڑے واقعات)۔سنت کا تعارف:حدیث کی بنیادی،حدیث کی تاریخ ،حدیث کے اقسام،علوم الحدیث ،سنت اورحدیث، سنت کی قانونی حیثیت،منتخب احادیث مبارکہ۔اسلامی قانون اور اصولِ فقہ(اصولِ قانون) کا تعارف۔ اسلامی تہذیب و ثقافت۔ اسلام اور سائنس، اسلام کا معاشی نظام ،اسلام کا سیاسی نظام ، اسلام کا معاشرتی نظام۔

مجوزہ کتب:

اے۔حسن،اسلامی فقہ کے اصول،اسلامک ریسرچ انسٹییوٹ،انٹر نیشنل اسلامک یونیورسٹی،اسلام آباد،۱۹۹۳۔

م(محمد). ولی اللہ ، اسلامی فقہ اورجرائم کا قرآنی قانون،اسلامک بک سروس، ۱۹۸۲۔

ایچ۔ایس. بھاتیہ،اسلامی قانون کا مطالعہ،ریلیجن اینڈ سوسائٹی،ڈیپ اینڈ ڈیپ پبلیکیشنز ،نیا دہلی،۱۹۸۹۔

م۔ضیاء الحق،اسلامی شریعت کا تعارف، علامہ اقبال اوپن یونیورسٹی،اسلام آباد،۲۰۰۱۔

م۔حمید اللہ ،اسلام کا تعارف۔

کے۔احمد، اسلامی نظریہ حیات۔

م۔حمید اللہ ، خطباتِ بہاولپور۔

ایس۔اے، علی،اسلام کی روح۔

BCS-322 Software Packages
Prerequisite(s): Introduction to Computer
Credit Hours: 3+0
Specific Objectives of the Course:

The purpose of this course is to teach students the use of mathematical software's like MATLAB, MAPLE, and MATHEMATICA for solving computationally-difficult problems in mathematics. The students shall become well-versed in using these mathematical software and shall learn a number of techniques that are useful in calculus as well as in other areas of mathematics.

Course Outline:

The contents of the course are not fixed, however the following points should be kept in mind while teaching the course. The course should be taught in a computer lab setting. Besides learning to use the software, the students must be able to utilize the software to solve the computationally difficult problems in calculus and other areas of mathematics. At the end of the course, the students should have a good command on at least two of the three programs mentioned above. Introduction to simulations by using the mentioned software.

Recommended Books:

- D. M. Etter, D, Kuncicky, D. Hull, *Introduction to MATLAB*, Prentice Hall, Englewood Cliffs,NJ, USA, 2001
- F. Garven, *The Mapple Book*, Chapman & Hall/CRC, 2002
- S. Kaufmann, *Mathematica As a Tool, An Introduction with Practical Examples*, Springer, New York, 1994

MGC- 323 Physics-II

Prerequisite(s): Physics-I

Credit Hours: 3 + 0

Course Outline:

Heat and temperature: Temperature, kinetic theory of the ideal gas, work done on an ideal gas, internal energy of an ideal gas, Equipartition of energy, Intermolecular forces, Quantitative discussion, Vander waals equation of state, Statistical Mechanics: Statistical distribution and mean values, Mean free path and microscopic calculation of mean free path, distribution of molecular speeds, distribution of energies, Maxwell distribution, Maxwell Boltzmann energy distribution, internal energy of an ideal gas, Brownian motion, qualitative description, diffusion, conduction and viscosity, Thermodynamics: Review of previous concepts, First law of thermodynamics and its applications to adiabatic, isothermal, cyclic and free expansion, Reversible and irreversible processes, second law of thermodynamics, Carnot theorem, and Carnot engines, Heat engine. Refrigerators, Calculation of efficiency of heat engines, Thermodynamic temperature scale: Absolute zero: Entropy, Entropy in reversible process, entropy in irreversible process, Entropy & second law, Entropy & Probability, Thermodynamics functions: Thermodynamic functions (internal energy, Enthalpy, Gibb's function, Entropy, Helmholtz functions), Maxwell's relations, Energy equations and their applications.

Recommended Book:

- Halliday, D. Resnick, Krane, *Physics*, Vol. I & II, John Wiley, 5^{th} edition, 1999
- Halliday, D. Resnick, Krane, Walker, *Fundamental of Physics*, Extended ed. John Wiley, 5^{th} edition
- R. A. Hashimi, *A Textbook of Engineering and thermodynamics*
- M. Zemausty, *Heat and thermodynamics*, 5^{th} edition, McGraw Hill

MGC-324 Statistics
Prerequisite(s): Basic statistics at intermediate level
Credit Hours:3+0
Specific Objectives of the Course:
In the course "Probability Theory" the students learnt how to set up mathematical models of processes and systems that are affected by *chance*. In the present course the students would learn how to check these models against reality, to determine whether they are reliable/accurate enough for practical purposes or otherwise. This helps in making predictions and decisions.
Course Outline: Statistical measures, statistical description and graphical representation of data, introduction to probability theory, permutations and combinations, Sampling theory, events, mutually exclusive and inclusive events, frequency and sampling distributions, sampling procedures, Estimation of parameters, estimation of mean, variance, confidence intervals, decision theory, hypothesis testing and decision making, types of errors in tests, quality control, control charts for mean, standard deviation, variance, range, goodness of fit, chi-square test, Regression analysis, method of least squares and curve fitting, correlation analysis.
Recommended Books:

- MH. DeGroot, MJ, Schervish, *Probability and Statistics* (3rd edition), 2002, Addison-Wesley, Reading, Ma, USA
- RA. Johnson, *Probability and Statistics for Engineers*, 1994, Prentice-Hall, Englewood Cliffs, NJ, USA
- A.Papoulis, *Probability, Random Variables, and Stochastic Processes*, (3rd edition), 1991, McGraw Hill, New York
- T.Sincich, *Statistics by Examples*, 1990, Dellen Publication Company .

MFC-325 Calculus-I
Prerequisite(s): Mathematics at intermediate level
Credit Hours: 4+0
Specific Objectives of the Course:
Calculus is serving as the foundation of advanced subjects in all areas of mathematics. The course, equally, emphasizes the basic concepts and skills needed for mathematical manipulation. This Calculus focus on the study of functions of a single variable.
Course Outline:
Functions, upper and lower bounds of variables and functions, inverses of exponential, circular, hyperbolic and logarithmic functions, one sided and two sided limits of functions, continuity of functions and their graphical representations, properties of continuous function on closed bounded intervals, discontinuity of function and its types. Derivatives: Definition, techniques of differentiation. Derivatives of polynomials and rational, exponential, logarithmic and trigonometric functions, Inverse functions and their derivatives. 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. Mean value theorems. Indeterminate forms and L'Hopitals rule. Anti-derivatives and integrals. Riemann sums and the definite integral. Properties of Integral. The fundamental

theorem of calculus. Various techniques of integration. Reduction formulae and use of Gamma Beta Functions for integral.

.Recommended Books:

- J. Stewart, *Calculus* (5th edition or latest edition), 2002, Brooks/Cole
- H. Anton, I. Bevens, S. Davis, *Calculus: A New Horizen* (8th edition or latest), 2005, John Wiley, New York
- G. B. Thomas, A. R. Finney, *Calculus* (11th edition or latest edition), 2005, Addison-Wesley, Reading, Ma, USA

ENG-326 Communication Skills
Prerequisite(s): English Structure
Credit Hours: 3 + 0
Specific Objectives of the Course:
The course aims at enabling the students to meet their real life communication needs.
Course Outline:
Paragraph writing (practice in writing a good, unified and coherent paragraph), Introduction to Essay Writing, Study Skills (skimming and scanning, intensive and extensive, and speed reading, summary and precise writing, and comprehension), Academic Skills (Letter/memo writing, minutes of meetings, use of library and internet) Presentation Skills (Personality development with emphasis on content, style and pronunciation).
Recommended Books:

- A. J. Thomson and A. V. Martinet, *Practical English Grammar*, 3rd edition, Oxford University Press, 1997
- P. C. Wren and Martin, *English Grammar and Composition*
- M. C. Boutin, S.Brinand, F.Grellet, *Writing: Intermediate, Oxford Supplementary Skills*
- R. Nolasco, Writing: *Upper Intermediate, Oxford Supplementary Skills*
- B. Tomlinson, R.Ellis, *Reading: Advanced*, *Oxford Supplementary Skills*
- J. Langan, *Reading and Study Skills*
- R. Yorky, *Study Skills*

3^{rd} SEMESTER

ENG-431 Technical Writing and Presentations Skills
Prerequisite(s): English Structure, Communication Skills
Credit Hours: 3 + 0
Specific Objectives of the Course:
The course aims at enhancing the language skills and developing critical thinking of the students.
Course Outline:
Practice of paragraph writing, essay writing (descriptive, narrative, discursive, argumentative), academic writing (how to write a proposal for research paper/term paper with emphasis on style, content, language, form, clarity, consistency), technical report writing, progress report writing, CV and job applications.
Recommended Books:

- R.White, *Writing Advanced, Oxford Supplementary Skills*
- J. Langan, *College Writing Skills, McGraw Hill*
- L. G. Kirszner, S.R. Mandell, *Patterns of College Writing, St. Martin's Press*
- J. Neulib, K. S. Cain, S. Ruffus, M. Scharton, The Mercury Reader, Custom Publication, Illinois University

BCS-432 Computer Programming
Prerequisite(s): Introduction to Computer
Credit Hours: 2 + 1
Specific Objectives of the Course:
The purpose of this course is to introduce students to operating systems and environments.
Course Outline:
Introduction to programming, applications of programming in mathematics, program structure, flow chart, C/C^{++} language, building blocks, variables, data types, input/output, repetition (FOR, WHILE, DO), selection (IF, IF ELSE, ELSE IF) construct switch statement, conditional statement, function that returns a value using argument to pass data to another function, external variable, arrays and strings, pointers, structure, file processing and introduction to object-oriented programming.
Recommended Books:

- Dietel & Dietel, *C^{++} How to program,* 7^{th} Edition, Prentice Hall
- H. Schildt, C/C^{++} The Complete Reference, 4^{th} Edition, McGraw Hill Osborne media
- J. L. Hein, *Theory of Computations*: *An Introduction*, Jones and Bartlett, Boston
- R. Laffore, *Introduction to Object Programming*, McGraw Hill, New York

MFC-433 Algebra-I
Prerequisite(s): Mathematics at intermediate level
Credit Hours: 3 + 0
Specific Objectives of the Course:
This is the first course in groups, matrices and linear algebra, which provides basic background needed for all mathematics majors, is a prerequisite for many courses. Many concepts presented in the course are based on the familiar setting of plane and real three-space, and are developed with an awareness of how linear algebra is applied.
Course Outline:
Basic axioms of a group with examples, subgroups, order of a group, subgroups generated by

subset of a group, system of generators cyclic groups, cosets, Lagrange's theorem, introduction to permutations, even and odd permutations, cycles, lengths of cycles, transpositions, symmetric group, alternating groups. Preliminaries, normalizers and centralizers of a group, center of a group, normal subgroup, quotient groups, conjugacy relation between elements and subgroups, homomorphism and isomorphism between groups, homomorphism and isomorphism theorems, finite p-groups, internal and external direct products, endomorphism and automorphism of a group, characteristic and fully invariant subgroups, direct product of groups.

Recommended Books:

- E. Arnold, *Rings, Fields and Groups: An Introduction to Abstract Algebra*, 1983
- A. Majeed, *Group Theory*, Ilmi kitab Khana
- J. B. Farleigh, *A First Course in Abstract Algebra* (7th edition), Addison-Wesley
- I. D. Macdonald, *The Theory of Groups*, 1975, Oxford Clarendon Press, Ma., USA
- K. H. Dar, Abstract Algebra, ilmi Kitab Khana Lahore.

MGC-434 Physics-III

Prerequisite(s): None

Credit Hours: 3 + 0

Course Outline:

Electric charge and Electric Field: Charge, properties of charges, Coulombs Law, Field due to a point charge: due to several point charges, Electric dipole, Electric field of continuous charge distribution e.g Ring of charge, Disc of charge, infinite line of charge. Point charge in an electric field, Dipole in an electric field, Torque and energy of a dipole in uniform fields, Electric flux: Gauss's law; (integral and differential forms) and its application, Charge on isolated conductors, conductor with a cavity, field near a charged conducting sheet, Field of infinite line of charge, field of infinite sheet of charge, field of spherical shell and field of spherical charge distribution, Electric Potential: Potential due to point charge, potential due to collection of point charges, potential due to dipole, Electric Potential of continuous distribution charge, Poisson's and Laplace equation without solution, Field as the gradient or derivative of Potential, Potential and field inside and outside an isolated conductor, Capacitors and dielectrics: Capacitance, calculating the electric field in a capacitor, Capacitors of various shapes, cylindrical, spherical etc. and calculation of their capacitance, Energy stored in an electric field, Energy per unit volume, Capacitor with dielectric, Electric field of dielectric, An atomic view, Application of Gauss's law to capacitor with dielectric, Magnetic field effects and magnetic properties of Matter: Magnetic force on a charged particle, magnetic force on a current, recall the previous results, Do not derive, Torque on a current loop, Magnetic dipole: energy of magnetic dipole in field, Discuss quantitatively, Lorentz force with its application in CRO, Biot-Savart Law: Analytical treatment and applications to a current loop, force on two parallel current changing conductors, Ampere's law, integral and differential forms, applications to solenoids and toroid's, (integral form), Inductance: Faraday's Law of electromagnetic induction, review of emf, Faraday law and Lenz's Law, induced electric fields, calculation and application using differential and integral form, inductance, Basic definitions, Inductance of a solenoid, Toroid.

Recommended Books:

- Halliday, D. Resnick, Krane, *Physics*, Vol. I & II, John Wiley, 5th edition, 1999
- Halliday, D. Resnick, Krane, and Walker, *Fundamental of Physics*, Extended ed. John Wiley, 5th edition

- Ritz and Milford, *Introduction to Electromagnetic Field and Waves*
- R. J. Reitz, and J. M. Fredrick, *Foundations to Electromagnetic Theory,* 2nd edition, Addison-Wesley Publishing Co. 1970

MFC-435 Calculus-II
Prerequisite(s): Calculus-I
Credit Hours: 3+0
Specific Objectives of the Course:
Analytical geometry is serving as the foundation of advanced subjects in all areas of mathematical analysis. The sequence, equally, emphasizes the basic concepts and skills needed for mathematical manipulation. As continuation of Calculus, it focuses on the study of foundation of plane and one, two dimensional geometry.
Course Outline:
Curves and their representation in cartesian, polar and parametric forms, tangents and normal, maxima, minima and points of inflection, convexity and concavity, asymptotes and curve tracing, translation and rotation of axes in one dimension, general equation of the second degree and the classification of conic sections, conic in polar coordinates, tangents and normal, rectangular coordinate system, translation and rotation of axes in two dimension, direction cosines, ratios and angles between two lines, standard forms of equations of planes and lines, intersection of planes and lines, distance between points, lines and planes, shortest distance between lines, symmetry, intercepts and sections of a surface, spherical, polar and cylindrical coordinate systems, standard form of the equations of sphere, cylinder, cone, ellipsoid, parabolid and hyperboloid.

Recommended Books:
- J. Stewart, *Calculus* (5th edition or latest edition), 2002, Brooks/Cole
- H. Anton, I. Bevens, S. Davis, *Calculus: A New Horizen* (8th edition or latest), 2005, John Wiley, New York
- G. B. Thomas, AR Finney, *Calculus* (11th edition or latest), 2005, Addison-Wesley, Reading, Ma, USA

4th SEMESTER

MFC-441 Affine Euclidean Geometry
Prerequisite(s): Calculus I
Credit Hours:3+0

Specific 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 (magnitude) 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:

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

MGC-442 Accounting
Prerequisite(s): None
Credit Hours:3+0
Specific Objectives of the Course:
The primary aim of this course is to provide students with an introduction to the process and function of financial reporting by the organizations. While a large proportion of the course is aimed at understanding accounting as a process, taking a preparers' perspective. We will also seek to develop an understanding of the importance of the role of accounting in today's society.
After studying this course the student will be able to understand: The language of accounting and financial reporting; Complete Accounting Cycle, Preparation and the role of Journal, Ledger and subsidiary books, and Preparation of balance sheet, profit and loss account and statement of cash flows.
Course Outline:
Accounting and its role, Accounting Defined, Why study Accounting , Financial statements, Major fields of Accounting, Accounting as a Career, Basic Accounting Concepts, The Entity Concept, The Reliability (or Objectivity) principle, The cost Principle, The Going-Concern Assumptions, The Stable Currency Assumptions, Ethics-the-Most Fundamental Principle of

Accounting, The recording process, Debit Credit Rules, The Classification Issue, The Recording Process, Analysis of Transaction, The Journal, The Ledger, Balancing the Accounts Preparation of Financial Statements, Preparing Trial Balance, Locating and correcting errors in recording process, Preparing Profit and Loss Account and Balance Sheet The adjusting and closing entries, Need for Adjusting Entries, Recording adjusting entries, Preparing adjusted trial balance, Recording closing entries, Preparing post-closing trial balance, Preparing work-sheet, Preparation of Financial Statements, Accounting for trading organization, Accounting for Purchases and Sales, Return and allowances, Cash and trade Discounts, Periodic System, Perpetual Stock System, Accounting Systems, Subsidiary ledgers, Cash Book, Petty cash book, Control Accounts, Cash and temporary investment, Nature and Composition of Cash, Cash Management and Control, Maintaining Bank Account, Bank Reconciliation, Short term investments, Accounting for debtors and stock, Accounting Treatment of Bad Debts, Direct write-Off Method, Aging Schedule, Percentage of Sales Method, Recoveries of Bad debts Stock, Accounting for property, plant and equipment, Property, Plant and Equipment, Depreciation methods, Revaluation, Review of Useful life, Intangible Assets and Amortization, Wasting Assets and Depletion.

Recommended Books:

- Williams, Haka, Bettner: Financial & Managerial Accounting, Latest Edition, Prentice Hall
- M. Amanullah Khan: Financial Accounting, Latest Edition
- Meigs and Meigs, Accounting for Business Decision, 9th Edition/Latest edition

MGC-443 Physics-IV

Prerequisite(s): Physics at Intermediate level

Credit Hours: 3 + 0

Course Outline:

Origin of quantum theory: Black body radiation, Stefan Boltzmann, Wien's and Planck's law, consequences. The quantization of energy, Photoelectric and Compton effect, Line spectra, Explanation using quantum theory, Wave Nature of Matter: Wave behavior of particle (wave function etc) its definition and relation to probability of particle, De-broglie hypothesis and its testing, Davisson-Germer Experiment and J.P. Thomson experiment, Wave Packets and particles, localizing a wave in space and time, wave function, Normalization, expectation value, Atomic Physics: Bohr's theory (review), Frank-Hertz experiment, energy levels of electron, Atomic spectrum, Angular momentum of electrons, vector atom model, Orbital angular momentum. Spin quantization, Bohr's Magneton. X-ray spectrum (Continuous and Discrete) Moseley's law, Pauli's exclusion principle and its use in developing the periodic table, Nuclear Physics: Basic properties of a nucleus, Mass and Atomic Numbers, Isotopes, mass and size of a nucleus, Nuclear force (Basic Idea), Nuclear Radii, Nuclear masses, Binding energy, mass defect, Nuclear Spin and Magnetism, Natural Radioactivity: Laws of radioactive decay, half-life, mean life, chain disintegration; Alpha- Beta and Gamma decays (Basics idea), Measuring ionizing radiation (units i.e. Curie, Rad etc.), Nuclear Reactions: Basic Nuclear reaction, Q-value, Exothermic, Endothermic Nuclear model , Nuclear Fusion, Thermonuclear Fusion.

Recommended Books:

- Halliday, D. Resnick, Krane, *Physics,* Vol. I & II, John Wiley, 5th edition, 1999
- Halliday, D. Resnick & Walker, *Fundamental of Physics*, Extended ed. John Wiley 5th Ed
- A. Beiser, *Concepts of Modern Physics*, 4th edition McGraw-Hill book Company, 1987

MFC-444 Linear Algebra
Prerequisite(s): Basic Algebra
Credit Hours: 3 + 0
Specific Objectives of the Course:
This is a course in abstract linear algebra. The majority of follow up courses in both pure and applied mathematics assume the material covered in this course.
Course Outline: Algebra of matrices, determinants, matrix of a linear transformation, row and column operations, rank, inverse of matrices, solution of homogeneous and non-homogeneous equations, orthogonal transformation. Vector spaces, subspaces, linear dependence and independence, linear span of a subset of a vector space, bases and dimensions of a vector space, sums and direct sums of subspaces of a finite dimensional vector space, dimension theorem, linear transformation, null space, image space of linear transformation, rank and nullity of a linear transformation, relation between rank, nullity and dimension of the domain of a linear transformation, matrix of linear transformation, change of basis, inner product spaces, orthogonal and orthonormal basis, similar matrices and diagonalization of a matrix, Home (V,W), dimension and basis of Home (V,W), dual space and dual basis, annihilators, Eigen values and Eigen vectors and minimal polynomials.
Recommended Books:
- S. J. Axle, Linear Algebra Done Right, *Undergraduate Texts in Mathematics,* 1996, Springer, New York, Schaum's outlines series
- G. Birkhoff, S. Maclane, *A Survey of Modern Algebra* (4th edition), AKP
- W. L. C. Perry, *Elementary Linear Algebra*, 1988, McGraw-Hill, New York

MFC-445 Calculus-III
Prerequisite(s): Calculus –I and II
Credit Hours: 4+0
Specific Objectives of the Course:
Multivariate calculus is serving as the foundation of advanced subjects in all areas of mathematics. The sequence, equally, emphasizes the basic concepts and skills needed for mathematical manipulation. The main focus will be on the study of functions having two, three or more variables.
Course Outline: Function of several variables, limit and continuity, derivability and differentiability, chains rules, properties of several variable function, Euler's theorem, total differentials and explicit and implicit functions, extreme values: maxima and minima with or without constraints, Tayler's theorem in multi variable and its various form, chain of variables, functions of functions, double and triple integrals with applications (area of surfaces and volumes of revolution using double and triple integrals) line integrals, integration on R^2 : integrals over a region, the Green's, the divergence and the Stokes theorems with applications.
Recommended Books:
- J. Stewart, *Calculus* (5^{th} edition or latest edition), 2002, Brooks/Cole (suggested text)
- H. Anton, I. Bevens, S. Davis, *Calculus: A New Horizen* (8^{th} edition or latest), 2005, John Wiley, New York
- G. B. Thomas, A. R. Finney, *Calculus* (11^{th} edition or latest), 2005, Addison-Wesley, Reading, Ma, USA

MGC-446 Economics
Prerequisite(s): None
Credit Hours: 3 + 0
Specific Objectives of the Course:
The main purpose of this course is to familiarize the students with the main concepts used in the field of economics.
Course Outline:
Introduction: Definition, Nature, Scope and Importance (Micro and Macro Economics) Description, Analysis and Policy, Economic Methodology, Consumer Behavior: Definition and meaning, Marginal Utility, Law of Diminishing Marginal Utility Consumer's Surplus Indifference curve approach, Demand: Definition, Laws of Demand, Changes in Demand, Elasticity of Demand and its measurement, Supply: Supply, Changes in supply, Demand and Supply Relationship, Equilibrium Analysis, Production: Concept of Factor of Production, Land Labor, Capital &Entrepreneur, Laws of Returns and their application to Agriculture Sector, Costs: Costs over time period Fixed, Variable, Total, Average and Marginal, Market: Perfect and Imperfect Competition, Price and output determination under perfect and Imperfect competition, Market price and Normal price, Monopoly, Oligopoly, Duopoly and Price Control(Basic Concepts), Factor Pricing: Rent, Wages, Interest and Profit, National Income: Concepts of National Income-GNP, Circular flow of national Income. Measurement of National Income: National Income at market price, at factor Cost; Measurement of national Product in current rice and in constant prices, Money: Evolution, Forms, Functions, Importance and Role of Money, Value of Money: Quantity Theory of Money, Cash Balance Theory of money, Measurement of Value of Money, Devaluation of Money, Trade Cycle: Phases, Causes & Remedies, Theory of Trade Cycles, Inflation: Kinds, Causes, & Remedies, Balance of Payments: Balance of Trade, Balance of Payments, Causes of Disequilibrium and Measures, Public Finance: Meaning, Difference between Private and Public Finance, Income and Expenditure of Public Bodies, Kinds of Taxes and Cannons of Taxes, Economics in Islam: Economic role of State in Islam, Zakat and Ushr.
Recommended Books:

- M. Irshad, *Economics*, Naveed Publications Lahore
- S. M. Ali, *Economics*, Ilmi Kutab Khana, Urdu Bazar, Lahore
- L. G. Reynolds Irwin, *Micro Economics-Analysis & Policy*, Irwin Homwood Illinois
- N. S. Barrett, *The Theory of Macro Economics Policy*, Prentice Hall
- E. Shapiro, *Macro Economic Analysis*, Harcourt Brace
- M. A. Saeed-Nasir, *Textbook of Economics*, Ilmi Kutab Khana, Lahore
- S. Rizavi, *Economics*
- P. A. Sameulson, *Economics*

5^{th} SEMESTER

MFC- 551 Algebra-II (Ring Theory and Fields)
Pre-requisite(s)**:** Algebra-I
Credit Hours: 3+0
Specific Objectives of the Course: a ring will be defined as an abstract structure with a commutative addition, and a multiplication which may or may not be commutative. This distinction yields two quite different theories: the theory of respectively commutative or non-commutative rings.
Course Outline: Introduction to Ring theory and Field and their structure, Quotient Rings, Integral domain, Homomorphism of a Ring, Kernel of a Ring, Isomorphism of a Ring, Maximal ideals, Prime ideals, Euclidian rings, or Euclidian domain, Polynomial rings over a unique factorization domain, the field of quotients of an integral domain, Field structure, Ordered ring and field, introduction to extension field, Algebraic extensions, Finite field.
Recommended Books:

- *R.B.J.T. Allenby (1991). Rings, Fields and Groups. Butterworth-Heinemann. ISBN 0-340-54440-6.*
- Atiyah M. F., Macdonald, I. G., *Introduction to commutative algebra*. Addison-Wesley Publishing Co., Reading, Mass.-London-Don Mills, Ont. 1969 ix+128 pp.
- *T.S. Blyth and E.F. Robertson (1985). Groups, rings and fields: Algebra through practice, Book 3. Cambridge university Press. ISBN 0-521-27288-2.*
- Faith, Carl, *Rings and things and a fine array of twentieth century associative algebra*. Mathematical Surveys and Monographs, 65. American Mathematical Society,

MMC-552 Real Analysis-I
Prerequisite(s): Calculus-I, Calculus-II and III
Credit Hours: 3 + 0
Specific Objectives of the Course:
This is the first rigorous course in analysis and has a theoretical emphasis. It rigorously develops the fundamental ideas of calculus and is aimed to develop the students' ability to deal with abstract mathematics and mathematical proofs.
Course Outline:
Real number system and extended real number system, convergence of sequence, sub-sequences, Cauchy sequences and completence, sequence and series and various test for the convergence of the series, Cauchy general principle of convergence, continuous functions and their properties, discontinuity, monotonic functions, differentiation, and uniform continuity, term by term differentiation and integration, intermediate value and Darboux theorem, definition and existence of the integral, the integral as a limit of sum, Riemann integration theory, functions of several variables, continuity and total differentials, extreme values (maxima and minima), implicit function theorem, Jacobian's, improper integrals and their convergence.
Recommended Books:
- R. G. Bartle, DR. Sherbert, *Introduction to Real Analysis* (3rd edition), 1999, John Wiley
- W. Rudin *Introduction to Mathematical Analysis*
- Apostal, *Mathematical Analysis*
- E. G. Philips, *A course of Analysis*

- W. Kaplan, *Advance Calculus*
- W. Fulks, *Advanced Calculus*, John Wiley, New York
- S. C. Malik, *Mathematical Analysis*

MFC-553 Ordinary Differential Equations
Pre-requisite(s)**:** Calculus
Credit Hours: 3+0
Specific Objectives of the Course:
This course will provide the foundation for all advanced subjects in Mathematics. Strong foundation and applications of Ordinary Differential Equations is the goal of the course.
Course Outline:
Basic definition of differential equations, formation of differential equations, initial and boundary value problems, differential equations of the first order and first degree, equations with separable variable, homogeneous differential equations, equations reducible to homogeneous form, exact differential equations, integrating factors, rules for determinations of integrating factors, linear equations of the first order, Non-linear equations of the first order, linear differential equations of high order, solution of homogeneous linear equations, principle of superposition and Wronksian, determination of particular integral, short methods for finding particular integral, orthogonal trajectories, Cauchy-Euler equations, 2^{nd} order linear differential equations, reduction of order method, undetermined Coefficient method, variations of parameters method.
Recommended Books:
- D.G. Zill, M.R, Cullen, *Differential Equations with Boundary-Value Problems*, (latest Edition), PWS Publishing Company
- D.G. Zill, *Advanced Engineering Mathematics*, Jones and Bartlett Publishers, 2005
- Erwin Kreyszig, *Advanced Engineering Mathematics*, John Wiley and Sons (9^{th} edition)
- G.E. Andrews, R. Askey, and R. Roy, *Special Functions*, Cambridge University Press

MMC-554 Vector and Tensor Analysis
Prerequisite(s): Calculus and Analytical Geometry
Credit Hours: 3 + 0
Specific Objectives of the Course:
This course shall assume background in calculus. It covers basic principles of vector and tensor analysis which are frequently used in applied mathematics.
Course Outline:
Vectors in 3 dimension, the dot and the cross products, triple products, vector differentiation, vector integration, the gradient, divergence, curl, and their applications, the divergence theorems of Gauss, Stokes's theorem, and Green's theorem in the plane, curvilinear coordinates, introduction to tensor analysis, summation convention, kronecker delta, contra variant and covariant vectors and tensor, Fundamental operations with tensors, symmetric, and skew symmetric tensors, Metric tensor, conjugate or reciprocal tensors, christoffel's symbols, Geodesics, Geodesics equation, Covariant derivatives, permutation symbols and tensors, tensors form of gradient, divergence and Curl.
Recommended Books:
- Bourne D. E, Kendall PC, *Vector Analysis and Cartesian Tensors* (2nd edition)
- N. A. Shah, *Vector and Tensor Analysis*, 2005, A-One Publishers, Lahore

- G. D. Smith, *Vector Analysis*, Oxford University Press, Oxford
- M. R. Spiegel, *Vector Analysis*, 1974, McGraw Hill, New York

MMC- 555 Differential Geometry
Prerequisites: Calculus-II
Credit Hours: 3 + 0
Specific Objectives of the Course:
In this course the students will be familiarizing with planes and planes curves and the action of total and partial differentials on varies planes.
Course Outlines:
Space Curve, The moving trihedral Curvature, Torsion and skew curvature, Serret-Frenet formula, Osculating circle and sphere, Curves of constant slope or cylindrical helices, The spherical indicaterices and their curvature and torsion, Concepts of surface. Tangent plane, Envelope and characteristics relating to one parameter family of surfaces, Edge of regression, Developable surfaces and developable associate with a space curve, Parametric curves, Two fundamental forms, Meosnier’s theorem, Principal directions and principal curvature, Lines of curvature, Euler’s theorem, Geodesics and Geodesic equations.
Recommended Books:
- C. E. Weatherburn, *Differential Geometry of three Dimensions*, Cambridge University Press
- D. J. Struik, *Lecture on classical Differential Geometry*, Addison Wesley Publishing
- T. J. Wilmore, *An Introduction to Differential Geometry*, Clarendon Press, Oxford

MMC-556 Topology
Prerequisites: Calculus and Set Theory
Credit Hours: 3 + 0
Specific Objectives of the Course:
This course provides a simple concept of set and the action of functions on various sets. It also gives the detailed what is topology and metric spaces and how they are formed from specific sets. It also discusses the continuity rule upon the topological and metric spaces. In this course a brief introduction is discussed about closed, derived open set exterior, interior, neighborhood, sphere, open sphere and closed sphere.
Course Outlines:
Topological spaces, limit points (or accumulation points), derived set, closure of a set, interior, exterior and boundary points, sub-space and relative topology, real line topology and its examples, metric spaces, limit point, adherent point, closure of a set, sequences in metric space, complete metric spaces and its basic theorems and examples, Bairs category theorems and Cantor intersection theorem, continuity and homeomorphism: continuous functions, continuous functions in topological spaces, convergent sequences, homeomorphism, open function, closed functions, bases and sub-bases, definitions of base and sub-bases of topological and metric spaces and fundamental results and examples.
Recommended Books:
- M. Iqbal, *Introduction to Topology*
- Dr. A. Majeed, *Introduction to general Topology and Functional Analysis*
- C. Adams, R. Franze, *Introduction to Topology pure and Applied*

6th SEMESTER

MMC-561 Number Theory
Prerequisite(s): Mathematics at intermediate level
Credit Hours: 3+0
Specific Objective of the Course:
This course covers those topics of number theory which are the essential ingredients for a beginner. In this course the students leans the basics concepts of number theory, as the theory of number has always occupied a unique position in the world of mathematics. Because of the basic nature of its problem, number theory has a fascinating appeal for the leading mathematicians as well as for thousands of armatures. This course also familiarizes the students with the applications of some theorems.
Course Outline:
Divisibility, divisibility tests, Euclidean Algorithm, GCD and LCM of integers, prime number, properties of prime numbers, fundamental theorem of arithmetic's, the Tau and sigma functions, congruence relation, solutions of system of linear congruencies, congruence of higher degree, Chinese reminder theorem and its applications, Euler's phi-function and its applications, Fermat's little theorem and its applications, Wilson's theorem and its applications, perfect number and Mersenne's primes, Fermat number, Linear Diophantine equation, reduced residue system, complete residue system.
Recommended Books:

- M. Mushtaq Suhail, *Elementary Theory of Number*, Jadeed book depot, Urdu bazaar Lahore
- K. C. Chowdhury, *A First Course in Number Theory*, Asian Book Private Limited
- T. Koshy, *Elementary Number Theory with Applications*, Academic Press is an imprint of Elsevier
- K. H. Rosen, *Elementary Number Theory and its Applications*, Addison-wesley, Publishing Company

MMC-562 General Topology
Prerequisite: Basic Topology
Credit hours: 3+0
Specific Objectives of the Course:
This course deals with the topological properties of figures with the help of which we can study complicated geometrical figures by decomposing them into simplest geometrical figures. It is used in Geography, Physics, Computer and studying different crystal structure and Allotropic forms of various elements in Chemistry.
Course Outlines:
Separation Axioms, introduction of T_0, T_1, T_2, T_3 and T_4 spaces, normal and regular and completely regular spaces, Urysohn's lemma and metrization theorem, hereditary properties, Bair's Category theorems, Cantor set and Canter intersection theorem, compactness, covers and open covers, compact set and compact subset, Hein Borel theorem for compactness and sequentially compact sets and locally compact sets, connectedness, connect and separated sets and spaces, connectedness on the real line, components, locally connectedness, Path and arc wise

connectedness, product spaces, product topology and product of metric spaces, base for finite product topology examples of product spaces.

Recommended Books:

- Dr. A. Majeed, *Introduction to general Topology and Functional Analysis*
- S. Willards, *General Topology* Adison Wesley N.Y. 1970
- C. Adams, R. Franze, *Introduction to Topology pure and Applied*
- G. F Simmon, *Introduction to Topology and Modern Analysis,* McGraw Hill book

MMC-563 Complex Analysis

Prerequisites: Calculus and Analytical geometry

Credit Hours: 3 + 0

Specific Objectives of the Course:

This is an introductory course in Complex 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 Outlines:

The algebra and the Geometry of complex numbers, Cauchy-Riemann equations, harmonic functions, elementary functions, branches of logarithm, complex exponents, Contours and contour integrals, the Cauchy-Goursat theorem, Cauchy integrals formulas, the Morera theorem, maximum modules principle, the Liouville theorem, the Roche theorem, fundamental theorem of Algebra, Convergence of sequences and series, the Taylor series, the Laurent series, uniqueness of representation, zeros of analytic functions, Residues and poles and the residue theorem, evaluation of improper integrals involving trigonometric functions, integrals around a branch point, the argument principle, Special function Beta, Gamma functions and hyper geometric and Legender functions.

Recommended Books:

- R. V. Churchill, J. W. Brown, *Complex Variables and Applications* (5^{th} edition), 1989
- *Complex Analysis*, Schaum's Outlines Series

MMC-564 Classical Mechanics

Prerequisite(s): Vector and Tensor Analysis

Credit Hours: 3 + 0

Specific Objectives of the Course:

This course builds grounds in principles of classical mechanics, which are to be used while studying quantum mechanics, statistical mechanics, electromagnetism, fluid dynamics, spaceflight dynamics, astrodynamics and continuum mechanics.

Course Outline:

Particle kinematics, radial and transverse components of velocity and acceleration, circular motion,newtonian mechanics, the Newtonian model of gravitation, calculus of variations, Hamilton's principle, lagrangian and hamiltonian dynamics, symmetry and conservation laws, central-force motion, two-body problem, orbit theory, Kepler's laws of motion (the law of ellipses, the law of equal areas, the harmonic law), satellite motion, geostationary and polar satellites, kinematics of two-particle collisions, Basics of special theory of relativity, motion in non-inertial reference frame, rigid-body dynamics,3-D-rigid bodies and mechanical equivalence, center of mass and gravity, motion of a rigid body, inverted pendulum and stability, gyroscope), coupled oscillations, vibrating strings, wave equation in one dimension.

Recommended Books:

- A. Bedford, W. Fowler, *Dynamics: Engineering Mechanics*, Addision-Wesley, Reading,
- T. L. Chow, *Classical Mechanics*, 1995, John Wiley, New York
- H. Goldstein, *Classical Mechanics* (2nd edition), 1980, Addison-Wesley, Reading
- J. B. Marion, *Classical Dynamics of Particles and Fields* (2nd edition), 1970, New York
- J. L. Synge, B. A. Griffith, *Principles of Mechanics*, McGraw Hill, New York

MMC-565 Partial Differential Equations
Pre-requisite(s)**:** Ordinary Differential Equations
Credit Hours: 3+0
Specific Objectives of the Course:
This course will provide a strong foundation to solve different kinds of PDEs using different techniques.
Course Outline:
Course Outline:
Classification of PDEs, First-order linear PDEs, The method of characteristics, General constant coefficient first-order linear PDEs, Variable coefficient first-order linear PDEs, Two-Point Boundary Value Problems, Fourier series, The Fourier Convergence Theorem, Even and Odd Functions, Separation of Variables; Heat, Wave and Laplace equations and its solution by the method of separation of variable in rectangular, polar, cylindrical and spherical coordinates
Recommended Books:

- *Lokenath Debnath, Tyn Myint-U*, *Linear Partial Differential Equations for Scientists and Engineers*
- William E. Boyce, Richard C. DiPrima, Elementary Differential Equations and Boundary Value Problems
- Nakhle H.Asmar, *Partial differential Equation with Fourier Series and Boundary Value Problem*, New Jersey
- Richard Haberman, *Elementary Applied Partial Differential Equations with Fourier Series and Boundary Value Problems*, 1997
- Dennis G. Zill, *Differential Equations with Boundary Value Problem*, PWS Publishing Company

MMC-566 Real Analysis-II
Prerequisite(s): Real Analysis-I
Credit Hours: 3 + 0
Specific Objectives of the Course:
A continuation of real analysis, this course rigorously develops integration theory. Like real integral calculus and real analysis emphasizes on proofs.
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.

Recommended Books:

- R. G. Bartle, D. R. Sherbert, *Introduction to Real Analysis* (3rd edition), 1999, John Wiley, New York
- W. Rudin, *Introduction to Mathematical Analysis*
- Apostal, *Mathematical Analysis*
- E. G. Philips, *A Course of Analysis*
- W. Kaplan, *Advance Calculus*
- W. Fulks, *Advanced Calculus*, John Wiley, New York
- S. C. Malik, *Mathematical Analysis*

7^{th} SEMESTER

MMC-671 Functional Analysis
Prerequisite(s): Linear Algebra and Basic Topology
Credit Hours: 3 + 0
Course Outline:
Normed spaces: Definition and examples of Normed spaces, convergent sequences, Cauchy sequences in norm spaces, equivalent norm, quotient norm, and theorems on normed space, Banach Spaces: Definition and examples of Banach spaces, Characterization of Banach spaces, Bounded Linear Transformations, Functional and their examples, Various characterizations of bounded (continuous) linear operators, The space of all bounded linear operators, The open mapping and closed graph theorems, principle of uniform boundedness. Hahn-Banach theorem on norm spaces. Some important consequences of the Hahn-Banach theorem, Hilbert Spaces: Inner product spaces and their examples, The Cauchy-Schwarz inequality, Hilbert spaces, Orthogonal complements, The projection theorem, The Riesz representation theorem. Bounded linear operators in Hilbert spaces. Spectral properties of bounded linear operator in Hilbert spaces.
Recommended Book:
- E. Kreyszig, Introductory Functional Analysis with Applications, John Wiley, 1978
- J. Maddox, Elements of Functional Analysis, Cambridge, 1970
- G. F. Simmon, Introduction to Topology and Modern Analysis, Mc-Graw-Hill, N.Y.1983
- W. Rudin, Functional Analysis, Mc-Graw-Hill, N.Y., 1983

MMC-672 Numeric Analysis
Prerequisite(s): Calculus and Basic Algebra
Credit Hours: 3 + 1
Specific Objectives of the Course:
This course is designed to teach the students about numerical methods and their theoretical bases. The students are expected to know computer programming (i.e. Matlab, Mathcad etc.) to be able to write program for each numerical method. Knowledge of calculus and linear algebra would help in learning these methods and to form basic Matlab codes for these.
Course Outline:
Introduction to error analysis, method for the solution of nonlinear equation and their convergence, bisection method, Regula Falsi method, fixed point iteration method, Newton-Rapson method, Secant method, interpolation and polynomial approximation, Lagrange's interpolation, Newton's divided difference, Forward difference and Backward difference formulae, Laplace and Bassel formula of interpolation, numerical integration and error estimates, Rectangular, Trapezoidal and Simpson rule, numerical solution of system of algebraic linear equation: Gauss elimination method, Gauss Jordon method, matrix inversion, Cramer's rule, LU decomposition, Choleski's factorization method, Tridiagonal method, Jacobi and Gauss Seidal methods. The method of characteristics, Eigen value problems; Estimation of Eigen values and corresponding error bounds, Gerschgorins theorem and its applications Schurs theorem, Power method, Shift of origin, Deflation method for the subdominant Eigen values.
Recommended Books:
- K. E. Atkinson, *An Introduction to Numerical Analysis* (2^{nd} edition), 1989, John Wiley,

- R. L. Burden, J. D. Faires, *Numerical Analysis* (5^{th} edition), 1993, PWS Publishing
- S. C. Chapra, R. P. Canale, *Numerical Methods for Engineers,* 1988, McGraw Hill, New
- N. Bhatti*, Numerical Analysis with* C^{++} 5^{th} edition

MCC-673 Mathematical Methods

Prerequisite(s): Ordinary differential equations and Partial Differential Equations

Credit Hours: 3+0

Specific Objectives of the Course:

The purpose of this course is to teach students, various methods and techniques for solving differential equations of applied nature and applications.

Course Outline:

Introduction to power series, series solutions, solutions about ordinary point, singular points and regular points of ordinary differential equations, Frobenius methods; Case-I, Case-II, solutions of Bassel and Legendre equations, kinds of Basel equations and applications, Harmit and Hyper geometric differential equations, Sturm-Liouville problems and boundary value problems, 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. and its properties, applications of Laplace transform in solutions of differential equations, solutions of systems of differential equations by Laplace equations, heat, wave and Laplace equations and its solution by Laplace transform.

Recommended Books:

- D. G. Zill, M.R. Cullen, *Differential Equations with Boundary-Value Problems*, (latest Edition), PWS Publishing Company
- A. K. Sharma, *Advanced Differential Equations*, Discovery Publishing House, 2010

8^{th} SEMESTER

MCC-681 Probability Theory
Pre-requisite(s): Calculus
Credit Hours: 3 + 0
Specific Objectives of the Course:
This course is designed to teach the students how to handle data numerically and graphically. If data are influenced by chance effect, the concepts and rules of probability theory may be employed, being the theoretical counterpart of the observable reality, whenever *chance* is at work.
Course Outline: Probability, random and continuous variables, probability distributions, mean, standard deviation, variance and expectation, Mathematical expectation, Discrete distribution: Moment generating and cumulative distributions, Discrete probability distribution, The Binomial distribution, Hyper geometric distribution, Negative Binomial distribution, the Poisson distribution, Geometric distribution, Uniform distribution, Continuous distribution: Uniform distribution, the normal exponential distributions, Gamma and Beta distributions, Cauchy distribution, Log-Normal distribution, Weibull distribution.
Recommended Books:

- M. H. DeGroot, M. J. Schervish, *Probability and Statistics* (3rd edition), 2002, Addison-Wesley, Reading, Ma, USA
- Papoulis, Probability, *Random Variables, and Stochastic Processes,* (3rd edition), 1991, McGraw Hill, New York
- T. Sincich, *Statistics by Examples*, 1990, Dellen Publishing Company.

MFC- 682 Integral Equations
Prerequisite(s): Differential Equations
Credit Hours: 3 + 0
Course Outline:
Introduction to Integral equation, their origin and classification, some important identities, Laplace, Fourier and other Transforms, Volterra Integral equation, Volterra Integral equation of first kind and second kind, Numerical solution of Volterra integral equation, Fredholm Integral equation, Fredholm Integral equation with degenerate kernel, and with symmetric Kernel, Fredholm Integral equation of the second kind with numerical Solution, the Green's function of Fredholm Integral equation and the Green's function existence of the solution.
Recommended Books:

- Abdul J. Jerri, *Introduction to Integral Equations with Applications*, 1985
- W. V. Lovitt, *Linear Integral Equations*, Dover Publications 1950
  F. Smith, *Integral Equations*, Cambridge University Press
  F. G. Tricomi, *Integral Equations*, Interscience, 1957

Elective Courses

MEC-674 Mathematical Modeling
Prerequisite(s): Differential Equations
Credit Hours: 3 + 0
Specific Objectives of the Course:
Mathematics is used in many areas such as engineering, ecological systems, biological systems, financial systems, economics, etc. In all such applications one approximates the actual situation by an idealized model. This is an introductory course of modeling, consisting of three parts: modeling with ordinary differential equations and their systems; partial differential equations; and integral equations. The course will not be concerned with the techniques for solving the equations but with setting up the equations in specific applications. Whereas the first two types of equations have already been dealt with, the third type has not. Consequently, solutions of the former will be discussed but of the latter will barely be touched upon.
Course Outline:
Concepts of model, modeling and simulation functions, linear equations, linear-differential equations, nonlinear differential equations and integral equations as models, introduction to simulation techniques ordinary differential equations: modeling with first order differential equations: Newton's law of cooling; radioactive decay; motion in a gravitational field; population growth; mixing problem; Newtonian mechanics. Modeling with second order differential equations: vibrations; Modeling with periodic or impulse forcing functions, Modeling with systems of first order differential equations; Partial Differential Equations: Methodology of mathematical modeling; objective, background, approximation and idealization, model validation, compounding, Modeling wave phenomena (wave equation); Modeling the heat equation and some application to heat conduction problems in rods, Modeling the potential equation (Laplace equation), Applications in fluid mechanics, gravitational problems, Equation of Continuity.
Recommended Books:

- F. R. Giordano, MD.Weir, *Differential Equations: A Modeling Approach*, 1994, Addison- Wesley, Reading, Ma, USA
- K. K. Tung, *Topics in Mathematical Modeling*
- U. T. Myint, L. Debnath, *Partial Differential Equations for Scientists and Engineers* (3rd edition), 1987, North Holland, Amsterdam
- S. Robert*, An Introduction to Programming and Numerical Methods in MATLAB*

MEC- 675 Advanced Group Theory

Pre-requisite(s)**:** Basic Algebra
Credit Hours: 3+0
Specific Objectives of the Course: The advance algebra is the extention of Abstract algebra which has many applications in structure analysis, etc.
Course Contents: Sylow theory**,** applications of Sylow theory, generating systems for finite symmetric and alternating groups. Simple groups, simplicity of An for 5, Zassenhaus lemma, Normal series, Composition series, Jordan Holder theorem, Solvable groups, The derived series of a group, The lower and upper Central series of a group and Nilpotent groups.

Recommended Books:

- E. Arnold, *Rings, Fields and Groups: An Introduction to Abstract Algebra*, 1983
- A Majeed, *Group Theory*, Ilmi kitab Khana
- Zia-Ul-Haq, *Mathematical Techniques*, Carvan Books Publishing Company
- J. B. Farleigh, *A First Course in Abstract Algebra* (7^{th} edition), Addison-Wesley, Reading, Ma., USA
- I. D. Macdonald, *The Theory of Groups*, 1975, Oxford Clarendon Press, Ma., USA
- Kiramat Husain Dar, Abstract Algebra, ilmi Kitab Khana Lahore.

MEC-676 Optimization Theory

Prerequisite(s): Basic Algebra, Real Analysis

Credit Hours: 3 + 0

Specific Objectives of the Course:

The main objective is to teach the basic notions and results of mathematical programming and optimization. The focus will be to understand the concept of optimality conditions and the construction of solutions. Students should have a good background in analysis, linear algebra and differential equations.

Course Outline:

Linear programming: simplex method, duality theory, dual and 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, functional depending on several variables, variational problems in parametric form, transportation models and networks.

Recommended Books:

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

MEC-677 Measure Theory

Prerequisite(s): Real analysis and Basic topology

Credit Hours: 3+0

Specific Objective of the Course:

This course is devoted to Lebesgue integration and related topics, a basic part of modern analysis. There are classical and abstract approaches to the integral, and we have chosen the classical one. The classical approach is based on the theory of measure. Measure can be defined and studied in various spaces, but we will primarily consider n-dimensional Euclidean spaces.

Course Outlines:

Limit superior , Limit inferior, Measure, Outer measure, Lebesgue measure, Counting Measure, Lebesgue Measurable set, Measurable functions, Elementary properties of measurable function, Lebesgue integral, Riemann integral, Relationship between Riemann and Lebesgue integral, Properties of the Lebesgue integral, The integral of arbitrary measurable functions, Relation between Riemann–Stieltjes and Lebesgue integrals, L^p spaces, Properties of L^p spaces, Holder inequality, Minkowski inequality.

Recommended Books:

- Richard L. Wheeden and Antoni Zygmund, *Measure and Integral, An Introduction to Real Analysis*
- Elias M. Stein & Rami Shakarchi, *Real Analysis Measure Theory, Integration and Hilbert Spaces*, Princeton University Press Princeton and Oxford
- N. L. Carothers, *Real Analysis*, Cambridge University press

MEC-678 Fluid Mechanics

Prerequisite(s): Calculus, Basics of Physic

Credit Hours: 3 + 0

Course Outline:

Real and ideal fluids, Force , Pressure, Density, Specific volume, Specific weight, Stress and strain, Young's modulus, Viscosity, Surface tension, Steady and unsteady flow, turbulent flow, laminar flow, two-dimensional flow, three-dimensional flow, Eulerian and Lagrangian Flow Descriptions, Path line, Streamline, stream tube, Stream filament, Stream surface, Streak line, The equation of continuity, The acceleration field, The Euler equation, The total derivative, Bernoulli's theorem, Flow of dry water continued, Flux, Vorticity and rotation, The velocity potential, Laplace's equation, Uniform flow, Source and sink, Viscosity, Deformation, The equations of motion for viscous (wet) fluids, The Navier-Stokes equation, Viscous, incompressible, laminar flow, A. channel flow (2D counterpart of pipe flow), No-Slip Condition, Channel flow, Laminar flow in a pipe, Viscous flow past a circular cylinder, Reynolds number, Reynolds number.

Recommended Books:

- Buffler, *Introduction to fluid mechanics PHY2009S*, Department of Physics, University of Cape Town
- Kundu and Cohen, *Fluid Mechanics*, 4th Edition, by Academic Press, NY. 2008
- G. K. Batchelor, *An Introduction to Fluid Dynamics*, 2nd Edition, by Cambridge University Press, Cambridge. 2000
- F. M. White, *Fluid Mechanics*, 7th Edition, McGraw Hill, NY, 2011

MEC-679 Stochastic Processes

Prerequisite(s): Calculus and Mathematical Statistics

Credit Hours: 3+ 0

Specific Objectives of the Course:

The objectives of this course is to make certain that each student knows the theoretical methods of probability models and stochastic processes including Markov chains, Brownian Motion, Queuing theory, and stochastic differential equations.

Course Outline:

Review of probability theory with main emphasis on conditional probability and conditional expectation, Theory of Markov chains, Continuous-time Markov chains, Renewal theory and its application, Queuing theory, stochastic processes, stopping times, continuous times martingales, the Doob-Meyer Decomposition theorem, continuous square-integrable Martingales, Random Walk, Brownian motion, the strong Markov property and the reflection principal, Brownian

Filtration, the Brownian sample path, stochastic integrals, The Ito rule, The Girsanov's Theorem, stochastic differential equations, strong solutions, weak solutions, Gauss-Markov processes, the general one dimensional linear equation, connections with partial differential equations.

Recommended Books:

- H. Taylor and S. Karlin, *An Introduction to Stochastic Modeling*, 3rd edition, 1998
- Sheldon M. Ross, *Introduction to Probability Models*, 10th edition, 2010
- N. Shiryaev, *Probability*, Springer, New York, 1995
- Karatzas, St. Shreve, *Brownian Motion and Stochastic Calculus*, Springer-Verlag, New York 1992

MEC-683 Quantum Mechanics

Prerequisite(s): Modern Physics

Credit Hours: 3+0

Course Outline:

Wave-Particle, Plan-Einstein relation, Debroglie relations, Schrodinger equation, Normalization of wave function, Waves-Pocket, Heisenberg indeterminacy or UIXCER Taint principal, Phase velocity, Group velocity, Stationary states, Properties of a waves function, Linear operators, Orthogonal basis in waves equation, Closure relation, Parseval relation, Orthonormalization relation, Delta functions, Ketand Bro vectors, the adjoint operators, Eigen value equations and observables, Projection operation, Basic postulates of Quantum theory, Implementations of the Schrödinger Equations, Conservative system, Angular momentum, Time-Energy Uncertainty, Raising operators, Spin Observable, Hormonic oscillator, Hydrogenic atoms, Pauli Exclusion Principal.

Recommended Books:

- D. J. Griffiths, *Introduction to Quantum Mechanics*, latest edition
- R. L. Liboff, *Introductory Quantum Mechanics*, 4th edition
- *Quantum Mechanics,* Schaum Outline series

MEC- 684 Heat and Mass Transfer

Pre-requisite(s)**:** Ordinary and Partial differential equations

Credit Hours: 3+0

Specific Objectives of the Course:

This course will provide the basic concepts of conduction, convection and radiation heat transfer. It will help the students to understand how to formulate and be able to solve one and two dimensional conduction heat transfer problems. Solution techniques will include both closed form and numerical methods. Convection effects will be included as boundary conditions. Moreover, the students will understand the fundamentals of the relationship between fluid flow, convection heat transfer and mass transfer and will apply empirical correlations for both forced and free convection to determine values for the convection heat transfer coefficient. They will then calculate heat transfer rates using the coefficients. In addition to this, students will understand the basic concepts of radiation heat transfer to include both black body radiation and gray body radiation and will be able to evaluate radiation view factors using tables and the view factor relationships.

Course Outline:

One-dimensional heat conduction problem, Two-dimensional heat conduction problem, Transient heat conduction, Principles of convection heat and mass transfer, Equations of forced convections, Equations of free convections, Principles of radiation heat transfer, Radiation exchange between surfaces, Heat exchanger analysis, Mass transfer.

Recommended Books:

- Incropera and DeWitt, Fundamentals of Heat Mass Transfer, 6th edition.

MEC- 685 Advanced Number Theory

Prerequisite(s): Number Theory

Credit Hours: 3+0

Specific Objective of the Course:

This course contains some advance topics of number theory, this course enable the students to solve higher degree congruence's. In this course the students also learn to solve an equation containing three variables using modulo concepts etc. This course also familiarize the students with the solutions of an equation in Z_n where n is prime or composite. This subject covers some topics of graduate level.

Course Outline:

Primitive roots, The order of appositive integer, Theory of indices, Lagrange theorem, Polynomials congruence, Quadratic congruence Divisibility in rings, Solutions of Congruence using indices, Quadratic residues, Quadratic residues of primes, Euler Criteria for quadratic residues, Legendre's symbols, Quadratic reciprocity law, The Jacobi symbol, Solution of the problem of the type $ax+by+c=0$, Farey sequences, Continued fractions, Finite continued fraction, Infinite continued fraction, Quadratics congruence with composite moduli, Composites with primitive roots.

Recommended Books:

- I. Niven, H. S. Zuckerman and H. L. Montgomery, *An Introduction to the Theory of Number*, John Wiley & Sons, Inc.
- K. C. Chowdhury, *A First Course in Number Theory*, Asian Book Private Limited
- T. Koshy, *Elementary Number Theory with Applications*, Academic Press is an imprint of Elsevier Kenneth
- H. Rosen, *Elementary Number Theory and its Applications*, Addison-wesley

MEC- 686 Analytical Dynamics

Pre-requisite(s): Classical Mechanics and PDEs

Credit Hours: 3+0

Course Outline:

Dynamics of a Rigid Body; Moments and product of inertia, D' Alembert's principle, Motion about a fixed axis, Linear Momentum and Kinetic energy of a rigid body, Compound pendulum, Motion in two dimension, Finite forces; impulsive forces, Lagrange's equations in generalized coordinates, Dynamics of a Particle; Uniplanar motion, acceleration parallel to fixed axes, polar coordinates, moving axes, central forces, stability of orbits, acceleration varying as the inverse square of the distance, Kapler's laws, Planetary motions, Tangential and Normal accelerations, Motion in a resisting medium, Angular momentum and rate of change of angular momentum for a system of particles.

Recommended Books:

- S. L. Loney, Dynamics of a particle and Rigid Bodies
- F. Charlton, A Text Book of Dynamics

MEC-687 Difference Equations

Prerequisites: ODEs, PDEs and Numeric and symbolic computations

Credit Hours: 3+0

Aims and objectives: Many problems in probability give rise to difference equations. Difference equations relate to differential equations as discrete mathematics relates to continuous mathematics. Anyone who has made a study of differential equations will know that even supposedly elementary examples can be hard to solve. By contrast, elementary difference equations are relatively easy to deal with. Aside from probability, computer scientists take an interest in difference equations for a number of reasons. For example, difference equations frequently arise when determining the cost of an algorithm in big-O notation. Since difference equations are readily handled by program, a standard approach to solving a nasty differential equation is to convert it to an approximately equivalent difference equation.

Course Contents: Introduction to difference equations**,** classification of difference equations, homogeneous and inhomogeneous, linear and nonlinear difference equations of order one, two and n-order. Difference equations with variable and constants coefficients. Solutions of difference equations by undermined coefficient method. Characteristic polynomial of the equation. Complementary and particular solutions of difference equations. Some Applications of difference equations to real world problems.

Recommended Books:

- Mathematical Methods, Ilmi Kitab Khana, Lahore
- Chiang, Alpha. *Fundamental Methods of Mathematical,Economics*, McGraw-Hill, 3rd Ed
- Baumol, William. *Economic Dynamics*, Macmillan, third edition, 1970

MEC-688 Convex Analysis

Prerequisite: Real and Complex Analysis

Credit Hours: 3+0

Specific Objectives of the Course: This course will focus on fundamental subjects in convexity, duality, and convex optimization algorithms. The aim is to develop the core analytical and algorithmic issues of continuous optimization, duality, and saddle point theory using a handful of unifying principles that can be easily visualized and readily understood.

Course Contents: Basic convexity concepts, Definition of a Convex Set, Examples of Convex Sets, Convex Cones Supporting Hyperplane, Hyperplanes and conjugacy, Separation of Disjoint Convex Sets, Convex Functions, Definition of a Convex Function, Properties of Convex Functions, Convexity of Level Sets, Continuity of Convex Functions, Generalizations of Convex Functions, Quasiconvex Functions, Pseudo convex Functions, Relationship Among Various Types of Convexity, Convexity at a Point, Convexity and optimization, Polyhedral convexity, Lagrangian duality, Fenchel duality, conic duality, saddle point theory. Convexity in Hilbert spaces and its applications.

Recommended Books:

- Bertsekas, Dimitri. *Convex Optimization Theory*. Athena Scientific, 2009
- Rockafellar, Ralph. *Convex Analysis*. Princeton University Press, 1996.
- Boyd, Stephen, and Lieven Vandenberghe. *Convex Optimization*. Cambridge University Press, 2004

- Kreyszig - Introductory Functional Analysis with Applications, latest edition.

MEC-689 Econometrics
Prerequisite (s): Introduction to Economics and Mathematical Statistics
Credit Hours: 3+0
Specific Objectives of Course:
The course provides a foundation to estimate econometric models with special emphasis on ordinary least square method.
Course Outline:
Introduction, definition and scope of econometrics, econometric models vs. statistical models, ingredients of econometric modeling, specification, estimation, verification or evaluation and forecasting, The classical linear regression model, the simple linear regression model (SLRM), estimation of SLRM by ordinary least squares (OLS) interpretation of estimated coefficients and their economic meanings, hypothesis testing and analysis of variance, the multiple linear regression model (MLRM), estimation of MLR model by OLS and its assumptions interpretation of estimated coefficients and their economic meanings, regression through origin, double log estimation and computation of elasticities, using R-square and adjusted R-square as a measure of 'Goodness of Fit' and some problems with its use, testing the significance of individual coefficients, testing the significance of the model as a whole, analysis of variance.
Recommended Books:
- D. Gujrati, *Basic Econometrics*, Mc-Graw Hill, (latest edition)
- Koutsoyiannis, *Theory of Econometrics*, McMillan, (latest edition)
- G. M. K Madnani, *Introduction to Econometrics Principles and Applications*
- R.J. Wonnacot, *Econometrics*, John Wiley, New York
- Wonnacot, E. Pindyck, *Econometric Models & Economic Forecasts*, 3rd edition
- Griffiths, Judge, *The Theory and Practice of Econometrics*, John Willey and Sons

Study Tour of Students

Study tours can vary from short term (3 days) to long term (01 week). The study tours have many positive outcomes one of it is a learning component, secondly it include numerous recreational and cultural activities within the country. The students shall develop their trend of research, academics, curricular and co-curricular activities of the visited centers/ institutions. Further, carrier counseling shall be arranged for the students in various institutions/ industries. Therefore, in 8th semester of BS-Mathematics students shall be allowed a study tour by the Shaheed Benazir Bhutto University, Sheringal, Dir (U). The cost includes transportation, food, accommodation and remuneration for the tour incharge(s) by the Shaheed Benazir Bhutto University, Sheringal, Dir (U).

Annexure B

Item No: 02

Master of Philosophy in Mathematics

Doctor of Philosophy in Mathematics

Degree Awarded: Master of Philosophy in Mathematics (M.Phil in Mathematics)

Doctor of Philosophy in Mathematics (PhD in Mathematics)

Marks Breakdown for Courses

Item	**Maximum Marks for Courses (3 - 0)**
Mid-Term Examination	30%
Internal Marks (Assignments, Quizzes, Presentations)	20%
Final-Term Examination	50%
Total	100

Master of Philosophy in Mathematics

Degree Awarded: Master of Philosophy in Mathematics (M.Phil in Mathematics)

Entrance Requirements: AS per HEC criteria.

Total Credit Hours: As per SBBU Byelaws.

SCHEME OF STUDIES
(Semester-Wise Breakdown)

1th Semester

S. No.	Course Code	Course Title	Marks	Credit Hours
1	MAT-	Core-I	100	3(3-0)
2	MAT-	Core –II	100	3(3-0)
3	MAT-	Core –III	100	3(3-0)
4	MAT-	Core-IV	100	3(3-0)
Total			**400**	**12**

2th Semester

S. No.	Course Code	Course Title	Marks	Credit Hours
5	MAT-	Elective-I	100	3(3-0)
6	MAT-	Elective-II	100	3(3-0)
7	MAT-	Elective-III	100	3(3-0)
8	MAT-	Elective-IV	100	3(3-0)
Total			**400**	**12**

Doctor of Philosophy in Mathematics

Degree Awarded: Doctor of Philosophy in Mathematics (PhD in Mathematics)

Entrance Requirements: M.Phil/ MS in Mathematics with at least 3 CGPA with other requirement as per HEC policy.

Total Credit Hours: 18 Credit hour for course work and PhD thesis.

SCHEME OF STUDIES
(Semester-Wise Breakdown)

1th Semester

S. No.	Course Code	Course Title	Marks	Credit Hours
1	MAT-	Core-I	100	3(3-0)
2	MAT-	Core-II	100	3(3-0)
3	MAT-	Core-III	100	3(3-0)
Total			**300**	**09**

2nd Semester

S. No.	Course Code	Course Title	Marks	Credit Hours
	MAT-	Elective-I	100	3(3-0)
	MAT-	Elective-II	100	3(3-0)
	MAT-	Elective-III	100	3(3-0)
Total			**300**	**09**

CORE COURSES

S. No	Course Code	Course Name	Credit hours
1	MAT-801	Advanced Real Analysis	03
2	MAT-802	ODEs and Computational Linear Algebra	03
3	MAT-803	Mathematical Techniques	03
4	MAT-804	Partial Differential Equations	03
5	MAT-805	Integral Equations	03
6	MAT-806	Group Theory	03
7	MAT-807	Functional Analysis	03
8	MAT-808	Numerical Methods	03
9	MAT-809	Riemannian Geometry	03
10	MAT-810	Advanced Mathematical Physics	03
11	MAT-811	Metric Fixed Point Theory	03
12	MAT-812	Fractional Differential Equations	03
13	MAT-813	Computational Fluid	03
14	MAT-814	Ring Theory and Applications	03
15	MAT-815	Impulsive Differential Equations	03
16	MAT-816	Fixed Point Theory in Modular Function Spaces	03

MAT-801 Advanced Real Analysis
Credit hours: 3
Specific Objective of the Course: This course will appeal to the students in pure and applied mathematics as well as research in statistics, education, engineering and economics. This course addresses functions spaces and provides familiar applications, such as the Weierstrass and Stone-Weierstrass approximation theorems, functions of bounded variation, Riemann-Stieltjes integration etc. This course is an enormous field with application to many areas of mathematics. Roughly speaking, it has applications to any setting where one integrates functions, ranging from harmonic analysis on Euclidean space to partial differential equations on manifolds, from representation theory to number theory, from probability theory to integral geometry, from ergodic theory to quantum mechanics.
Course Outlines: Infinite Dimensional Spaces, Sequence Spaces, Completions, Metric Spaces, Quasi Metric Space, Normed Vector Spaces, Limits in Metric Spaces, More Inequalities, Continuous Functions, Homeomorphisms, The Space of Continuous Functions, Connected Sets,

Compactness, Continuous Functions on a Compact Interval, Compact Metric Spaces, Sequences of Functions, Point wise and Uniform Convergence ,Interchanging Limits, The Space of Bounded Functions, Functions of Bounded Variation, Separable Spaces, Power Series, Radius of Convergence, Riemann-Stieltjes Integral ,The Space of Integrable Functions.

Recommended Books:

- N. L. Carothers, Bowling Green State University, Real Analysis, Cambridge University Press.
- Mukherjea and K.Pothoven, University of South Florida Tampa, Real and Functional Analysis, Plenum Press. New York and London.
- Arthur Mattuck, Massachusetts Institute of Technology, Introduction to Analysis, Prentice Hall Upper Saddle River, New Jersey 07458.
- Anthony W. Knapp, Basic Real Analysis, Birkhauser Bosten. Basel.Berlin.

MAT-802 ODE's and Computational Linear Algebra

Credit hours: 3

Specific Objective of Course:

Many physical laws are most simply and naturally formulated as differential equations. For this reason, differential equations have been studied by the greatest mathematicians and mathematical physicists since the time of Newton. Differential equations are mostly used in dynamical systems and electrical networks. They are much easier to treat than partial differential equations, whose unknown functions depend on two or more than two independent variables.

Course Outlines:

Review of Ordinary Differential Equations including First, Second and high Order Linear differential Equations with Constant and variable Coefficients. Modeling with first and higher order differential Equations. Modeling with first and higher order nonlinear differential equations. Power Series Solutions about Ordinary, Regular and Singular Points, Plane Autonomous Systems, Existence and Uniqueness Theorems, Strum-Lowville Systems, Expansions in Eigen Functions. Eigen values and Eigen vectors and their applications to systems of ODEs. Orthogonal functions and Fourier series analysis.

Recommended Books:

- Ordinary Differential Equations Fourth Edition By Garrett Birkhoff Harvard University
- Differential Equations Computing and Modeling Fourth Edition C. Henry Edwards and David E. Penny University of Georgia

MAT- 803 Mathematical Techniques

Credit hours: 3

Course objectives: The main objective of this course is to familiarize students with a range of mathematical terminology that are essential for solving advanced problems in applied sciences.

Course contents: Introduction to complex algebra; complex functions; De Moivre formula; Cauchy-Riemann conditions; line integral; Cauchy's integral theorem; Cauchy's integral formula; Cauchy's integral and derivative of the functions; Taylor expansion; analytic extension; poles of the function; determination of residues; Laurent development; mapping; cut line, branch point and multi-valued functions; conformal mapping; singularities; Residue Theorem; Cauchy principal value. Complex vector spaces, Hermitian inner products, The eigenvalue problems and application, Eigenvectors and eigenvalues, Diagonalisability, Spectral theorem for hermitian transformations,: quadratic forms Application: normal modes , Application: near equilibrium dynamics . Analytic functions, Differentiability and analyticity, Complex powers and line integrals, Laurent series and Contour integrals, residues and contour integrals, Integrals on the Real Axis. Special functions, Gamma, Beta and Mittage Leffler functions, the zeta functions. Conformal mapping and conformal derivative and integrals. Sequences and Series, Fourier series and its consequences. The Fourier series of periodic functions, Application: steady-state response.

Recommended Books:

- J. Figueroa-O'Farrill **,** Mathematical Techniques III , Second Version of December 5, 2004.
- D. Jordan, ,Mathematical techniques, 1994
- D. Jordan , Mathematical Techniques: An Introduction for the Engineering, Physical, and Mathematical Sciences 4th Edition, ISBN-13: 978-0199282012.

MAT-804 Partial Differential Equations

Credit hours: 3

Aims and Objectives: Mathematical models involving evolutionary partial differential equations (PDEs) as well as ordinary differential equations (ODEs) arise in many diverse applications, such as fluid flow, image processing and computer vision, physics-based animation, mechanical systems, relativity, earth sciences, and mathematical finance.

Contents:

Introduction to PDEs, classifications of PDEs and review of separation of variable method. Introduction to the heat equation, Wave equations, The Heat and Wave Equations in 2D and 3D Quasi Linear PDEs. Introduction to the fundamental solution, uniqueness of the solutions. Fundamental solution and the global Cauchy problem of heat and wave equations. Laplace's and Poisson's equations, Fundamental solution and Green functions. Introduction to Schrödinger's equation, Transport equations and Burger's equation. The Maxwell equations of electrodynamics. Infinite Domain Problems and the Fourier Transform.

Recommended Books:

- N. Sneddon, Elements of Partial Differential Equations, McGraw-Hill Book Company
- R. Ennemyer, Introduction to Partial Differential Equations and Boundary Value Problems, McGraw-Hill Book Company
- M. Humi, and W. B. Miller, Boundary Value Problems and Partial Differential Equations, PWS-Kent Publishing Company, Boston
- C. R. Chester, Techniques in Partial Differential Equations
- R. Haberman, Elementary Applied Partial Differential Equations
- Salsa, Sandro. *Partial Differential Equations in Action: From Modelling to Theory*. Springer, 2010.

MAT-805 Integral Equations

Credit hours: 3

Aims and objectives: Integral equations are the important tools to model many real world problems related to physics, biology, dynamics etc. The existence theory for the said equations is important to investigate physical behavior of the phenomenon's and process.

Course contents: Preliminary concept of the integral equation, Historical background of the integral equations. Classification of integral equations: Volterra integral equations, Fredholm integral equations, Singular integral equations, Integro-differential equations. Converting Volterra equation to ODE, Converting IVP to Volterra equations, Converting BVP to Fredholm integral equations, Types of solution techniques. The method of successive approximations. Existence theorem of Picard's method. Abel's problem. The weakly-singular Volterra equation.

Recommended Books:

- Integral Equations and their Applications. WITeLibrary. Home of the Transactions of the Wessex Institute, the WIT electronic-library 2001.
- Solutions of Nonlinear Integral Equations and Their Application to Singular Perturbation Problems. Thesis by. Douglas Warren vlillett. 1963.
- Related Articles.

MAT-806 Group Theory

Credit hours: 3

Course Outline:

Introduction to Sylow theory and its Applications, Simple groups, Simplicity of An for 5, Zassenhaus lemma, Normal series, Composition series, Jordan Holder theorem, Solvable groups, The derived series of a group, The lower and upper Central series of a group and Nilpotent groups and applications. Growth of nilpotent and polycyclic groups, Polynomial growth of nilpotent groups, Wolf 's Theorem for semi-direct products Z^n x Z. Distortion of a subgroup in a group. Solvable groups: Definition and basic properties, Milnor's theorem.

Recommended Books:

- John. B Fraleigh, A first Course in Abstract Algebra, Addison-Wesley Pub Co. London
- M. Hall, Theory of groups, The MacMillan Company N. Y. (1959)
- Lan D McDonald, The theory of groups, Oxford University Press (1975)
- T. Rose, A Course of group theory, Cambridge University Press (1978)
- Majeed, Theory of groups, IImi Kitab Khana, Lahore (1994)
- T. Inui, Y. Tanabe, Y. Onodera, Application of Group Theory in Physics, Springer Verlage, 1990

MAT-807 Functional Analysis

Credit hours: 3

Aims and objectives: To construct existence theory and stability analysis and best numerical techniques required fundamental knowledge of functional analysis. Functional analysis is the backbone in the existence theory, stability analysis and numerical approximations of applied problems arising in science, engineering and technology.

Course contents: Introduction to normed, Banach and Inner product spaces, Hilbert spaces. Bounded linear operators in Hilbert spaces and their various characterizations. Self adjoint, normal, unitary and projection operators. Compact and contraction operators, elementary spectral theory. Introduction to Banach Fixed point theorem and its applications. Iterative methods. Reflexive spaces, Hahn-Banach Theorem for real and complex version. Weak and strong topologies and the Banach-Alouglu theorem. The Main theorem of iterative methods for linear operator equations. Reiz representation theorems and Reiz potentials and its applications.

Recommended Books:

- Functional Analysis by Alexander C. R. Belton, Cambridge University Press, Cambridge, 2004 and 2006.
- E. Kreyszig, Introductory functional analysis with applications, John Wiley & Sons, Inc., New York, 1978.
- P. Lax, Functional analysis, John Wiley & Sons, Inc., New York, 2002.
- G. Pisier, Introduction to Operator Space Theory, London Mathematical Society Lecture Noes Series 294, Cambridge University Press, Cambridge, 2003.
- W. Rudin, Functional analysis, second edition, McGraw-Hill, Inc., New York.
- G. F. Simmons, Introduction to topology and modern analysis, McGraw-Hill, Inc.,New York, 1963.
- J. Weir, Lebesgue integration and measure, Cambridge University Press, Cambridge, 1973.
- E. Kreyszig, Introductory functional analysis with applications, John Wiley & Sons, Inc., New York, 1978.

MAT-808 Numerical Methods
Credit hours: 3
Specific Objective of the Course:
Problems in linear algebra arise in a wide variety of scientific and engineering applications including the design of structures, the analysis of electrical networks, and the modeling of chemical processes. This course will cover the analysis and implementation of algorithms used to solve linear algebra problems in practice. We will study algorithms for linear systems solution, linear least-squares problems, and eigenvalue and singular value problems. We will develop numerical algorithms for these four main-stream problems. The quality of a numerical algorithm is often judged based on two criteria namely efficiency (vaguely speaking number of arithmetic operations required) and accuracy. We will analyze the accuracy and efficiency of the numerical algorithms developed. We will also examine issues of problem sensitivity and algorithmic stability and ways to improve efficiency by taking advantage of special matrix structures.
In each case, we will also study the computational tools underlying the algorithm (generally, techniques for matrix factorization and for introducing zeros into a matrix). Emphasis will be on dense linear algebra although we will introduce sparse linear algebra as class interest and time permit.
Course Outline: This is a general outline of the material we will cover (not necessarily in this order). It is subject to change according to time and class interests.

1. Fundamentals of Numerical Computation
    a. Matrix-Vector operations
    b. Counting of floating point operations
    c. IEEE floating point arithmetic
    d. Vector and matrix norms
    e. Sensitivity analysis and condition numbers
    f. Forward and backward errors and their analysis
2. Numerical Solution of Linear Systems
    a. Properties of linear systems

   b. Solving triangular systems
   c. The Basic Linear Algebra Subprograms
   d. Gaussian elimination
   e. LU decomposition
   f. Cholesky factorization
   g. The sensitivity of linear systems
3. Round-off error, stability, and conditioning
4. Linear Least Squares Problems (Over determined Systems)
   a. Projectors and QR factorization
   b. Gram-Schmidt Orthogonalization
   c. Givens rotations
   d. Householder transformations
   e. The least squares problem defined
   f. Algorithms for the least squares problem
5. Numerical Computation of Eigenvalues and Eigenvectors
   a. Properties of the eigenvalue decomposition
   b. The QR algorithm
   c. Rayleigh quotient iteration
   d. Schur factorization
   e. Sensitivity of eigenvalues and eigenvectors
6. The Singular Value Decomposition and its Computation
   a. Properties of the singular value decomposition
   b. Methods for the singular value decomposition.

Recommended Books:

- Lloyd N. Trefethen and David Bau, "Numerical Linear Algebra", SIAM 1997.
- G. H. Golub and C. F. Van Loan, "Matrix Computations", Johns Hopkins University
- J. W. Demmel, "Applied Numerical Linear Algebra", SIAM 1997.
- D. S. Watkins, "Fundamentals of Matrix Computations", Wiley-Inter-science, 2nd Ed
- Biswa Datta, "Numerical Linear Algebra and Applications", 2nd Edition, SIAM, 2010

MAT-809 Riemannian Geometry

Credit hours: 3

Importance of the course: Basis ideas of Riemannian geometry such as Riemannian metric, covariant differentiation, geodesics and curvature belong to the core of mathematical knowledge and are widely used in applications that range from general relativity in physics to mechanics and engineering. Besides that, this subject is one of the most beautiful in mathematics, containing such gems as Gauss's Theorem Egregious and the Gauss-Bonnet Theorem providing a link with the topology of surfaces. The course introduces these ideas. Riemannian geometry is used in almost all areas of mathematics and its applications, including physics and engineering.

Course Outlines: Introduction of a covariant derivative. Expression in local coordinates. Manifolds, sub manifolds, mappings, vector fields, Lie derivative, Tensors Riemannian connection, covariant derivatives, Riemannian curvature. Isometric immersions, Riemannian submersions, conformal metrics. Exponential map, Jacobi fields, conjugate points. Complete manifolds, Hadamard manifolds. Spaces of constant curvature: hyperbolic space. Symmetric spaces, homogeneous spaces. Cut locus, closed geodesics, Preissman's Theorem. Complete manifolds of nonnegative curvature. Flat manifolds, Bieberbach's theorem, almost-flat manifolds.

Recommended Books:

- I. Chavel: Riemannian Geometry, a modern introduction
- F. Warner, Foundations of Differentiable Manifolds and Lie groups
- S. Kobayashi, K. Nomizu, Foundations of Differential Geometry
- M Hirsch, Differential Topology
- M. do Carmo, Riemannian Geometry
- J. Cheeger, D. Ebin, Comparison Theorems in Riemannian Geometry
- J. Milnor, Morse Theory

MAT-810 Advanced Mathematical Physics

Credit hours: 3

Importance: In this course we will discuss mathematical techniques used to solve physical problems.The goal of this course is to help the research students to make connections between some of their preparatory math work and their current and future physics courses.

Course Outlines: Introduction to Vector spaces, inner product and Hilbert spaces, Rotations, transformations, and linear operators. Eigenvalues, Diagonalization, and Special Matrices. Spectral properties of linear operator's spectrum and resolvent set. Radius of convergence of matrices. Normal modes. Curvilinear coordinates and parallel transport. Differential operators in curvilinear coordinates. Green's functions; self-adjoint differential equations; hermitian operators, Gram-Schmidt orthogonalization process; orthogonal polynomials; completeness of the Eigen functions; Bessel's inequality; Schwarz inequality; expansion of Green's functions; Green's functions in one dimension; Dirac delta function; gamma function; Bessel functions of the first kind; Legendre polynomials; associated Legendre polynomials; Spherical function; Hermite polynomials; Laguerre polynomials; associated Laguerre polynomials; calculus of variations; Rayleigh-Ritz variational technique. Differential equations and series solutions. The Sturm-Liouville problem. Representation and a little on Lie groups analysis.

Recommended Books:

- Butkov, *Mathematical Physics* Addison Wesley
- Courant & Hilbert, *Methods of Mathematical Physics*
- Arfken & Weber, *Mathematical Methods for Physicists* 6th ed. Elsevier.
- Lea, *Mathematics for Physicists* Thompson Brooks Cole.

MAT-811 Metric Fixed Point Theory
Credit hours: 3
Course Contents:
Metric Spaces, Normed Spaces, Banach Spaces, Fixed point Space, Banach Contraction Principle(BCP) and its applications, The Converse problem, Extension and generalization of Banach Contraction principle , Caristi, s fixed theorem , Boyd–Wong Theorem**,** Set valued contractions, generalized contractions(Kannan contraction, Cheterge contraction , weak contraction, rational type contraction etc.) , Multivalued versions of BCP, Hausdorff metric, Nadler' fixed point theorem, Some extensions of BCP under generalized distances, Fixed point for non-expensive mappings, Ultra Metric Spaces and its Properties.
Recommended Books:
- Fixed Point Theory and Applications, R. Agarwal, M. Meehan and D. O Regan , Cambrige University Press
- Topics in Fixed Point Theory by Saleh_Almezel, Qamrul Hasan_Ansari Mohamed Amine_Khamsi Springer International Publishing Switzerland 2014.
- E. Kreyszic , Introductory functional Analysis and Applications
- Handbook of Metric Fixed Point Theory by William A. Kirk and Brailey Sims published by Kluwer Academic Publishers
- Fixed Point Theory by Andrzej Granas and James Dugundji, Springer Publisher.

MAT-812 Fractional Differential Equations
Credit hours: 3
Specific Objective of the Course:
Fractional derivatives provide an excellent instrument for the description of memory and hereditary properties of various materials and processes. This is the main advantage of fractional derivatives in comparison with classical integer-order models, in which such effect are in fact neglected. The advantages of fractional derivatives become apparent in modeling mechanical and electrical properties of real materials, as well as in the description of rheological properties of rocks, and in many other fields.
The other large field which requires the use of derivatives of non-integer order is the recently elaborated theory of fractals. Fractional calculus also appears in the theory of control of dynamical systems.
Course Outlines:
Basic concept about Fractional Calculus, Fractional Derivatives and Integrals, introduction to some fixed point theorems including Banach, Schauder and Schaefer etc for obtaining the Existence and Uniqueness Theorems, formation of Green's Function, Other Methods for the Solution of Fractional-order Equations, existence theory for one, two and more solutions of Fractional-order equations and their Systems and Controllers, Survey of Applications of the Fractional Calculus.
Recommended Books:
- An Introduction to Fractional Derivatives, Fractional Differential Equations, by Igor Podlubny Technical University of Kosiee, Slovak Republic.

- An Introduction to Fractional Calculus and Fractional Differential Equations by Kenneth Miller Mathematical Consultant Formally Professor Of Mathematics New York University and Bertram Ross University of New Haven.

MAT-813 Computational Fluid Dynamics
Credit hours: 3
Specific Objective of the Course:
The field of computational fluid dynamics has a broad range of applicability.The first step involves the specification of the problem, including the geometry, flowconditions, and the requirements of the simulation. The geometry may result from measurements of an existing configuration or may be associated with a design study. Alternatively, in a design context, no geometry need be supplied. Instead, a set of objectives and constraints must be specified. Flow conditions might include, for example, the Reynolds number and Mach number for the flow over an airfoil. The requirements of the simulation include issues such as the level of accuracy needed, the turnaround time required, and the solution parameters of interest. It is generally accepted that the phenomena of importance to the field of continuum fluid dynamics are governed by the conservation of mass, momentum, and energy.
Course Outlines:
The Basic Equations of Fluid Dynamics, Governing Equations, The Flow and its Mathematical Description, Principles of Solution of the Governing Equations, Partial Differential equations: Analytic aspects, Finite Volume and Finite Difference Discretization on Non-uniform grids, Inviscid Flow, Boundary Layer Flow, Flow Governed by reduced Navier-Stokes Equations, Incompressible Viscous Flow, Compressible Viscous Flow.
Recommended Books:

- Computational Fluid Dynamics: Principles and Applications By J. Blazek AlstomPower Ltd.,Baden-Daettwil, Switzerland.

Principles of Computational Fluid Dynamics By Pieter Wesseling Faculty of Information Technology and Systems Delft University of Technology Netherlands.

MAT-814 Ring Theory and its Applications
Credit hours: 3
Specific Objective of the Course:
Ring theory is important as a foundation for algebraic geometry and complex analytic geometry. The idea of a ring is so fundamental that it is also vital in many applications of Mathematics. Indeed it is so fundamental that many other vital tools of Applied Mathematics are built from it. For example, the crucial notion of linearity, and linear algebra, which is a practical necessity in Physics, Chemistry, Biology, Finance, Economics, Engineering and so on, is built on the notion of a vector space, which is a special kind of ring module.

Course Outlines:
Rings and Fields, Type of Rings, Subring and characteristic of a ring Integral Domain, Fermat' s and Euler Theorem, Ring of Polynomials, Ring Homomorphism , Factorization of Polynomials

over a Field, Eisenstein Criterion, Non-commutative Examples, Ring of Endomorphism, Ordered Rings and Fields, Ideals and Factor Rings, Prime and Maximal Ideals, Sum and Direct Sum of Ideals, Nilpotent and Nil Ideals, Fundamental Homomorphism Theorem, Ideal Structure in $\mathbf{F}[\mathbf{x}]$, Introduction to Extension Fields, Algebraic and Transcendental Elements, Unique factorization domains and Euclidean domains.

Recommended Books:

- P. B. Bhattacharya, S. K. Jain and S. R. Nagpaul, Basic Abstract Algebra, Cambridge University Press.
- D. S. Dummit and Richard M. Foote, Abstract Algebra, John Wiley & Sons, Inc.
- J. B. Fraleigh, A First Course in Abstract Algebra, Pearson.
- H. Matsumura, Commutative ring theory, Cambridge University Press

MAT-815 Impulsive Differential Equations

Credit hours: 3

Aims and objectives: In daily life we are facing to numerous physical and biological phenomenon that are subject to abrupt changes in their sate. Such process and phenomenon include earth quake, fluctuation of economy in financial mathematics, storm and disease dynamics, etc. The impulsive differential equations are increasingly use to model such like process. To make such differential equations applicable different aspects have been investigated for the aforesaid equations including qualitative theory, stability analysis etc.

The aims and objectives of this course is to train graduate students to establish the qualitative theory and derive sufficient conditions for the existence of solutions of impulsive differential equations of classical as well as fractional order.

Course contents: Introduction to impulsive differential equations. Investigation of initial and boundary value problems of impulsive differential equations, their existence theory and stability analysis. Study of nonlocal boundary value problems of impulsive differential equations. Investigation of implicit type impulsive differential equations and their applications. Iterative techniques for impulsive differential equations.

Recommended Books:

- V Lakshmikantham , D D , P S Simeonov, Theory of Impulsive Differential Equations, Series in Modern Applied Mathematics: Volume 6, 1989.
- Mykola Perestyuk, Impulsive differential equations, Institute of Mathematics, Academy of Sciences of the Czech Republic, 2011.
- Yong Zhou , Basic theory of fractional differential equations , World Scientifc Publishing Co. Pte. Ltd **,** 2014.
- A. M. Samoilenko, N. A. Perestyuk, Impulsive differential equations, World Scientific, Singapore, 1995.
- N. A. Perestyuk, V. A. Plotnikov, A. M. Samoilenko, N. V. Skripnik, Differential equations with impulse effects: Multivalued right-hand sides with discontinuities, DeGruyter Studies in Mathematics 40, Walter de Gruyter Co, Berlin, 2011.

MAT-816 Fixed Point Theory in Modular Function Spaces

Credit hours: 3

Course Contents:

Lebesgue spaces, Modular function spaces, examples of Modular function spaces, Space E_p, convergence theorem, Vitali Property, Uniform Convexity in Modular Function Spaces, Parallelogram Inequality and Minimizing Sequence Property, Uniform Non-compact Convexity in Modular Function Spaces, Contractions in Modular Function Spaces, Nonexpansive and Pointwise Asymptotic Non-expansive Mappings, KKM and Ky Fan Theorems in Modular Function Spaces, Fixed Point Construction Processes, Modular Metric Spaces, Banach Contraction Principle in Modular Metric Spaces, Non-expansive Mappings in Modular Metric Spaces.

Recommended Books:

- 1.Fixed Point Theory in Modular Function Spaces, Mohamed A. Khamsi and Wojciech M. Kozlowski, 2008.

ELECTIVE COURSES

S. No	Course Code	Course Name	Credit hours
1	MAT-817	Graph Theory	03
2	MAT-818	Applied Dimensional Analysis and Modeling	03
3	MAT-819	Fractional Calculus	03
4	MAT-820	Numerical Solutions of Differential Equations	03
5	MAT-821	Dynamical Systems and Ergodic Theory	03
6	MAT-822	Mathematical Modeling in Physical Sciences	03
7	MAT-823	Methods of Mathematical Physics	03
8	MAT-824	Dynamical Systems and Control Theory	03
9	MAT-825	Topological Fixed Point Theory	03
10	MAT-826	Fuzzy Fixed Point Theory	03
11	MAT-827	Fuzzy Sets and their Applications	03
12	MAT-828	Applications of Fixed Point Theory in Generalized Spaces	03
13	MAT-829	Advance Mathematical Methods	03
14	MAT-830	Mathematical Methods For Arbitrary order Differential Equations	03
15	MAT-831	Theory of Majorization	03
16	MAT-832	Fuzzy Algebra	03
17	MAT-833	Nonlinear Analysis and its Applications	03
18	MAT-834	Near Rings	03
19	MAT-835	Topological Algebra	03
20	MAT-836	Nilpotent And Soluble Groups	03
21	MAT-837	Nonlinear Dynamics and Nonlinear Waves Phenomena	03
22	MAT-838	Advanced Optimization Theory	03
23	MAT-839	Dynamical System Theory	03
24	MAT-840	Biomechanics	03
25	MAT-841	Applied Numerical Analysis	03

26	MAT-842	Mathematical Biology	03
27	MAT-843	Graph Labeling	03
28	MAT-844	LA-semi groups	03
29	MAT-845	Lebesgue Spaces with Variable Exponent	03
30	MAT-846	Advanced Measure Theory	03
31	MAT-847	Semi group Theory	03
32	MAT-848	Fuzzy Group Theory	03
33	MAT-849	Approximation Theory	03
34	MAT-850	Finite Element Methods	03
35	MAT-851	Fourier Analysis	03
36	MAT-852	Numerical Methods for Partial Differential Equations	03
37	MAT-853	Bio-Mathematics	03
38	MAT-854	Advanced Fluid Mechanics	03
39	MAT-855	Introduction To Computational Soft wares and Research Methodology	03
40	MAT-856	Mathematical Inequalities And Applications	03
41	MAT-857	Advance Convex Analysis	03
42	MAT-858	Theory of Semirings	03
43	MAT-859	MPhil Dissertation	18
44	MAT-960	PhD Dissertation	36

MAT-817 Graph Theory

Credit hours: 3

Course Outlines:

Introduction, Basic definitions and examples, subgraphs, adjacency matrix of a graph, graph isomorphism, connectivity, paths and cycles, Eulerian graphs, Hamiltonian graphs, trees and spanning trees, labeling of trees, minimum spanning trees, Kruskal's and prim'salgorithm for finding minimum spanning trees, bipartite graphs and multipartite graphs, planar graphs, line graphs, Euler's formula, Dual graphs, product of graphs, coloring of graphs, graphs labeling, bandwidth labeling of graphs.

Recommended Books:

- Theory and Problems of Graph theory, by V.K. Balakrishnan, Schaum's Oulines Series
- Graph theory III by Reinhard Diestel, Electronic Edition 2005
- Introduction to Graph Theory by R.J Wilson, Fourth edition
- Graph theory with applications by J. A. Bondy and U. S. R. Murty 1982

MAT-818 Applied Dimensional Analysis and Modeling

Credit hours: 3

Specific Objectives of the Course:

The student being introduced to dimensional analysis for the first time is always amazed by the demonstration, without recourse to full physical analysis, that the period of oscillation of a simple pendulum must be proportional to the square root of the pendulum length and independent of its mass. The rationale for this relationship is, of course, based on the simple argument that each term of a "properly" constructed physical equation needs to be dimensionally homogeneous with the others. Likewise, the student is also impressed by the application of such results to predicting full-scale behavior from measurements using a scale model. From this simple example, dimensional arguments can be taken to increasing levels of complexity, and can be applied to a wide range of situations in science and engineering.

Course Outlines:

Mathematical Preliminaries, Formats and Classification**,** Dimensional Systems**,** Transformation of Dimensions, Arithmetic of Dimensions, Dimensional Homogeneity, Structure of Physical Relations, Systematic Determination of Complete Set of Products of Variables, Transformations, Number of Sets of Dimensionless Products of Variables, Dimensional Modeling.

Recommended Books:

- Applied Dimensional Analysis and Modeling by Thomas Szirtes Toronto, Ontario, Canada

MAT-819 Fractional Calculus

Credit hours: 3

Aims and objectives of the course: The recent trends in applied analysis is due to its tremendous applications in various field of science and engineering and other disciplines of applied sciences. One of the most interesting area is devoted to fractional calculus. Inview of classical calculus and real and complex analysis, the concept of derives and integrals are extended to fractional order for both differentiations and integrations. Such type of generalization of classical calculus is known as fractional calculus which is an active area of research today.

Contents: Special functions, The Gamma function, The Beta function, The Mittage-Leffler function, the Meline Rose function and the Wright function. Difference operator, forward and backward operators. Historical origins of fractional calculus. Introduction to fractional order derivatives and integrals. Riemann, Liouville-Caputo fractional derivative-Riesz-Feller fractional derivative-Grunwal-Letnikov, Hadamard fractional derivative. The Riemann-Liouville, the Caputo's, types derivatives and their properties and relationship. Fractional order derivatives and integrals of polynomials, rational and trigonometric functions. The left and right fractional order derivatives. Basic properties of fractional order derivatives and integrals (Linearity, composition, etc.), Leibnitz's rules of fractional differentiations. Geometrical interpretation of fractional order derivatives and integrals. Laplace of fractional order derivatives and integrals. Fourier transform of fractional order derivative. Solutions of linear ordinary fractional order differential equations by using Laplace. Introduction to Milin's Transform and its applications.

Recommended Books:

- I. Podlubny, Fractional differential equations (Mathematics in Science and Engineering vol 198, 1998.
- Tomas Kissela, Fractional differential equations and their applications, Diploma thesis, 2008.
- Kazufumi Ito, Fractional Evolution equations and their applications, Lecture notes, North Carolina state university, Department of Mathematics, Carolina Raleight, USA.
- Kai Diethelm, The Analysis of Fractional Differential Equations, Springerverlag, Braunschweig, 2010.

MAT-820 Numerical Solutions of Differential Equations

Credit hours: 3

Aims and objectives: Most of the mathematical models of nonlinear phenomenon of applied sciences and engineering has not exact solution. Therefore, it is necessary to seek the solutions to these problem approximately. For the best approximation, strong numerical techniques are required to find best approximate solutions to both ordinary and partial differential equations. The aims and objectives of this course is to train the researches of applied mathematics to develop numerical procedure for ordinary and partial differential equations.

Course contents: Introduction to Euler, modified Euler method, Taylor polynomials, Range-Kutta methods and its applications. Predictor-Corrector methods and its applications to fined numerical solutions of differential equations. Introduction to integral transforms like Hinkle, Sumudu, Natural and Fourier transforms and their applications to solve differential equations.

Recommended Books:

- Ordinary differential equations and Dynamical Systems, Gerald Teschl, 2004
- Elementary differential equations and boundary value problems / William E. Boyce Richard C. DiPrima – 7th ed , John Wiley & Sons, Inc., 605 Third Avenue, New York
- Cheney, W. and Kincaid, D., "Numerical Mathematics and Computing," Third Edition, Brooks/Cole Publishing Company, 1994.

- Buchanan, J.L. and Turner, P.R., "Numerical Methods and Analysis," McGraw-Hill, 1992.
- Numerical Analysis 9th-ed, Richard L. Burden and J. Douglas Faires, 2006, Brooks/Cole 20 Channel Center Street Boston, MA02210 USA.
- Ascher, U. M., R. M. M. Mattheij, and R. D. Russell, *Numerical solution of boundary value problems for ordinary differential equations*, Prentice-Hall, Englewood Cliffs, NJ, 1988, 595 pp. QA379.A 83 *712.*
- Botha, J. F. and G. F. Pinder, *Fundamental concepts in the numerical solution of differential equations*, Wiley-Interscience, New York, 1983, 202 pp. QA374.B74 *356.*

MAT-821 Dynamical Systems and Ergodic Theory

Credit hours: 3

Specific Objective of the Course:

The course will provide an introduction to subject of dynamical systems, from a pure-mathematical point of view. The first part of the course will be driven by examples so that students will become familiar with various basic models of dynamical systems. We will then develop the mathematical background and the main concepts in topological dynamics, symbolic dynamics and ergodic theory. Dynamical systems are an exciting and very active field in pure and applied mathematics, which involves tools and techniques from many areas such as analyses, geometry and number theory. A dynamical system can be obtained by iterating a function or letting evolve in time the solution of equation. Even if the rule of evolution is deterministic, the long term behavior of the system is often chaotic. Different branches of dynamical systems, in particular ergodic theory, provide tools to quantify this chaotic behaviour and predict it in average. At the beginning of this lecture course we will give a strong emphasis on presenting many fundamental examples of dynamical systems, such as circle rotations, the baker map on the square and the continued fraction map. Driven by the examples, we will introduce some of the phenomena and main concepts which one is interested in studying. In the second part of the course, we will formalize these concepts and cover the basic definitions and some fundamental theorems and results in topological dynamics, in symbolic dynamics and in particular in ergodic theory. We will give full proofs of some of the main theorems. During the course we will also mention some applications both to other areas of mathematics, such as number theory, and to very concrete problems as data storage and Internet search engines.

Course Outlines: Basic notions: dynamical system, orbits, fixed points and fundamental questions; Basic examples of dynamical systems: circle rotations; expanding maps of the circle and the shift map; the Baker's map; the CAT map and toralautomorphisms; the Gauss transformation and Continued Fractions. Topological Dynamics: basic metric spaces notions, transitivity, minimality; topological conjugacy; topological mixing; topological entropy. Symbolic Dynamics: Shift and Subshifts spaces, topological dynamical properties of shift spaces, symbolic coding, coding of the CAT map. Ergodic Theory: basic measure theory notions; invariant measures, Poincare recurrence, ergodicity using Fourier series, mixing, ergodic theorems (Birkhoff Ergodic Theorem, ergodic theorem for Markov chains); applications to Internet Search

Recommended Books:

- An Introduction to Dynamical System by M. Brin and G. Stuck (Chapter 1 to 4) (The first three chapters contains the topics will be presented (in expanded and simplifyed exposition) during the course.)
- "A first course in Dynamics by B. Hasselblatt and A. Katok (This is the most accessible of the three. Most of the topics which we will cover from this book appear in Chapter 8 and 9.)
- "Dynamical Systems and Ergodic Theory" by M. Pollicott and M. Yuri

MAT-822 Mathematical Modeling in Physical Sciences

Credit hours: 3

Specific Objectives of the Course:

Mathematical modeling is the process of creating mathematical representation of some phenomenon in order to gain a better understanding of that phenomenon. The main goal of this course is to learn how to make a creative use of some mathematical tools, such as difference equations, ordinary and partial differential equations and numerical analysis, to build a mathematical description of some physical problems. During the course the students will be required to work on papers written by scientists from several fields of science, such as biology and physics, and they will practice on some specific modeling problems. The final exam will consist in the completion of a self-consistent modeling project.

Course Outlines:

Introduction to Modeling: modeling process, overview of different kinds of models, Qualitative Modeling with Functions, Modeling with Dimensional Analysis, Modeling with Difference Equations:(a) Overview of basic concepts concerning matrices, eigenvalues and eigenvectors;
(b) Fixed points, stability and iterative processes;(c) Applications to population growth.
Modeling with Ordinary Differential Equations:(a) Overview of basic concepts in ODE and stability of solutions: existence and uniqueness for 1st order IVPs, Picard iteration, numerical methods, higher order IVPs; (b) Linear operators, coupled linear systems, phase plane, stability analysis;(c) Some applications: growth of cells, market growth, enzyme reactions, examples in mechanics and electric circuits, Empirical Modeling with Data Fitting:(a) Error function, least squares method;(b) Fitting data with polynomials and splines, Modeling with Partial Differential Equations:(a) Overview of the key properties of some particular kinds of PDEs: advection, diffusion, advection-diffusion;(b) Separation of variables, equilibrium solutions, stability and linear stability;(c) Travelling waves, spatially periodic solutions (patterns);(d) Some applications: stripes on the skin of the Marine Angelfish, analysis of temperature from the Greenland Ice Sheet.

Recommended Books:

- A First Course in Mathematical Modeling, by F. R. Giordano, M.D. Weir and W.P. Fox
- Modeling and Quantitative Methods in Fisheries By Malcolm Haddon A CRC

MAT-823 Methods of Mathematical Physics

Credit hours: 3

Specific Objective of the Course:

This is a calculus based Mathematical Methods course for mathematicians and students of the physical sciences

Course Outlines:
Functions of many variables, partial differentiation with applications. Most of the Mathematical equations of physics and chemistry involve partial differentiation and this section is a basic introduction to this calculus. Optimization; maximum and minimum values, with and without constraints. Lagrange Multipliers. Curve fitting. The theory of optimization is of importance in diverse applications in the physical and social/economic sciences. Introduction to Fourier series, with applications in the solution of partial differential equations. The theory of Fourier series is of fundamental importance in all the physical sciences. Multiple integrals and Green's Theorem.
Recommended Books:
- Mathematical Techniques by Jordan and Smith (Oxford).
- R. Courant and D. Hilbert, Methods of Mathematical Physics, Wiley, 2008
- H. Jeffreys and B. Jeffreys, Methods of Mathematical Physics, Cambridge University

MAT-824 Dynamic Systems and Control Theory
Credit hours: 3
Specific Objective of the Course:
To provide comprehensive understanding of complex behaviour of nonlinear physical systems, with an emphasis on chaos and the general theory of control of nonlinear dynamical systems.
Course Outlines:
Characterization of chaos in different systems, bifurcations, Rossler system, mappings, Poincaré section, p-cycles, folding and stretching, Lyapunov exponents, Henon map, saddle manifolds, homoclinic tangles, and basin of attraction, fractals and fractal dimensions. Linear dynamical systems, basics, state space solutions and realizations, stability, controllability&observability, state feedback and state estimation. Optimiation problems of dynamic Systems, optimization problems with path constaints, optimal feedback control, linear systems with quadratic criteria, optimal feedback control in the presence of uncertainity, Bellman's equation & dynamical programming: (a) calculus of variations, (b) computational aspects. Nonlinear system analysis: phase plane analysis, Lyapunov theory, advanced stability theory. Nonlinear Control Systems Design: Feedback linearization, sliding mode control, adaptive control, control of multi-input physical systems,schochastic and adaptive control.
Recommended Books:
- T. Kailath, A.H. Sayed, and B. Hassibi, Linear Estimation, Prentice Hall
- H.K. Khalil, Nonlinear Systems, Prentice Hall
- R. Bellman, Adaptive Control Process, Princeton University Press
- A.E. Bryson and Y.C. Ho, Applied Optimal Control, Hemisphere Publishing
- C.T.Chen, Linear System Theory & Design, Oxford University Press
- Robert F. Stengel, Optimal Control & Estimation, Dower Publications

MAT-825 Topological Fixed Point Theory
Credit hours: 3
Specific Objective of the Course: To forward the knowledge of how to establish and use topological fixed point theorems for the investigations of applied problems and other abstract problems of functional, integral and differential and algebraic equations.

Course Contents:
Topological Vector Spaces, Fixed point property , The fixed point theorems of Brouwer and Schauder , Schauder–Tychonoff, KKM theorem, Ky Fan and Kakutani Maps , Ky Fan theorem, coincidence theorems , approximation of fixed point, variation inequalities, Extension of the KKM –map principle and its application, two function theorem and its applications, multivalued mappings , convexity structures and fixed points, multivalued non-expansive mappings, Asymptotically non-expensive mappings**.**

Recommended Books:

- Topics in Fixed Point Theory by Saleh_Almezel, Qamrul Hasan_Ansari Mohamed Amine_Khamsi Springer International Publishing Switzerland 2014.
- Fixed Point Theory by Andrzej Granas and James Dugundji, Springer Publisher.
- Fixed Point Theory in Distance Spaces, by William_Kirk and Naseer_Shahzad, Springer International Publishing Switzerland 2014.
- Fixed Point Theory for Lipschitzian-type Mappings with Applications, by Ravi P. Agarwal Donal O'Regan and D.R. Sahu, Springer.
- Fixed Point Theory and Best Approximation: The KKM-map Principle, by Sankatha Singh, Bruce Watson and Pramila Srivastava, Springer-Science+Business Media, B.V.

MAT-826 Fuzzy Fixed Point Theory

Credit hours: 3

Course Contents: Fuzzy set, Fuzzy metric space, F-convergence, F-Cauchy's sequence, F-complete fuzzy metric space, F-continuity, Fuzzy contractive mapping, Fuzzy contractive sequence, Banach contraction theorem in fuzzy metric spaces, Kramosil and Michalek's fuzzy metric spaces, Menger space, Probabilistic contraction, Banach contraction theorem for M-complete fuzzy metric spaces, Convergence in the sense of Fréchet, Edelstein fuzzy contractive mappings, R-weak commutatively of type (P) in fuzzy metric spaces, Compatible maps and compatible maps of types (α) and (β), common fixed point theorems for compatible maps of type (β) on fuzzy metric spaces, cyclic weak ϕ−contractions in fuzzy metric spaces, non-Archimedean fuzzy metric space.

Recommended Books and Articles:

- Kankana Chakrabarty, Ranjit Biswas, , Sudarsan Nanda, On fuzzy metric spaces, Fuzzy Sets and Systems, Volume 99, Issue 1, 1 October 1998, Pages 111–114.
- Valentín Gregori, , Almanzor Sapena, On fixed-point theorems in fuzzy metric spaces, Fuzzy Sets and Systems, Volume 125, Issue 2, 16 January 2002, Pages 245–252.
- R. Vasuki, P. Veeramanib, Fixed point theorems and Cauchy sequences in fuzzy metric spaces, Fuzzy Sets and Systems, Volume 135, Issue 3, 1 May 2003, Pages 415–417.
- Dorel Miheţ. A Banach contraction theorem in fuzzy metric spaces, Fuzzy Sets and Systems, Volume 144, Issue 3, 16 June 2004, Pages 431-439.
- Dorel Miheţ. On fuzzy contractive mappings in fuzzy metric spaces, Fuzzy Sets and Systems, Volume 158, Issue 8, 16 April 2007, Pages 915-921.
- Y.J. Cho, H.K. Pathak, S.M. Kang and J.S. Jung, Common fixed points of compatible maps of type (β) on fuzzy metric spaces, Fuzzy Sets and Systems, Volume 93, Issue 1, 1 January 1998, Pages 99-111.

- Dorel Miheţ Fuzzy ψ-contractive mappings in non-Archimedean fuzzy metric spaces, Fuzzy Sets and Systems, Volume 159, Issue 6, 16 March 2008, Pages 739–744.
- George and .P. Veeramani, On some results of analysis for fuzzy metric spaces, Fuzzy Sets and Systems, Volume 90, Issue 3, 16 September 1997, Pages 365-368.
- D. Gopal , M. Imdad , C. Vetro , M. Hasan, Fixed Point Theory for Cyclic Weak ϕ−contraction in Fuzzy Metric Spaces, Journal of Nonlinear Analysis and Application, Volume 2012, Year 2012 Article ID jnaa-00110, 11 Pages.
- M. Imdad and J. Ali Some common fixed point theorems in fuzzy metric spaces, Mathematical Communications, 11(2006), 153-163 153,

MAT-827 Fuzzy Sets and Their Applications

Credit hours: 3

Specific Objective of the Course:

At the end of the course the readers will be able to know about Classical Sets via Fuzzy Sets, Types of Fuzzy Sets, Operations on Fuzzy Sets, Zadeh's Extension Principle, Fuzzy Relations, and Possibility Theory.

Course Outlines:

Fuzzy Sets

Classical sets via Fuzzy Sets, Need for fuzzy sets, Definition and Mathematical representations, Level Sets, Fuzzy functions, Zadeh's, Extension Principle.

Operations on [0,1], Fuzzy negation, triangular norms, t-norms, fuzzy implications, Aggregation Operations, Fuzzy Functional Equations.

Fuzzy Binary and n-ary relations, composition of fuzzy relations, Fuzzy Equivalence Relations, Fuzzy Compatibility Relations, Fuzzy Relational Equations.

Fuzzy Measures, Evidence Theory, Necessity and Belief Measures, Probability Measures via Possibility Measures.

Fuzzy Decision Making, Fuzzy Relational Inference, Compositional Rule of Inference, Efficiency of Inference, Hierarchical.

Fuzzy If-Then Rule Base, Inference Engine, Takagi-Sugeno Fuzzy Systems, Function Approximation.

Recommended Books:

- George J Klir and Bo Yuan, *Fuzzy Sets and Fuzzy Logic: Theory and Applications*, Prentice Hall NJ,1995.
- H.J. Zimmermann, *Fuzzy Set Theory and its Applications*, Allied Publishers, New Delhi, 1991.
- Kevin M Passino and Stephen Yurkovich, *Fuzzy Control*, Addison Wesley Longman, 1998.
- Michal Baczynski and Balasubramaniam Jayaram, *Fuzzy Implications*, Springer Verlag, Heidelberg, 2008.

MAT-828 Applications of Fixed Point Theory in Generalize Spaces

Credit hours: 3

Course Contents:

Banach Spaces, Hilbert spaces, Fixed point results in generalized spaces (metric spaces, b-metric spaces, complex valued metric spaces, G-metric spaces etc.), Applications of fixed point results to Functional equations, matrix equations, differential and integral equations, Variational inequality and variational inclusion mapping.

Recommended Books:

- Fixed Point Theory by Andrzej Granas And James Dugundji, Springer Publisher.
- Fixed Point Theory in Ordered Sets and Applications, Siegfried Carl and Seppo Heikkilä
- Fixed Point Theory for Lipschitzian-type Mappings with Applications, by Ravi P. Agarwal Donal O'Regan and D.R. Sahu, Springer.
- Fixed Point Theory and Applications, R. Agarwal, M. Meehan and D. O Regan , Cambrige University Press

MAT-829 Advance Mathematical Methods

Credit hours: 3

Aims and objectives: At graduate level the research scholars of physics, mathematics and computational sides need some best numerical methods for treating the nonlinear differential equations numerically. Some already known methods are not adequate for treating most of the nonlinear problems of differential ad integral equations. Therefore some iterative methods have been developed to find best approximate solutions to nonlinear problems of applied sciences.

Course contents: Euler, Tyler methods, Heun;s methods and applications**.** Introduction to Adomian polynomial and Adomian decomposition method and its applications to differential and integral equations. Introduction to homotopy analysis (HAM), Variation iteration method (VIM), homotopy perturbation method (HPM), Laplace homotopy decompositions method (LHDM), differential transform methods and its generalizations and the applications of these methods in nonlinear differential equations. Introduction to operational matrices and numerical solutions by using operational matrices methods.

Recommended Books and Articles

- Alfio Quarteroni, Riccardo Sacco, Fausto Saleri Numerical Mathematics, ISBN 0-387-98959-5nSpringer-VerlagnNew YorknBerlinnHeidelbergMSPIN 10747955. (2000).
- .H. He, Variational iteration method for autonomous ordinary differential systems, Applied Mathematics and Computation 114 (2–3) (2000) 115–123.
- J.H. He, Some asymptotic methods for strongly nonlinear equations, International Journal of Modern Physics B 20 (10) (2006) 1141–1199.
- M.A. Abdou, A.A. Soliman, Variational-iteration method for solving Burger's and coupled Burger's equations, Journal of Computational and Applied Mathematics 181 (2) (2005) 245–251.
- S. Momani, S. Abuasad, Application of He's variational-iteration method to Helmholtz equation, Chaos, Solitons & Fractals 27 (5) (2006) 1119–1123.
- B.A. Finlayson, The Method of Weighted Residuals and Variational Principles, Academic press, New York, 1972.

- S.J. Liao, Beyond Perturbation: *Introduction to the Homotopy Analysis Method, Chapman Hall/CRC Press, Boca Raton.,* 2003.
- A. H. M. Abdilraze, *Admoian Decomposition method: convergence analysis and numerical approximations, M.sc. Dissertation, McMaster University Hamilton.,* Canada, 2008.
- Z. Odibat, Differential transform method for solving Volterra integral equation with separable kernels, Math. Comput. Model., 48(2008) 1144 - 1146.

MAT-830 Mathematical Methods for Arbitrary Order Differential Equations

Credit hours: 3

Aims and objectives: Investigations of numerical solutions of non-integer order differential equations is an attractive area of research in recent times. Since as compared to classical differential and integral operators, fractional differential and integral operator are global operators. Therefore to find exact solutions to fractional differential equations is a challenging job. Therefore strong motivation has been found to develop numerical procedure for the approximate solutions of fractional differential/integral equations.

Course Contents: Introductions to homotopy analysis and perturbations methods for treating fractional differential/ integral equations. Approximate solutions of fractional differential/ integral equations by using differential transform methods and Adomian decomposition methods. Applications of Laplace-Adomian decompositions methods to fractional differential/ integral equations. Introduction of variation iteration method and its applications to find numerical solutions of fractional differential/ integral equations.

Recommended Books:

- J.K. Zhou, Differential transform and its Applications for Electrical Circuits, Huazhong University Press, Wuhan, China, 1986.
- A. H. M. Abdilraze, Admoian Decomposition method: convergence analysis and numerical approximations, M.sc.
- Dissertation, McMaster University Hamilton , Canada 2008.
- K. Deimling, Nonlinear Functional Analysis, Springer-Verlag, New York, 1985.
- E. Zeidler, Nonlinear Functional Analysis an Its Applications. I: Fixed Point Theorems. Springer, New York (1986).

MAT-831 Theory of Majorization

Credit hours: 3

Course Contents:

Majorization theory is a key tool that allows us to transform complicated non-convex constrained optimization problems that involve matrix-valued variables into simple problems with scalar variables that can be easily solved. The additive majorization relation plays an important role in the design of linear MIMO transceivers, whereas the multiplicative majorization relation is the basis for nonlinear decision-feedback MIMO transceivers.

Course outlines:

Basic theory of convex functions, weighted and unweighted majorization theorems, applications of majorization theorem, Fuch’s, Dragomir’s, Shoshana- Pečarić’s, Niezgoda’s majorization results and relations between their results, generalization of majorization theorem for the class of n-convex functions by using Taylor's formula and Green function as well as Abel-Gontscharoff Polynomial, n-exponential convexity, n-exponential convexity for the functional obtained from the generalized majorization inequalities, some examples for exponential convexity results, Favard's and Berwald's inequalities and their generalizations.

Recommended Books:

- P. J. Davis, Interpolation and Approximation, Blaisdell Boston, 1961.
- J. Pečarić, F. Proschan and Y. L. Tong, Convex functions, Partial Orderings and Statistical Applications, Academic Press, New York, 1992.
- A. W. Marshall, I. Olkin and B. C. Arnold, Inequalities: Theory of Majorization and Its Applications (Second Edition), Springer Series in Statistics, New York 2011.
- R. P. Agarwal and P. J. Y. Wong, Error Inequalities in Polynomial Interpolation and their Applicationns, Kluwer Academic Publishers, Dordrecht, 1993.
- D. V. Widder: The Laplace Transform, Princeton Univ. Press, New Jersey, 1941.
- R. Bhatia, Matrix Analysis, New York: Springer-Verlage, 1997.

MAT-832 Fuzzy Algebra

Credit hours: 3

Specific Objective of the Course:

At the end of the course the readers will be able to know about fuzzy subsemigroups, Fuzzy Rings, and fuzzy ideals of a semigroup and rings: can provide examples related to the course content as well.

Course Outlines:

Introduction

The concept of Fuzziness with examples, Operations of fuzzy sets, Fuzziness as uncertainty.

Algebra of Fuzzy Sets: Equivalence relations and partitions, Composing mappings, Alpha-cuts, Images of alpha-level sets, Operations on fuzzy sets.

Fuzzy Relations: Definitions and Examples, Binary Fuzzy Relations, Operations on Fuzzy relations, Fuzzy Partitions.

Fuzzy Semigroups: Fuzzy ideals of semigroups, Fuzzy quasi-ideals, Fuzzy bi-ideals of Semigroups, Characterization of different classes of semigroups by the properties of their fuzzy ideals fuzzy quasi-ideals and fuzzy bi-ideals.

Fuzzy Rings: Fuzzy ideals of rings, Prime, semiprime fuzzy ideals, Characterization of rings using the properties of fuzzy ideals

Recommended Books and Materials:

- J. N. Mordeson, Fuzzy Semigroups, Springer-Verlage, 2003. D.S. Malik and Nobuki Kuroki
- H. T. Nguyen and A First course in Fuzzy Logic, Chapman and Hall/CRC Elbert A. Walker 199
- D. Dubois and H. Prade, Fuzzy Sets and Systems: Theory and Applications
- J. N. Mordeson and Fuzzy Commutative algebra, World Scientific, 1998.D.S. Malik

- M. Ganesh, Introduction to Fuzzy Sets and Fuzzy Logic, Prentice-Hall of India, 2006

MAT-833 Nonlinear Analysis and its Applications

Credit hours: 3

Prerequisite: General Topology and Functional Analysis

Aims and objectives: This course will enable research students how to deal nonlinear problems for their respective solutions. They will be enabled to know how the techniques works in different situations and how the problems solutions are obtain by using the technique of nonlinear analysis.

Course contents:. Banach and Hilbert spaces, contraction operators. Introduction to homotopy and its applications. Monotone iterative techniques of contraction operators, Fixed point theorem of Banach, Schaudar, Schaefer, Brower's and applications in nonlinear differential and integral equations. Degree theory and its applications, the Brouwer degree theory, the Schauder degree theory and topological degree theory. The Picard-Lindelop theorem and its applications.

Recommended Books

- Martin Schechter, An Introduction to Nonlinear Analysis, University of California, Irvine**,** Cambridge University Press 2004.
- Akhiezer, N. I.The Calculus of Variations.New York, Blaisdell, 1962.
- Berger, M. S.Nonlinearity and Functional Analysis. New York, Academic , Press, 1977.
- Pavel Dr ´ abek, Jaroslav Milota, Lectures on Nonlinear Analysis, Czech Republic, Plzen-Prah,2004.
- Collin Adams and R. Franzosa, Introduction to topology pure and applied , second edition 2012.

MAT-834 Near Rings

Credit hours: 3

Course Outlines:

Near Rings, Ideals of Near-rings, Isomorphism Theorems, Near Rings on finite groups, Near-ring modules. Isomorphism theorem for R-modules, R-series of modules, Jorden-Holder- Schrier Theorem, Type of Representations, Primitive near-rings R-centralizers, Density theorem, Radicals of near-rings.

Recommended Books:

- G. Pilz, (1982), "Near-Rings: What They Are and What They Are Good For" in Contemp. Math., 9, pp. 97–119. Amer. Math. Soc., Providence, R.I., 1981.
- G. Pilz, "Near-rings, the Theory and its Applications", North-Holland, Amsterdam, 2nd edition, (1983).
- J. Clay, "Nearrings: Geneses and applications", Oxford, (1992).

MAT-835 Topological Algebra

Credit hours: 3

Course Outlines:

Definition of a Topological algebra and its Examples. Adjunction of Unity, Locally Convex Algebras, Idempotent and m-convex sets, Locally Multiplicatively convex (l.m.c) algebras, Q-algebras, Frechet algebras, Spectrum of an element, Spectral radius, Basic theorems on Spectrum, Gelfand-Mazur Theorem. Maximal ideals, Quotient algebras, Multiplicative linear functionals and their continuity, Gelfand transformations, Radical of an algebra, Semi-simple algebras, Involutive algebras, Gelfand-Naimark theorem l.m.c. algebras.

Recommended Books:

- E. Beckenstein, L. Narici and C. Suffel, Topological Algebras, North-Holland Company, 1977.
- A. Mallios, Topological Algebras, Selected Topics, North-Holland Compnay, 1986. T. Husain, Multiplicative Functions on Topological Algebras, Pitman Advanced Publishing Program, 1983.
- E. Michael, Locally Multiplicatively-convex Topological Algebras, Memoirs Amer. Math. Soc. No.11, 1951.

MAT-836 Nilpotent and Soluble Groups

Credit hours: 3

Course Outlines:

Normal and Subnormal Series, Abelian and Central Series, Direct Products, Finitely Generated Abelian Groups, Splitting Theorems, Soluble and Nilpotent Groups, Commutators Subgroup, Derived Series, The Lower and Upper Central Series, Characterization of Finite Nilpotent Groups, Fitting Subgroup, Frattini Subgroup, Dedekind Groups, Supersoluble Groups, Soluble Groups with Minimal Condition. Subnormal Subgroups, Minimal Condition on Subnormal Subgroups, The Subnormal Socle, the Wielandt Subgroup and Wielandt Series, T-Groups, Power Automorphisms, Structure and Construction of Finite Soluble T-Groups.

Recommended Books:

- D.J.S. Robinson, A Course in the Theory of Groups, Graduate Textes in Mathematics 80, Springer, New York, 1982.
- K. Doerk, T. Hawkes, Finite Soluble Groups, De Gruyter Expositions in Mathematics 4, Walter De Gruyter, Berlin, 1992.

MAT-837 Nonlinear Dynamics and Nonlinear Waves Phenomena

Credit hours: 3

Specific Objective of the Course:

Nonlinear Dynamics and Nonlinear wave phenomena are of great importance in the physical world, and have been for a long time a challenging topic of research for both pure and applied mathematicians. This course focuses on analytical and physical aspects of nonlinear dynamics and nonlinear wave phenomena. This important area of research has traditionally interesting aspects of the theory of nonlinear waves, especially as described by one and two space-dimensional integrable PDEs, and inverse problems relating to this area. All of these topics have seen significant advances in recent years, and research is very active. The present course focuses more specifically on nonlinear waves and recent related techniques, presenting nonlinear wave propagation models and specific properties. The course will also include the classical inverse scattering transforms and some recent advances in this field. It aims to describe various different aspects of the relevant theory to an audience of postgraduate students and young postdoctoral researchers in applied mathematics.

Course Outlines:
Review of phase plane analysis, limit cycles. Perturbation techniques for weakly nonlinear systems. Nonlinear forced vibrations, jump phenomena, synchronization, super harmonic and sub harmonic resonance. The classical water wave problem and derivation of model equations Derivation of canonical equations of mathematical physics from the water wave problem, with focus on weakly nonlinear dispersive waves. Introduction to multiple scale analysis, the nonlinear Schroedinger equation as an envelope equation. Mean field generation. Multiple scale formalism with a few examples. Derivation of the Davey-Stewartson system. The nonlinear Schroedinger equation: Basic dynamical effects, Solutions in one space dimension; Solution Instability for tranverse perturbation. Structural properties of the NLS equation: Lagrangian and Hamiltonian structure, Noether theorem, invariances and conservation laws. The initial value problem: Existence theory, Long-time behavior; finite-time blowup. Analysis of the blow-up: self-similarity, modulation analysis, rate of blow-up.

References:

- W. Strauss: Nonlinear Wave Equations, CBMS, Volume 73, American M. Society
- C. Sulem and P.-L. Sulem: The Nonlinear Schroedinger Equation: Self-focusing and Wave Collapse, Appl. Math. Sciences, Volume 139, 1999, Springer
- Thierry Cazenave :Semilinear Schroedinger Equations, AMS, Lecture Notes of the Courant Institute, vol 10, 2003
- Jean Bourgain: Global solutions of Nonlinear Schroedinger equation, AMS, C. Series

MAT-838 Advance Optimization Theory
Credit hours: 3
Specific Objective of the Course:
Optimization is central to any problem involving decision making, whether in engineering or in economics. The task of making entails choosing between various alternatives. This choice is governed by our desire to make the best decision. The measure of goodness of the alternatives is described by an objective function or performance index. Optimization theory and methods deal with selecting the best alternative in the sense of the objective function. The area of optimization has received enormous attention in recent years, primarily because of rapid progress in computer technology, including the development and availability of user friendly software, high speed and parallel processors, and artificial neural networks.

Course Outlines:
Vector Spaces and Matrices, Rank of matrix, Linear Equations, Transformations, Eigenvalues and Eigenvectors, Matrix norms, Line segment, Convex sets, Elements Of Calculus, Sequence and Limits, Differentiability, The Derivative Matrix, Level Sets, Taylor Series, Un-constrained Optimization, Basics of Set-Constrained and Unconstrained Optimization, One Dimensional search Methods, Linear Programing,

References:

- An Introduction to Optimization Second Edition by Edwin K. P. Chong and H. Z. Stanislaw
- Optimization Theory with Applications by Donald A. Pierre Department of Electrical Engineering University of Bozeman, Montana

MAT-839 Dynamical System Theory
Credit Hours: 3
Specific Objective of the Course:
Establishing the theoretical basis of linear and non-linear dynamical systems in both continuous and discrete time. Learning how to anticipate the qualitative behaviour of the time-evolution of linear, weakly nonlinear and strongly nonlinear dynamical systems. Applying this to models from various fields.

Course Outlines: Time domain solution, Stability: Definition, Exponential of a diagonalizable matrix, Stability of a linear system with a diagonalizable state matrix, Existence and uniqueness of the solutions, Asymptotic behaviour, Jordan normal form, General form of the free solution of linear systems, Stability of linear systems (general case), Asymptotic Behaviour, Solution of linear autonomous systems, Classification of the flows of 2-d autonomous continuous-time systems, Stability of linear systems, Classification of equilibria and sketching of phase portraits, Phase portraits of 3-dim autonomous systems, Stability of linear discrete-time systems, Link with Frequency Domain Analysis, Nonlinear systems: Introduction to nonlinear systems, Iterations of the logistic map, Van der Pol oscillator, Stability of nonlinear systems: Large-scale notions of (in) stability, Boundedness and asymptotic uniform boundedness of solutions, Lyapunov functions for proving boundedness and asymptotic uniform boundedness of the solutions, Large-scale notions of (in)stability, Special class of systems: Hamiltonian systems, Small-scale notions of (in)stability, Stability of a solution, Criterion for stability of a fixed/equilibrium point, Stable and unstable manifold of a fixed/equilibrium point, Sketching the flow in the vicinity of a fixed/equilibrium point in 2 dimensions, Lyapunov functions for estimating the basin of attraction of an asymptotically stable equilibrium/fixed point and for proving global asymptotic stability of an equilibrium/fixed point, Special class of systems: Gradient systems, Stability of periodic solutions of discrete-time systems, Stability of periodic solutions of continuous-time systems, Bifurcations: Implicit Function Theorem, 1-parameter bifurcations of equilibrium and fixed points: necessary conditions for the eigenvalues of the Jacobian matrix, Existence of periodic solutions, Stability of periodic solutions, Fold bifurcation in one-dimension, Pitchfork bifurcation inone-dimension, Andronov-Hopf bifurcation in one-dimension

Recommended Books:

- C. J, Harris, J.E. Mills, Stability of linear systems: some aspects of kinematic similarity, Elsevier Science
- P.G. Drazin, Nonlinear Systems, Cambridge University Press
- S. Wiggins, Introduction to Applied Nonlinear Dynamical Systems and Chaos
- T. Dougherty, Systems and Control: An Introduction to Linear, Sampled and Non-Linear Systems, World Scientific
- S.N. Chow, and J.K. Hale, , Methods of bifurcation theory, Springer-Verlag
- D. Luo, Bifurcation Theory and Methods of Dynamical Systems, World Scientific

MAT-840 Bio-Mechanics

Credit hours: 3

Specific Objective of the Course:

Biomechanics is mechanics applied to biology. Biomechanics seeks to understand the mechanics of living systems. It is the modern subject with ancient roots and covers a very wide territory. The research in this area comes from the realization that biology can no more understood without biomechanics than an airplane can without aerodynamics. For an airplane, mechanics enables us to design its structure and predict its performance.

Course Outlines:

Introduction: A Sketch of the History and Scope of the Field, Stress, Strain, Strain Rate, The meaning of the Constitutive Equation, The Non-viscous Fluid, The Flow Properties of Blood, Newtonian Fluid, Non Newtonian Fluids, Navier Stokes Equations.

Recommended Books:

- Biomechanics Mechanical Properties of Living Tissues Second Edition By Y. C. Fung Department of Bioengineering University of California USA.

MAT-841 Applied Numerical Analysis

Credit hours: 3

Specific Objective of the Course:

The purpose of numerical analysis is two-fold: To find acceptable approximate solutions when exact solutions are either impossible or so arduous and time-consuming as to be impractical, and To devise alternate methods of solution better suited to the capabilities of computers.

This course will cover the general issues arising in numerical computing and implementation of algorithms used to solve numerical problems in practice. We will develop numerical algorithms for the main-stream problems. The quality of a numerical algorithm is often judged based on two criteria namely efficiency (vaguely speaking number of arithmetic operations required) and accuracy. We will analyze the accuracy and efficiency of the numerical algorithms developed.

We will also examine issues of problem sensitivity and algorithmic stability and ways to improve efficiency.

Course Outline: This is a general outline of the material we will cover (not necessarily in this order). It is subject to change according to time and class interests.

1. Mathematical Preliminaries and Error Analysis
    a. Round-off Errors and Computer Arithmetic
    b. Algorithms and Convergence
2. Solutions of Equations in One Variable
    a. The Bisection Method
    b. Fixed-Point Iteration
    c. Newton's Method and Its Extensions
    d. Error Analysis for Iterative Methods
    e. Accelerating Convergence
3. Interpolation and Polynomial Approximation
    a. Interpolation and the Lagrange Polynomial
    b. Divided Differences

c. Hermite Interpolation

d. Cubic Spline Interpolation

4. Numerical Differentiation and Integration
    a. Numerical Differentiation
    b. Richardson's Extrapolation
    c. Elements of Numerical Integration
    d. Composite Numerical Integration
    e. Romberg Integration
    f. Adaptive Quadrature Methods
    g. Gaussian Quadrature
5. Approximation theory
    a. Discrete Least Squares Approximation
    b. Continuous Least Squares Approximation
    c. Chebyshev polynomials
    d. Rational Function Approximation
    e. Trigonometric polynomial Approximation
    f. Fast Fourier transforms
6. Initial-Value Problems for Ordinary Differential Equations
    a. The Elementary Theory of Initial-Value Problems
    b. Euler's Method
    c. Higher-Order Taylor Methods
    d. Runge-Kutta Methods
    e. Multistep Methods
    f. Variable Step-Size Multistep Methods
7. Boundary-Value Problems for Ordinary Differential Equations
    a. Shooting methods.
        i. The method of bisection
        ii. The Newton–Raphson method
    b. Matrix methods
        i. Linear boundary value problem.
        ii. Nonlinear boundary value problem
    c. Collocation method
8. Numerical Methods for Partial Differential Equations
    a. Hyperbolic Partial Differential Equations
    b. Parabolic Partial Differential Equations
    c. Elliptic Partial Differential Equations
9. Other topics of interest to you.

Recommended Books:

- Brian Bradie, A Friendly Introduction to Numerical Analysis, 2006, Prentice Hall
- Burden and Faires, Numerical Analysis, 10th edition 2010, Brooks Cole

- J Kendall Atkinson, Elementary Numerical Analysis, 3rd edition 2004, Wiley
- J. H. Mathews, and K. D. Fink, Numerical Methods Using Matlab (4th ed.)

MAT-842 Mathematical Biology
Credit hours: 3
Specific Objective of the Course:
Mathematical biology is a fast-growing, well-recognized, albeit not clearly defined, subject and is, to my mind, the most exciting modern application of mathematics. The increasing use of mathematics in biology is inevitable as biology becomes more quantitative. The complexity of the biological sciences makes interdisciplinary involvement essential. For the mathematician, biology opens up new and exciting branches, while for the biologist, mathematical modeling offers another research tool commensurate with a new powerful laboratory technique but only if used appropriately and its limitations recognized. However, the use of esoteric mathematics arrogantly applied to biological problems by mathematicians who know little about the real biology, together with unsubstantiated claims as to how important such theories are, do little to promote the interdisciplinary involvement which is so essential. Mathematical biology research, to be useful and interesting, must be relevant biologically. The best models show how a process works and then predict what may follow. If these are not already obvious to the biologists and the predictions turn out to be right, then you will have the biologists' attention. Suggestions as to what the governing mechanisms are may evolve from this. Genuine interdisciplinary research and the use of models can produce exciting results, many of which are described in this study.
Corse Outlines:
Population Dynamics , Continuous and Discrete Population Models for Single Species, Models for Interacting Populations, Age-structured Populations, Stochastic Population Growth, Dynamics of Infectious Diseases, Historical Asideon Epidemics, Simple Epidemic Models and Practical Applications , Modeling Venereal Diseases , Multi-Group Model for Gonorrhea and Its Control, AIDS: Modeling the Transmission Dynamics of the Human Immunodeficiency Virus (HIV) , HIV: Modeling Combination Drug Therapy , Delay Model for HIV Infection with Drug Therapy , Modeling the Population Dynamics of Acquired Immunity to Parasite Infection , Age-Dependent Epidemic Model and Threshold Criterion.
Recommended Books:
- Mathematical Biology. An Introduction, Third Edition by J. D. Murray, FRS
- Dynamical Models in Biology by Miklos Farkas School of Mathematics, Budapest University of Technology Budapest, Hungary

MAT-843 Graph Labeling
Credit hours: 3
Course Outlines:
Introductory Concepts, Basic definitions and examples, types of graph labeling, Graceful and Harmonious labeling, Magic labeling, Bandwidth labeling, definition and examples, The Cost of a Labeling, Bandwidth in Terms of Adjacency Matrices, Characterizing Bandwidth via Power of the Path Graph, Planarity and Bandwidth of Graphs, Density of a Graph and Bandwidth, Bandwidth of a graph under Edge Addition, Bandwidth of Graphs under graph operations, Bandwidth of Graph Products, Bandwidth Labeling of the Product of two Paths, Bandwidth of

Lattice Graphs on a Fan, Bandwidth of Lattice Graphs on a cone, Bandwidth of Classes of Graphs, Bounding and Tight Bounding functions for graphs, Bandwidth of Triangular Grids, Bandwidth Binary Trees, Bandwidth of Mobius Graphs

Recommended Books and Materials:

- A dynamic survey of graph labelling by Joseph A. Gallian
- Handbook of graph theory by Jonathan L Gross, Columbia University, New York, USA
- Graph theory III by Reinhard Diestel, Electronic Edition

MAT-844 LA-Semigroups

Credit hours: 3

Course outlines:

LA-semigroups and basic results, Connection with other algebraic structures, Medial and exponential properteis, LA-semigroups defined by commutative inverse semigroups, Homomorphism theorems for LA-semigroups, Abelian groups defined by LA-semigroups, Embedding theorem for LA-semigroups, Structural properties of LA-semigroups, LA-semigroups as a semilattice of LA-subsemigroups, Locally associative LA-semigroups, Relations on locally associative LA-semigroups, Maximal separative homomorphic images of locally associative LA-semigroups, Decomposition of locally associative LA-semigroups.

Recommended Books:

- Fundamentals of Semigroup Theory John M. Howie
- Amer. Math. Soc. Surveys, 7, Providence, R.I.
- Contemporary Abstract Algebra, by J. A. Gallian
- The Algebraic Theory of Semigroups, by A. H. Clifford, Volume I & II

MAT-845 Lebesgue Spaces with Variable Exponent

Credit hours: 3

Specific Objective of the Course:

Lebesgue Spaces with variable exponent is the generalized Lebesgue space, it generalize the classical Lebesge space where the exponent is constant. This course familiarize the students with the basics properties of variable exponent spaces, in this course the students learn the boundedness of the "Maximal and Potential Operators" in Lebesgue spaces & weighted Lebesgue Spaces with variable exponent.

Course Outlines:

Classical Lebesgue spaces, Lebesgue Space with variable exponent, Space of Homogenous type, History of variable exponent spaces, Elementary properties, Maximal Function, One-sided Maximal Function, Logrithmic Holder continuity, point wise estimates, the boundedness of the Maximal operators, the boundedness of Potential operators, Hardy-type Transforms, Weak type estimates, Necessary Conditions for the boundedness, Weighted Lebesgue Space, One-sided Potentials.

Recommended Books:

- Lars Diening, Petteri Harjulehto, Peter Hästö and Michael Růžička, Lesbesgue and Sobolev Spaces with variable exponents, Springer International Edition

- Ioseb Genebashvili, Amiran Gogatishvili, Vakhtang Kokilashvil and Miroslav Krbec, Weight Theory of Integral Transforms on Spaces of Homogenous Type, (Pitman Monographs& Surveys in Pure and Applied Mathematics)
- Alexender Meskhi, Measure of Non-copactness for Integral Operators in Weighted Lebesgue Spaces, Nova Science Publishers, Inc
- David E. Edmund, Vakhtang Kokilashvili and Alexender Meskhi, Bounded & Compact Integral Operators, Kulwer Academic Publishers

MAT-846 Advanced Measure Theory
Credit hours: 3
Specific Objective of the Course:
It generalizes the concept of the integral. Typically, the integral is introduced as the area under a given curve. Area is just a single specific example of a 'measure' -- there are many others. This course familiarize the student with the concept of, Riemann Integrals for continuous functions, Lebesgue Integral, Lebesgue measure etc. This course in general is roughly making sense of "Integration" for function more general than just the continuous one.
Course Outlines:
Measure, Measurable Sets, Non-Measurable Set, Measurable Functions, Elementary properties of Measurable Functions, Lebesgue Measure on Euclidean Spaces, Two Properties of the Lebesgue Measure, Measurable and Lebesgue Integrable Functions on Euclidean Spaces, The Convergence Theorem, Comparison of the Lebesgue Integral with the Riemann Integrals, The Lebesgue Dominated Convergence Theorem, Convergence in Measure, The space L1 of integrable functions, The Hardy-Littlewood maximal function, The Lebesgue differentiation theorem, Littlewood's three principles, Fubini's theorem and its Applications.
Recommended Books:

- Karen Saxe, Beginning Functional Analysis, Springer International Edition
- Elias M. Stein & Rami Shakarchi, Real Analysis Measure Theory, Integration and Hilbert Spaces, Princeton University Press Princeton and Oxford
- Richard L. Wheeden & Antoni Zygmund, Measure and Integral, An Introduction to Real Analysis
- Gerald B. Folland,Real Analysis Modern Techniques and Their Applications, A wiley-Intersciences Series of Text, Monograph, and Tracts

MAT-847 Semigroup Theory
Credit hours: 3
Course outlines:
Introductory ideas; Basic definitions, Monogenic semigroups, Ordered sets, semilattices and lattices, Binary relations; equivalences, Congruence, Free semigroups and monoids; presentations, Ideals and Rees congruencies, Lattices of equivalences and congruences, Green's equivalences; regular semigroups, Green's equivalences, The structure of D-classes, L.R.H.J and

D; Regular semigroups, regular D-classes, Regular semigroups, Ordinary and Partial Transformations; Basic Definitions, Graph of a (Partial) transformation, Linear Notation for Partial Transformations, the Semigroups T_n and PT_n, Composition of Transformations, Identity Elements, Zero Elements, Isomorphism of Semigroups, Regular and Inverse Elements, Idempotents, Nilpotent Elements. Semigroups of shift operators; Semigrgoup of multi-tiles, illustration of the semigroup, semigroup of one-tile, generators, presentation and caley table of semigroups, semigroup of various shaped boards.

Recommended Books:

- Fundamentals of Semigroup Theory John M. Howie
- Classical Transformation Semigroups by Olexandr Ganyushkin
- Techniques of Semigroup Theory , by Peter M. Higgins
- The Algebraic Theory of Semigroups, by A. H. Clifford, Volume I.

MAT-848 Fuzzy Group Theory

Credit hours: 3

Specific Objective of the Course: The course motivates and develops results and applications of fuzzy group theory. To introduce notation of a fuzzy subgroup of a group: develop some concepts about fuzzy subgroups.

Course Outlines: Fuzzy subsets and fuzzy subgroups, fuzzy Caley's theorem and fuzzy Lagrange's theorem, nilpotent, commutators, and solvable fuzzy subgroups, characterization of certain groups and fuzzy subgroups, fuzzy subgroup of abelian groups, direct products of fuzzy subgroups and fuzzy cyclic subgroups, equivalence of fuzzy subgroups of finite abelian groups, lattices of fuzzy subgroups.

Recommended Books:

- J. N. Mordeson, R. B. Kiran and A. Rosenfeld, Fuzzy Group Theory.
- J. George, Fuzzy sets and Fuzzy Logic.
- H. L. Kwang, first Course on Fuzzy Theory and Applications

MAT-849 Approximation Theory

Credit hours: 3

Aims and objectives: In applied analysis most of the problems have not exact solutions. Therefore a strong motivation is found for developing numerical procedure to find out best approximate solutions to the concerned problems. The aims and objectives of this course is to train the research students to use various polynomial either orthogonal or non-orthogonal to develop numerical schemes for the approximate solutions of the problems arising in engineering, and other disciplines of applied sciences.

Course contents: Introduction to Legendre, Bernstein, Jacobi, Lagurre and Chybshive, Bernoulli polynomials and their properties and recurrence relations. The Shifted Jacobi and The Shifted Legendre polynomials, the Hermit polynomials. Approximations of functions in terms of the above polynomials. The convergence analysis of the approximation of the above polynomials. The iterative technique and contraction mapping. Applications of above polynomials to the approximate solutions of differential and integral equations.

Recommended Books:

- E. Aparicio, Three theorems on approximation in the space L_p by means of polynomials with integral coeeficients , Collect. Math, 28(1977) , Spanish.
- G.G. Lorentz, Bernstein polynomials, University of Toronto Press, 1953.
- Henryk G. and Jose' L. P,On the Approximation Properties of Bernstein polynomials via Probabilistic tools, Boletin de la Asociacion Matematica Venezolana., (2003) .

  De Villiers, J. M, Mathematics of approximation, Atlantic Press, Amsterdam 2012.

MAT-850 Finite Element Methods

Credit hours: 3

Aims and Objectives: The finite element method (**FEM**) is a numerical method for solving problems of engineering and mathematical physics. It is also referred to as finite element analysis (**FEA**). Typical problem areas of interest include structural analysis, heat transfer, fluid flow, mass transport, and electromagnetic potential. The analytical solution of these problems generally require the solution to boundary value problems for partial differential equations. The finite element method formulation of the problem results in a system of algebraic equations. The method yields approximate values of the unknowns at discrete number of points over the domain. To solve the problem, it subdivides a large problem into smaller, simpler parts that are called finite elements. The simple equations that model these finite elements are then assembled into a larger system of equations that models the entire problem. Accurate representation of complex geometry**,** Inclusion of dissimilar material properties**,** Easy representation of the total solution**,** Capture of local effects.

Course Contents: History and derivation of the methods, the structure of finite element methods Applications. Solutions of some illustrative problems of PDEs and fluid problems by the FEM. Various types of finite element methods like generalization of the finite element method, conforming and non-conforming element method, Smoothed Finite Element Methods, Spectral element methods, Meshfree methods, Discontinuous Galerkin method, Finite element limit analysis, Stretched grid method.

Recommended Books and Articles:

- Daryl L. Logan (2011). A first course in the finite element method. Cengage Learning.
- P. Solin, K. Segeth, I. Dolezel: Higher-Order Finite Element Methods, Chapman & Hall/CRC ,Press, 2003.
- Hastings, J. K., Juds, M. A., Brauer, J. R., *Accuracy and Economy of Finite Element Magnetic , Analysis*, 33rd Annual National Relay Conference, April 1985.

MAT-851 Fourier Analysis

Credit hours: 3

Course Outlines. Coin Tossing, Law of Large Numbers, Rademacher Functions, Measure Theory, Random Models, Measurable Functions, Lebesgue Integral, Measurable Functions, Lebesgue Integral, Lebesgue Spaces, Inner Products, Hilbert Space, Fourier Series and their Convergence, Applications of Fourier Series, Fourier Integrals, Fourier Integrals of Measures, Central Limit Theorem, Brownian Motion.

Recommended Books

- Adams, Malcolm Ritchie, and Victor Guillemin. *Measure Theory and Probability*. Birkhäuse, 1996.
- Fourier Analysis - Theory and Applications (Spring 2004)

MAT-852 Numerical Methods for Partial Differential Equations
Credit hours: 3
Course Contents:
Fundamental concepts and examples, Well-posedness and Fourier methods for linear initial value problems, Numerical solutions of Laplace and Poisson equation, Heat equation, transport equation, wave equation, General finite difference approach and Poisson equation, Elliptic equations and errors, stability, Lax equivalence theorem, Spectral methods, Elliptic equations and linear systems, Conservation laws: Numerical methods, Conservation laws: High resolution methods.
Recommended Books:

- Numerical Methods for Partial Differential Equations Spring 2009.
- David Francis Mayers and Keith William Morton, Numerical Solution of Partial Differential Equations, Cambridge University Press New York, NY, USA ,2005.

MAT-853 Bio-Mathematics
Credit hour: 3
Aims and Objectives:
This course is an exploration in applications of mathematics to various biological, ecological, physiological, and medical problems. By the end of this course the student will be able to derive, interpret, solve, simulate, understand, discuss and critique discrete and differential equation models of biological systems.
Course outlines: Mathematical model, Discrete models, A discrete model of breathing, Systems of discrete equations: Tumor initiation, Nonlinear discrete equations: Steady states, Stability, Bifurcations, Nonlinear systems: The Nicholson-Bailey model, Continuous models, The Spruce Budworm outbreak model, Models in immunology, Tumor immune interactions, Multiple species models, Population dynamics, The Malthusian growth model, The Logistic equation, A model of species competition, The Lotka-Volterra predator-prey model, Stochastic population growth, A stochastic model of population growth, Infectious disease modeling, SIR models, Stochastic models, Multigroup models, Basic reproduction number, Next generation method, Equilibrium analysis, Stability analysis, Bifurcation.
Recommended Books:

- Mathematical Biology, Jeffrey R. Chasnov, The Hong Kong University of Science and Technology, 2009.
- *Mathematical Models in Biology,* Magraw-Hill, 1988.

MAT-854 Advanced Fluid Mechanics
Credit hours: 3

Specific Objectives: To introduce the basic principles of fluid mechanics. Understanding the basic concepts in fluid static and fluid dynamics.

Course Outline: Fluid Properties: Ideal and real fluids, viscosity and compressibility of fluids, fluid pressure, absolute, gauge and vacuum pressures, difference between static and dynamic pressure, flow velocity and flow rate. Fluid statics: Measurement of static pressure, stagnation pressure, pressure in a fluid under the action of gravity, homogeneous fluid, constant-velocity rotation of a liquid around-fixed axis, hydraulic circuits, force on container wall, force on flat surfaces, force on curved surfaces, buoyancy of fluid at rest, stability of a floating body, surface tension and capillary tubes. Fluid dynamics: One dimensional inviscid flow (flow filament theory), equation of continuity, Euler's equations of motion, Bernoulli's equation, impulse and momentum, one dimensional viscous flow, generalized Bernoulli's equation, flow in conduits. Dimensional analysis, similitude and its applications: Buckingham- Pi theorem, Reynolds' law of similitude.

Recommended Books:

- Fundamentals of Fluid Mechanics, By Munson, Young and Okiishi, John Wiley & Sons.
- Fluid Mechanics, By Frank M. White McGraw-Hill.
- Fluid Mechanics by Shames McGraw-Hill. McGraw-Hill Science/Engineering/Math.
- Engineering Fluid Mechanics, By Clayton T. Crowe, Donald F. Elger, John A. Roberson, John Wiley & Sons.

MAT-855 Introduction to Computational Softwares and Research Methodology

Credit hours: 3

Aims and Objectives: Methodology is the systematic, theoretical analysis of the methods applied to a field of study. It comprises the theoretical analysis of the body of methods and principles associated with a branch of knowledge. Computational software are the demanding task of modern research. Applied research without computational software may not possible.

Couse out lines: There are no formal prerequisites for this course. It is intended to assist graduates in learning the basics of programming in general and programming in computational softwares. Only the very basics of programming in Matlab, Maple, Mathematica will be covered, with the goal of having students become comfortable enough to continue learning these softwares. To train the graduates how why we do research, what are the methodologies. How to make the research fruit full and marketable.

Recommended Books and Articles:

- S. Rajasekar, et.al., Research Methodology, 2013.
- Howell, K. E. Introduction to the Philosophy of Methodology. London, (2013)

MAT-856 Mathematical Inequalities and Applications

Credit hours: 3

Aims and Objectives:

Inequalities are one of the most important instruments in many branches of mathematics such as functional analysis, theory of differential and integral equations, interpolation theory, harmonic analysis, probability theory, etc. They are also useful in mechanics, physics and other sciences. The usefulness of Mathematical inequalities is felt from the very beginning and is now widely acknowledged as one of the major driving forces behind the development of modern real analysis

Course outlines:

Jensen's and Jensen-Steffensen's inequalities, Hermite-Hadamard's, Slater's and some companion inequalities to the Jensen inequality, deduction of the Hölder, Cauchy Schwartz, AM-GM inequalities from Jensen's inequality, Young's, Chebyshev's and Gruss inequalities, some determintal and matrix inequalities, refinements, reverses, generalizations, multi-dimensional version and applications of the above mentioned inequalities.

Recommended Books:

- E. F. Beckenbach and R. Bellman, Inequalities, Springerverlag, Berlin, 1961.
- G. H. Hardy, J. E. Littlewood and G. Polya, Inequalities, 2nd Ed., Cambridge University Press, Cambridge 1952.
- D. S. Mitrinović, Analytic Inequalities, Springer-Verlag, Berlin, 1970.
- J. Pečarić, F. Proschan and Y. L. Tong, Convex functions, Partial Orderings and Statistical Applications, Academic Press, New York, 1992.
- D. S. Mitrinović, J. Pečarić and A. M. Fink, Classical and new inequalities in analysis, Kluwer Academic Publishers, The Netherlands, 1993.
- E. Hewitt and K. Stromberg, Real and Abstract Analysis, Springer-Verlag, 1965.

MAT-857 Advance Convex Analysis

Credit hours: 3

Aims and Objectives: Convex analysis deals with the study of convex sets and convex functions. There is main connection between convex functions and convex sets, namely the domain of convex functions must be a convex set. Convex functions play an important role in many fields of mathematics such as optimization, control theory, operations research, geometry, differential equations, functional analysis etc. as well as in applied sciences e.g. in economics and finance. They have a lot of interesting and fruitful properties, e.g. continuity and differentiability properties or the fact that a local minimum turns out to be a global minimum etc. They even allow establishing a proper and general theory of convex functions. In this course we will learn some advance theory of convex functions and convex sets and some related results.

Course outlines:

Convex and affine sets, Convex and affine hull, convex and log- convex functions, continuity and differentiability of convex function, epigraph, properties of first order divided difference of convex function, Affine function, sub differential of convex function, support of convex functions, J- Convex functions and relation between convex and J- convex functions, criteria for checking a function, composition of functions, addition of functions and multiplication of function to be convex, Gateaux derivative of convex function, Gradient inequality for convex function in terms of Gateaux derivative. N-convex functions, n-exponentially convex functions.

Recommended Books:

- A. W. Roberts and D. E. Varberg, Convex functions, Academic Press, New York, 1973.

- C. P. Niculescu and L. E. Persson, Convex functions and their applications, CMS Books in Mathematics, Springer-Verlage, New York, 2006.
- R. T. Rockafellar, Convex Analysis, New Jersey Princeton University, 1972.
- D. S. Mitrinovic, J. Pecaric and A. M. Fink, Classical and new inequalities in analysis, Kluwer Academic Publishers, The Netherlands, 1993.

MAT-858 Theory of Semirings
Credit hours: 2
Objectives: The main objective of the course is to provide the student with basic knowledge about semirings and semimodules. In particular, the differences between modules over rings and semimodules over semirings will be highlighted and discussed in details.
Outlines: Hemirings and Semirings: definitions and examples. Building new semirings from old. Complemented elements in semirings, ideals is semirings, prime and semiprime ideals in semirings, factor semirings, morphisms of semirings, regular semirings, semimodules over semirings, morpisms of semimodules, factor semimodules, free projective and injective semimodules.
Recommended Books:
- J. S. Golan, The theory of Semirings and their applications in mathematics and theoretical computer science, Longman Scientific & Tehnical John Wiley & sons New York, 1992.
- U. Hebisch and H. J. Weinert, Semirings algebraic theory and applications in computer science, World Singapore, New Jersey London Hong Kong, 1998.

Annexure C

Course Codes for the Supporting Subjects in Different Departments.

The following course codes are suggested for an approval for different Departments of Shaheed BB University, Sheringal Dir (U).

Department	Semester	Course Title	Suggested Course Code	Remarks
Computer Sci.	1st	Calculus and Analytical Geometry	MCC-311	
	2nd	Linear Algebra	MCC-321	
	3rd	Multivariate Calculus	MCC-431	
	4th	Differential Equations	MCC-441	
	7th	Numerical Computing	MCC-671	
Biotechnology	1st	Mathematics (Pre-Calculus)	MCB-311	
	2nd	Biomathematics	MCB-321	
Sociology	2nd	Compulsory Mathematics	MCS-321	
Botany	1st	Mathematics-I	MCB*-311	
	2nd	Mathematics-II	MCB*-321	
Zoology	1st	Mathematics	MCZ-311	
Chemistry	1st	Mathematics-I	MCC*-311	
	2nd	Mathematics-II	MCC*-321	
Pharmacy	2nd	Pharmaceutical Mathematics	MCP-321	
Geology	1st	Mathematics-I	MCG-311	
	2nd	Mathematics-II	MCG-321	
Forestry	1st	Mathematics-I	MCF-311	
Environmental Sci.	1st	Mathematics	MCE-311	
	2nd	Statistics	MCE-321	
Islamic Studies	1st	Mathematics-I	MCI-311	
	3rd	Mathematics-II	MCI-431	

Management Sci.	3rd	Business Mathematics	MCM-431	
	4th	Business Statistics	MCM-441	
	5th	Inferential Statistics	MCM-551	
Agriculture	1st	Mathematics-I	MCA-311	
	2nd	Mathematics-II	MCA-321	

Note:

MCC=Mathematics Course for Computer Science
MCB=Mathematics Course for Biotechnology
MCB*=Mathematics Course for Botany
MCZ=Mathematics Course for Zoology
MCC*=Mathematics Course for Chemistry
MCP=Mathematics Course for Pharmacy
MCG=Mathematics Course for Geology
MCF=Mathematics Course for Forestry
MCE=Mathematics Course for Environmental Science
MCI=Mathematics Course for Islamic Studies
MCM=Mathematics Course for Management Science
MCA= Mathematics Course for Agriculture
MCS= Mathematics Course for Sociology

Annexure D

Agenda Item: External Examiner for the Thesis Evaluation.

PANEL OF EXAMINERS FOR THESIS EVALUATION AND / OR VIVA VOICE OF BS (4Year Programme), MSc and MPhil /PhD PROGRAMS

S. No	Name	Mailing Address
1.	Dr. Kamal Shah	Assistant Professor, Department of Mathematics, University of Malakand.
2.	Dr. Muhammad Sarwer	Assistant Professor, Department of Mathematics, University of Malakand.
3.	Dr. Ghaus ur Rahaman	Assistant Professor, Department of Mathematics, University of Swat.
4.	Dr. Muhammad Nauman	Assistant Professor, Department of Mathematics,Comsat University Attock
5.	Dr. Gohar Ali	Assistant Professor, Department of Mathematics, Islamia College University peshawer.
6.	Dr. Muhammad Adil Khan	Assistant Professor, Department of Mathematics, University of Peshawer
7.	Dr. Gul Rahmat	Assistant Professor, Department of Mathematics, Islamia college university Peshawar.
8.	Dr. Akbar Zada	Assistant Professor, Department of Mathematics, Islamia College University Peshawar.
9.	Dr. Muhammad Ishaq	Assistant Professor, Department of Mathematics, NUST Islamabad.
10.	Dr. Fawad Hussain	Lecturer, Department of Mathematics, Comsat University Abbotabad.
11.	Dr. Muhammad Ishaq	Assistant Professor, Department of Mathematics, NUST University University, Islamabad
12.	Dr. Haider Ali	Lecturer, Department of Mathematics, University of Peshawar.
13.	Dr. Kamran	Lecturer, Department of Mathematics, ICPU, Peshawar.
14.	Dr. Arshad Ali	Assistant Professor, Department of Mathematics, Islamia college university Peshawar.
15.	Dr. Muhammad Arif	Associate Professor, Department of Mathmatics, AWKUM
16.	Dr. Saeed Ahamd	Assistant Professor, Department of Mathematics, University of Malakand.
17.	Dr. Imtiaz Ahamd	Assistant Professor, Department of Mathematics, University of Malakand.
18.	Dr. Faiz Muhammad Khan	Assistant Professor, Department of Mathematics and Statistics, University of Swat.
19.	Dr. Amir Khan	Lecturer, Department of Mathematics and Statistics, University of swat.

20.	Dr. Saeed Islam	Chairman/Professor, Department of Mathematics,AWKUM
21.	Dr. Abdus Saboor	Chairman, Department of Mathematics, KUST.
22.	Dr. Muhammad Asif Jan	Assistant Professor, Department opf Mathematics, KUST.
23.	Dr. Muhammad Farooq	Assistant Professor, Department of Mathematics, University of Peshawar.
24.	Dr. Rohul Amin	Lecturer, Department of Mathematics, University of Peshawar.
25.	Dr. Muhammad Ayaz Khan	Associate Professor, Department of Mathmatics, AWKUM
26.	Dr. Hassan Khan	Assistant Professor, Department of Mathmatics, AWKUM
27.	Dr. Asfandyar Khan	Assistant Professor, Department of Mathmatics, AWKUM

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