Shiv Nadar University

Department of Mathematics
School of Natural Sciences

Course Catalog and Syllabi – Academic Year 2012-13

Course Code and Title	Monsoon 2012	Spring 2013
CCC 101 – Mathematics in India	✓	
CCC 801 – Art of Numbers	✓	✓
MAT 000 – Tutorial	✓	
MAT 100 – Precalculus	✓	
MAT 101 – Calculus I	✓	✓
MAT 102 – Calculus II	✓	✓
MAT 110 – Computing	✓	
MAT 140 – Discrete Structures		✓
MAT 199 – Project	✓	✓
MAT 202 – Mathematical Methods	✓	
MAT 210 – Programming	✓	
MAT 220 – Real Analysis I		✓
MAT 240 – Algebra I	✓	
MAT 260 – Linear Algebra		✓
MAT 284 – Probability and Statistics		✓
MAT 299 – Project	✓	✓
MAT 600 – Basic Tools in Mathematics	✓	
MAT 601 – Mathematical Computing	✓	
MAT 620 – Measure and Integration		✓
MAT 622 – Topology	✓	
MAT 626 – Functional Analysis		✓
MAT 632 – Geometry		✓
MAT 642 – Graph Theory		✓
MAT 660 – Linear Algebra	✓	
MAT 680 – Numerical Analysis I		✓
MAT 684 – Statistics I	✓	
MAT 799 – Masters Project	✓	✓
MAT 800 – Reading Course	✓	✓

Notes

- CCC courses are part of the "Common Core Curriculum" of the SNU undergraduate program. These are half-semester courses with minimal prerequisites, open to any undergraduate student of SNU.
- Course numbers starting 0 through 5 designate undergraduate courses.
- Course numbers starting 6 and above designate graduate courses (Masters and PhD)
- 1st year BS Maths students have MAT 000, 100, 101, 110, 140, 199 and 260 as compulsory courses.
- 2nd year BS Maths students have MAT 102, 210, 220, 240, 284 and 299 as compulsory courses.

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Syllabus for CCC 101 – Mathematics in India

Credits (Lec:Tut:Lab) = 1.5:0:0 (3 lectures weekly over a half-semester)

Prerequisites: None

Overview: Mathematics had a rich history in ancient and medieval India. Indian mathematicians made original contributions to algebra, number theory and geometry; while the Kerala school made fundamental discoveries related to differential calculus and infinite series two centuries before their full development by Newton and Leibniz. This course will provide an overview of the story of mathematics in India, and also incorporate the social context and the connections with other civilizations.

Detailed Syllabus: Issues of dating, translation and interpretation; prehistory; the ancient civilizations of Egypt, Iraq, China and America; Indus Valley Civilization; Mathematics in the Vedas and Puranas; Pythagoras theorem; Applications to grammar, logic, astronomy and technology; Medieval mathematicians and schools of mathematics; Universities; Invention of Zero; Trigonometry; Rates of change; π; Connections with Greece, China and the Arabs; The Kerala school.

Assessment:

Assignments	20%
Class Performance	15%
Term Paper	40%
Presentation	25%

References:

1. *Mathematics in India* by Kim Plofker, Princeton University Press.
2. *Studies in the History of Indian Mathematics* by C S Seshadri (ed.), Hindustan Book Agency.
3. *Contributions to the History of Indian Mathematics* by Gerard G Emch et al (ed.), Hindustan Book Agency.
4. *History of Mathematics* by Carl B Boyer and Uta C Merzbach, Wiley.

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Syllabus for CCC 801 – Art of Numbers

Credits (Lec:Tut:Lab) = 1.5:0:0 (3 lectures weekly over a half-semester)

Overview: This course deals with two aspects of numbers. In the first part of the course we will take up some unexplored patterns that exist in nature, study them and understand some of their applications. The second part looks at numbers as carriers of information about our lives. Here we learn how to analyze and present data in ways that help us make sense of our lives. We'll use the spreadsheet program in Open Office to analyze the data in depth.

Detailed Syllabus:

Part A: Fun with Numbers

1. Moessner's Magic
2. Permutation, Combinations
3. Pascal Triangle, Binomial Theorem
4. Fibonacci Sequence
5. Some applications

Part B: Handling Data

6. Interacting with real time data
7. Descriptive Statistics like mean, median, mode, range, standard deviation, percentiles, quartiles
8. Introduction to a Spreadsheet program (Open Office or Excel)
9. Charts – Bar Charts, Histograms, Line Charts, Pie Charts
10. Simulations
11. Case Studies

Assessment:

Attendance	10%
Assignments + Quizzes	30%
Midterm	30%
Final	30%

References:

1. *The Book of Numbers* by John Horton Conway, Richard K. Guy. 2nd edition, Copernicus.
2. *The Heart of Mathematics: An Invitation to Effective Thinking* by Edward B. Burger, Michael Starbird. 3rd edition, Wiley.
3. *The Visual Display Of Quantitative Information* by Edward Tufte. 2nd edition, Graphics Press.
4. *Excel 2007 for Starters: The Missing Manual* by Matthew MacDonald. Shroff/O'Reilly.
5. *Analyzing Business Data with Excel* by Gerald Knight. Shroff/O'Reilly.

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Syllabus for MAT 000 – Tutorial

Credits (Lec:Tut:Lab) = 0:3:0 (3 hours of discussion weekly)

Prerequisites: None

Overview: This course is specially designed for undergraduates majoring in Mathematics and is a compulsory course during their 1st semester at SNU. Students will be introduced in a tutorial setting to issues regarding the nature and uses of Mathematics. The intent is to ease the transition from high school to university education, as well as to initiate the student into a more holistic view of Mathematics.

Detailed Syllabus: This course will take up issues such as the concepts of axioms and proof, the role of counter-examples, problem solving techniques, geometric intuition, the process of abstraction, etc. Some time will also be set aside for discussion of topics being studied in other courses.

References:

1. *What is Mathematics?* by Richard Courant and Herbert Robbins. 2nd edition, Oxford University Press, 2007
2. *How to Solve It* by G. Polya. 2nd edition, Prentice Hall India, 2007
3. *The Princeton Companion to Mathematics* by T. Gowers, J. Barrow-Green and I. Leader (editors). Princeton University Press, 2008.
4. *Mathematical Vistas* by Peter Hilton, Derek Holton and Jean Pedersen. Springer International Edition, 2010.

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Syllabus for MAT 100 - Precalculus

Credits (Lec:Tut:Lab)= 3:1:0 (3 lectures and 1 tutorial weekly)

Prerequisites: None

Overview: Introduction to modern mathematical language and reasoning: Sets and Functions, Proofs, Number Systems, Limits.

Detailed Syllabus:

1. **Sets:** Describing sets – roster and set-builder notation, empty set, subsets and equality, power set, finite and infinite sets, the language of logic (and, or, not, quantifiers), union, intersection, complement, Euler and Venn diagrams, algebra of sets, Cartesian product

2. **Relations and Functions:** Relations, functions, real functions and their graphs, increasing & decreasing functions, transformations of functions and their graphs, algebra of functions, composition, one-one functions, onto functions, inverse of a function

3. **Number Systems:** Review of **N**, **Z** and **Q,** mathematical induction, sup and inf, order completeness of **R,** Archimedean property of **R,** applications of completeness (existence of square roots, real powers), **C**.

4. **Catalog of Real Functions:** Polynomial functions and graphs, division of polynomials, factor theorem, rational functions, exponential functions, logarithmic functions, trigonometric functions, trigonometric graphs

5. **Limits:** Estimating limits numerically, examples of existence and non-existence, limit laws, applications of limit laws, one-sided limits, tangent lines and derivatives, limits at infinity, limits of sequences

Assessment:

Assignments	10%
Quizzes	10%
Class Performance/Seminars	10%
Midterm	30%
Final	40%

References:

1. *Precalculus* by James Stewart, Lothar Redlin and Saleem Watson. Cengage. 5th ed.
2. *Understanding Mathematics* by K B Sinha et al, Universities Press.
3. *Introduction to Real Analysis,* R G Bartle and D R Sherbert, Wiley India. 3rd ed.

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Syllabus for MAT 101 – Calculus I

Credits (Lec:Tut:Lab)= 3:1:0 (3 lectures and 1 tutorial weekly)

Prerequisites: Class XII mathematics or MAT 100 (Precalculus)

Overview: This course covers one variable calculus and applications. It forms the base for subsequent courses in advanced vector calculus and real analysis as well as for applications in probability, differential equations, optimization, etc.

Detailed Syllabus:

- **Differentiation:** Functions, limits, sandwich theorem, continuity, intermediate value theorem, tangent line, rates of change, derivative as function, algebra of derivatives, implicit differentiation, related rates, linear approximation, differentiation of inverse functions, derivatives of standard functions (polynomials, rational functions, trigonometric and inverse trigonometric functions, hyperbolic and inverse hyperbolic functions).
- **Applications of Differentiation:** Indeterminate forms and L'Hopital's rule, absolute and local extrema, first derivative test, Rolle's theorem, mean value theorem, concavity, 2^{nd} derivative test, curve sketching.
- **Integration:** Area under a curve, Riemann sums, integrability, fundamental theorem, mean value theorem for integrals, substitution, integration by parts, trigonometric integrals, partial fractions, improper integrals.
- **Applications of Integration:** Area between curves, volume, arc length, applications to physics (work, center of mass).
- **Ordinary Differential Equations:** 1^{st} order and separable, logistic growth, 1^{st} order and linear, 2^{nd} order linear with constant coefficients, method of undetermined coefficients, method of variation of parameters.

Assessment:

Assignments	20%
Quizzes	30%
Midterm	20%
Final	30%

Main References:

- *Essential Calculus – Early Transcendentals*, by James Stewart. Cengage, India Edition.
- *Advanced Engineering Mathematics*, Erwin Kreyszig, 9^{th} edition, Wiley India, 2011.

Supplementary References:

- *Advanced Engineering Mathematics*, Dennis G Zill and Warren S Wright, 4^{th} edition, Jones and Bartlett.
- *The Calculus Lifesaver*, by A Banner, Princeton, 2007.
- *Calculus and Analytic Geometry* by G B Thomas and R L Finney, 9^{th} edition, Pearson.

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Syllabus for MAT 102 – Calculus II

Credits (Lec:Tut:Lab)= 3:1:0 (3 lectures and 1 tutorial weekly)

Prerequisites: MAT 101 (Calculus I) or equivalent

Overview: The first part deals with series of numbers and functions. The second part is an introduction to multivariable calculus, finishing with the various versions of Stokes' theorem. The concepts and techniques covered here are used extensively in the social and natural sciences as well as in engineering to study systems with many dimensions.

Detailed Syllabus:

1. **Sequences and Series:** Limits of sequences, algebra of limits, series, divergence test, comparison and limit comparison tests, integral test, alternating series test, absolute convergence, root & ratio tests, power series, Taylor series

2. **Vectors:** Dot and cross product, equations of lines and planes, quadric surfaces, space curves, arc length and curvature

3. **Differential calculus in several variables:** Functions of several variables, level curves and surfaces, limits and continuity, partial derivatives, tangent planes, chain rule, directional derivatives, gradient, Lagrange multipliers, extreme values and saddle points, 2nd derivative test

4. **Double and triple integrals:** Double integrals over rectangles, double integrals over general regions, double integrals in polar coordinates, center of mass, triple integrals, triple integrals in cylindrical coordinates, triple integrals in spherical coordinates, change of variables

5. **Vector Integration:** Vector fields, line integrals, fundamental theorem, independence of path, Green's theorem, divergence, curl, parametric surfaces, area of a parametric surface, surface integrals, Stokes' theorem, Gauss' divergence theorem

Assessment:

Assignments	15%
Quizzes	15%
Midterm 1	15%
Midterm 2	15%
Final	40%

Main Reference:

- *Essential Calculus – Early Transcendentals*, by James Stewart. Cengage, India Edition.

Supplementary References:

- *Calculus and Analytic Geometry* by G B Thomas and R L Finney, 9th edition, Pearson.
- *Basic Multivariable Calculus* by J E Marsden, A J Tromba and A Weinstein, 1st edition, Springer (India), 2011.
- *Calculus* by Ken Binmore and Joan Davies, 1st edition, Cambridge, 2010.

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Syllabus for MAT 110 – Computing

Credits (Lec:Tut:Lab)= 1:0:1 (One lecture hour and two lab hours weekly)

Prerequisites: None

Overview: This course provides an introduction to the programs Matlab and Microsoft Excel as tools for mathematical computing. The focus is on their use in applications from the fields of Statistics, Finance, Image Processing etc. Student presentations of assignment solutions will be a major component of the course.

Detailed Syllabus:

1. **MATLAB:**
   - Arithmetic expressions, assignment, input and output, Boolean expressions, conditional statements
   - For loop, while loop, nested loops, nested conditionals, vectors, elementary graphics, color schemes in Matlab
   - Elementary math functions, Functions with multiple input parameters, plotting
   - Two dimensional arrays, sorting, searching, cell arrays, cell arrays of matrices
   - Working with image files

2. **EXCEL:**
   - Charts
   - Lookup, Match, Index, Offset functions
   - Embedding form controls in a spreadsheet
   - Array functions, Goal Seek, Solver
   - Descriptive statistics with Analysis Toolpak

Assessment:

Quizzes + Assignments	25%
Mid Term Exam	25%
Final Exam	50%

Main References:

1. *Programming in Matlab for Engineers* by Stephen J. Chapman, Cengage, 2011.
2. *Guide to Matlab* by Brian R. Hunt, Cambridge, 2001.
3. *Microsoft Excel 2010: Data analysis and Business Modeling* by Wayne L. Winston, Prentice Hall India.

Other References:

1. *Mastering Matlab 7* by Duane C Hanselman and Bruce L Littlefield, Pearson Education, 2005.
2. *Excel 2010 Formulas* by John Walkenbach, Wiley India, 2011.
3. *Favourite Excel 2010 Tips & Tricks* by John Walkenbach, Wiley India, 2011.

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Syllabus for MAT 140 – Discrete Structures

Credits: 3:0:1 (3 lectures and 1 tutorial weekly)

Prerequisites: None

Overview: This course covers finite processes. The first half deals with the foundations of mathematics – Symbolic logic, Set theory, and Relations. The second half takes up applications of these concepts in the areas of Combinatorics, Probability and Graph Theory. The contents of this course are also essential reading for students of Computer Science.

Detailed Syllabus:

1. **Relations and Digraphs:** Paths in relations and digraphs, Properties of relations, Equivalence relations and equivalence classes, Operations on relations, Connection between relations and some data structures, Transitive Closure and Warshall's algorithm.
2. **Recursion:** Division algorithm, gcd and lcm of two integers, Congruencies, Pigeonhole principle, Recurrence relations.
3. **Functions:** Frequently encountered functions in computer science, Permutation functions.
4. **Partial Orders:** Posets, Extremal elements in a poset, Lattice, Finite Boolean algebras, Functions on Boolean algebras, Karnaugh maps, Logic gates, Digital circuits.
5. **Trees:** Labeled trees, Tree searching, undirected trees, isomorphic trees, Minimal spanning trees, Prim's algorithm.
6. **Graphs:** Euler paths and circuits, Hamiltonian paths and circuits, isomorphic graphs, Transport networks, Matching problems, Colouring graphs.
7. **Introduction to Abstract Algebra:** Binary operations, Semi groups, Groups, Subgroups, Normal subgroups, Cyclic groups, Permutation Groups, Rings and Fields, Finite Fields.

Assessment:

Assignments	20%
Midterm 1	20%
Midterm 2	20%
Final	40%

Main References:

1. Bernard Kolman, Robert Busby, Sharon C. Ross, *Discrete Mathematical Structures*, Pearson Education, New Delhi.
2. Joseph A. Gallian, *Contemporary Abstract Algebra*, Narosa Publishing House, 4th Edition.

Other References:

1. Kenneth H. Rosen, *Discrete Mathematics and its Applications*, Tata McGraw-Hill, New Delhi.
2. C. L. Liu, D. P. Mohapatra, *Elements of Discrete Mathematics*, Tata McGraw-Hill, New Delhi.
3. J.P. Tremblay and R. Manohar, *Discrete Mathematical Structures with Applications to Computer Science*, 1st edition, Tata McGraw-Hill, New Delhi, 2001.

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Syllabus for MAT 199 – Project

Credits (Lec:Tut:Lab)= 3:0:0 (Students will earn 3 credits over two semesters)

Prerequisites: None

Overview: This is a compulsory course for students majoring or minoring in Mathematics. For students majoring in Mathematics, this course must be taken during their first year. Students attending this course will carry out a hands-on project over the full academic year. They shall work in groups on a topic chosen from applications of mathematics and computing, in areas such as finance, image recognition, encryption, coding theory, etc. The grades will be awarded at the end of the academic year.

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Syllabus for MAT 202 – Mathematical Methods

Credits (Lec:Tut:Lab)= 3:0:0 (3 lectures weekly)

Prerequisites: Class XII mathematics

Brief Description: The first part is an introduction to multivariable calculus, finishing with the various versions of Stokes' theorem. The second part deals with series of numbers and functions (such as power series and Fourier series) and their applications to solving differential equations. The concepts and techniques covered here are used extensively in the social and natural sciences as well as in engineering to study systems with many dimensions.

Detailed Syllabus:

1. **Computer Algebra System (CAS):** Equations, solving linear system, function definition, function evaluation, two and three dimensional plots, differentiation, integration, matrices, matrix algebra, simplification of expressions

2. **Differential calculus in several variables:** Space curves and arc length, functions of several variables, level curves and surfaces, limits and continuity, partial derivatives, tangent planes, chain rule, directional derivatives, gradient, Lagrange multipliers, extreme values and saddle points, 2^{nd} derivative test

3. **Double and triple integrals:** Double integrals over rectangles, double integrals over general regions, double integrals in polar coordinates, center of mass, triple integrals, triple integrals in cylindrical coordinates, triple integrals in spherical coordinates, change of variables

4. **Vector Integration:** Vector fields, line integrals, fundamental theorem, independence of path, Green's theorem, divergence, curl, parametric surfaces, area of a parametric surface, surface integrals, Stokes' theorem, Gauss' divergence theorem.

5. **Series and Applications:** Limits of sequences, algebra of limits, series, divergence test, comparison and limit comparison tests, integral test, alternating series test, absolute convergence, root & ratio tests, power series, Taylor polynomials and series, power series method for solving ODEs, Legendre's equation, Bessel's equation, orthogonal functions and Sturm-Liouville problem, periodic functions and trigonometric series, Fourier series, half-range expansions, Fourier integral, heat equation

Assessment:

Assignments	10%
Quizzes	10%
Midterm 1	15%
Midterm 2	15%
Final	50%

Main References:

- *Essential Calculus – Early Transcendentals*, by James Stewart. Cengage, India Edition.
- *Advanced Engineering Mathematics*, Erwin Kreyszig, 9th edition, Wiley India, 2011.

Supplementary References:

- *Advanced Engineering Mathematics*, Dennis Zill and Warren Wright, 4th ed., Jones & Bartlett, 2011.
- *Calculus and Analytic Geometry* by G B Thomas and R L Finney, 9th edition, Pearson.
- *Basic Multivariable Calculus* by J E Marsden, A J Tromba and A Weinstein, 1st edition, Springer (India), 2011.

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Syllabus for MAT 210 – Programming

Credits (Lec:Tut:Lab)= 1:0:1 (One lecture hour and three lab hours weekly)

Prerequisites: None

Overview: This course provides an introduction to formal programming languages via the medium of Python 3.0. The programming activities will be centered around mathematical models involving differential equations, algebraic systems, iterative processes, linear transformations, random processes etc. The course begins with Python language constructs and moves to an in-depth exploration of the SCIPY and NUMPY packages that hold the key to the desired mathematical simulations.

Detailed Syllabus:

1. **Basics of the PYTHON programming language:**
   - Input and output statements, formatting output, copy and assignment, arithmetic operations, string operations, lists and tuples, control statements
   - User defined functions, call by reference, variable number of arguments
   - One dimensional arrays, two dimensional arrays, random number generation
   - Classes, static data, private data, inheritance, scope of variables, nested functions

2. **The NUMPY and SCIPY packages:**
   - Numpy numerical types, data type objects, character codes, dtype constructors.
   - Mathematical libraries, plotting 2D and 3D functions, ODE integrators, charts and histograms, image processing functions.
   - File I/O, loading data from CSV files
   - Using SCIPY/NUMPY to solve models involving difference equations, differential equations, finding limit at a point, approximation using Taylor series, interpolation, definite integrals.

Assessment:

Project	25%
Mid Term Exam	25%
Final Exam	50%

Main References:

1. John Zelle, *Python Programming: An Introduction to Computer Science*. Franklin, Beedle & Associates Inc., Second Edition, 2010.
2. Ivan Idris, *Numpy 1.5 Beginner's Guide*. Packt Publishing, 2011.
3. Hans Petter Langtangen, *A Primer on Scientific Programming on Python*. Springer, Second Edition, 2011.

Other References:

1. Hans Petter Langtangen, *Python Scripting for Computational Science.* Springer, 2010.
2. David M. Beazley, *Python Essential Reference*, 3rd Edition. Pearson, 2009.

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Syllabus for MAT 220 – Real Analysis I

Credits (Lec:Tut:Lab)= 3:1:0 (3 lectures and 1 tutorial weekly)

Prerequisites: Calculus I (MAT 101) or equivalent

Overview: This course provides a rigorous base for the geometric facts and relations that we take for granted in one-variable Calculus. The main ingredients include sequences; series; continuous and differentiable functions on **R;** their various properties and some highly applicable theorems; Riemann integration. This is the foundational course for further study of topics in pure or applied Analysis, such as Metric Spaces, Complex Analysis, Numerical Analysis, and Differential Equations.

Detailed Syllabus:

6. **Fundamentals:** Review of **N**, **Z** and **Q**, order, sup and inf, **R** as a complete ordered field, Archimedean property and consequences, intervals and decimals. Functions: Images and pre-images, Cartesian product, Cardinality.

7. **Sequences:** Convergence, bounded, monotone and Cauchy sequences, subsequences, lim sup and lim inf.

8. **Series:** Infinite Series: Cauchy convergence criterion, Infinite Series of non-negative terms, comparison and limit comparison, integral test, p-series, root and ratio test, power series, alternating series, absolute and conditional convergence, rearrangement.

9. **Continuity:** Limits of functions, continuous functions, Extreme Value Theorem, Intermediate Value Theorem, monotonic functions, uniform continuity.

10. **Differentiation:** Differentiable functions on R, Local maxima, local minima, Mean Value Theorems, L'Hospital's Rule, Taylor's Theorem.

11. **Integration:** Upper and lower Riemann integrals, basic properties of Riemann integral, Riemann integrability of continuous and monotone functions, non-Riemann integrable functions, Riemann-Stieltjes integral, Fundamental Theorem of Calculus and consequences.

Assessment:

Class Performance	10%
Assignments	10%
Quizzes	20%
Midterm	30%
Final	30%

References:

1. *Elementary Analysis: The Theory of Calculus* by Kenneth A Ross. Springer India, 2004.
2. *Analysis I* by Terence Tao. Hindustan Book Agency. 2nd Edition, 2009.
3. *Principles of Mathematical Analysis* by Walter Rudin. McGraw-Hill. 3rd Edition, 2006.

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Syllabus for MAT 240 – Algebra I

Credits (Lec:Tut:Lab)= 3:1:0 (3 lectures and 1 tutorial weekly)

Overview: Learning traditional Abstract Algebra in a contemporary style. The course will cover the standard algebraic structures of groups, rings and fields up to the Fundamental Theorem of Algebra.

Detailed Syllabus:

Module I: Groups

1. Definition and examples, abelain and non-abelian groups, finite and infinite groups
2. Subgroups: characterisations, subgroup generated by a subset, commutator subgroup, center
3. Cyclic Groups: Properties, classification of subgroups
4. Permutation Groups: definition and notation, examples, properties, Symmetric group on n letters (S_n), Alternating group (A_n) on n letters
5. Cosets and Lagrange's theorem
6. External Direct Product: Definition and examples, properties, criteria for external direct product to be cyclic, finitely generated abelian groups

Module II: Morphisms

7. Normal subgroups, factor groups, internal direct products
8. Group homomorphism: Definition and examples, properties
9. Isomorphism, First Isomorphism Theorem, automorphism, properties, examples

Module III: Rings

10. Introduction to Rings: Definition, examples, properties
11. Subrings
12. Ideals, factor rings, prime ideals and maximal ideals
13. Polynomial Rings: Notation and terminology, division algorithm

Module IV: Extension Fields

14. Integral Domain, definitions and examples, Fields, Characteristic
15. Examples of Fields, algebraic and transcendental elements, degree of a field extension
16. Finite Fields: examples, Fundamental Theorem of Algebra

Main Reference:

- *Contemporary Abstract Algebra* by Joseph A. Gallian, 4th edition. Narosa, 1999.

Other References:

- *Topics in Algebra* by I.N. Herstein, 2nd Edition. Wiley India, 2006.
- *Algebra* by Michael Artin, 2nd Edition. Prentice Hall India, 2011.
- *A First Course in Abstract Algebra* by John B. Fraleigh, 7th Edition. Pearson, 2003.
- *Undergraduate Algebra* by Serge Lang, 2nd Edition. Springer India, 2009.

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Syllabus for MAT 260 – Linear Algebra

Credits (Lec:Tut:Lab)= 3:1:0 (3 lectures and 1 tutorial weekly)

Prerequisites: None

Overview: Linear Algebra provides the means for studying several quantities simultaneously. A good understanding of Linear Algebra is essential in almost every area of higher mathematics, and especially in applied mathematics. Matlab will be used throughout the course for computational purposes.

Detailed Syllabus:

1. Matrices and Linear Systems
2. Vector Spaces
3. Inner Product Spaces
4. Determinant
5. Eigenvalues and Eigenvectors
6. Positive definite matrices
7. Linear Programming and Game Theory

Assessment:

Assignments	20%
Quizzes	20%
Midterm	20%
Final	40%

Main References:

- *Linear Algebra and its Applications* by Gilbert Strang, 4th edition, Cengage.
- *Linear Algebra and its Applications* by David C. Lay, 3rd edition, Pearson.

Other References:

- *Linear Algebra: A Geometric Approach* by S. Kumaresan, PHI, 2011.

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Syllabus for MAT 284 – Probability and Statistics

Credits (Lec:Tut:Lab)= 3:1:0 (3 lectures and 1 tutorial weekly)

Prerequisites: Calculus I (MAT 101) or equivalent

Overview: Probability is the means by which we model the inherent randomness of natural phenomena. This course introduces you to a range of techniques for understanding randomness and variability, and for understanding relationships between quantities. The concluding portions on Statistics take up the problem of testing our theoretical models against actual data, as well as applying the models to data in order to make decisions. This course is a prerequisite for later courses in Advanced Statistics, Stochastic Processes and Mathematical Finance.

Detailed Syllabus:

1. **Probability:** Classical probability, axiomatic approach, conditional probability, independent events, addition and multiplication theorems with applications, Bayes' theorem.
2. **Random Variables**: Probability mass function, probability density function, cumulative density function, expectation, variance, standard deviation, mode, median, moment generating function.
3. **Some Distributions and their Applications:** Uniform (discrete and continuous), Bernoulli, Binomial, Poisson, Exponential, Normal.
4. **Sequences of Random Variables:** Chebyshev's Inequality, Law of Large Numbers, Central Limit Theorem, random walks.
5. **Joint Distributions:** Joint and marginal distributions, covariance, correlation, independent random variables, least squares method, linear regression.
6. **Sampling:** Sample mean and variance, standard error, sample correlation, chi square distribution, t distribution, F distribution, point estimation, confidence intervals.
7. **Hypothesis Testing:** Null and alternate hypothesis, Type I and Type II errors, large sample tests, small sample tests, power of a test, goodness of fit, chi square test.

Assessment:

Quizzes	20%
Assignments	20%
Midterm	20%
Final	40%

Main References:

- *A First Course in Probability* by Sheldon Ross, 6th edition, Pearson.
- *John E. Freund's Mathematical Statistics with Applications* by I. Miller & M. Miller, 7th edition, Pearson, 2011.

Other References:

- *Elementary Probability Theory: With Stochastic Processes and an Introduction to Mathematical Finance* by Kai Lai Chung and Farid Aitsahlia, 4th edition, Springer International Edition, 2004.
- *Introduction to the Theory of Statistics* by Alexander M. Mood, Franklin A. Graybill and Duane C. Boes, 3rd edition, Tata McGraw-Hill, 2001.

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Syllabus for MAT 299 – Project

Credits (Lec:Tut:Lab)= 3:0:0 (Students will earn 3 credits over two semesters)

Prerequisites: MAT 199

Overview: This is a compulsory 2nd year course for students majoring in Mathematics. Students attending this course will carry out a hands-on project over the full academic year. They shall work in groups on a topic chosen from applications of mathematics and computing, in areas such as finance, image recognition, encryption, coding theory, etc. The grades will be awarded at the end of the academic year.

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Syllabus for MAT 600 – Basic Tools in Mathematics

Credits (Lec:Tut:Lab): 3:1:0 (3 lectures and 1 tutorial weekly)

Overview: This course provides a knowledge of basic concepts and computational techniques from Linear Algebra and Statistics. It is intended primarily for graduate students of the sciences who need these areas of mathematics in their work.

Detailed Syllabus:

- **Linear Algebra**
  1. Euclidean space, subspaces, basis, dimension, linear systems, Gauss elimination.
  2. Matrix transformations, determinant, inverse, change of basis, kernel and range, eigenvalues and eigenvectors, diagonalization.
  3. Inner products, orthogonality, orthogonal matrices, Gram-Schmidt process, QR factorization, diagonalization of symmetric matrices, singular value decomposition.

- **Probability and Statistics**
  1. Frequency interpretation of probability, axiomatic probability, conditional probability, independent events, Bayes' theorem.
  2. Random variables, cdf, pmf and pdf, standard distributions such as binomial, Poisson, exponential and normal.
  3. Expectation, variance, standard deviation, Chebyshev inequality.
  4. Joint and marginal distributions, covariance and correlation, conditional distributions, regression, least squares, multinomial distribution, Cholesky decomposition, Monte Carlo simulation, PCA.
  5. Random samples, sample mean, sample variance, sample covariance, law of large numbers, Central Limit Theorem, maximum likelihood, confidence intervals.
  6. Hypothesis tests, large and small sample tests.

References:

1. *Linear Algebra & its Applications* by David C Lay
2. *Linear Algebra & its Applications* by Gilbert Strang
3. *Geometric Linear Algebra* by S Kumaresan
4. *John E Freund's Mathematical Statistics with Applications* by Miller & Miller
5. *Statistical Inference* by Cassella & Berger
6. *Introduction to Mathematical Statistics* by Hogg, Craig and McKean

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Syllabus for MAT 601 – Mathematical Computing

Credits(Lec:Tut:Lab): 1:0:1 (1 lecture and 2 lab hours weekly)

Prerequisites: None

Overview: In this course we introduce MATLAB as a platform for scientific computation and simulations; and follow with a brief introduction to C++ as a formal programming language. We also demonstrate how MATLAB and C++ can be integrated to build powerful applications. The course complements other graduate courses like Linear Algebra, Numerical Analysis and Optimization.

Detailed Syllabus:

1. **MATLAB:**
    - Arithmetic expressions, assignment, input and output, Boolean expressions, conditional statements.
    - For loop, while loop, nested loops, nested conditionals, vectors, elementary graphics, color schemes.
    - Elementary mathematical functions, functions with multiple input parameters, graphics functions.
    - Two dimensional arrays, contour plotting, sorting, searching, cell arrays, cell arrays of matrices, functions as parameters, structures.
    - Working with image files, acoustic file processing, recursive functions, solving linear programming problems.

2. **C++ Programming:**
    - Fundamental data types, operators, control structures, user defined functions
    - Arrays, pointers, function pointers, multi- dimensional arrays
    - Classes, constructors & destructors, bitwise operators
    - Integrating C++ with MATLAB – calling MATLAB functions within a C++ program.

Assessment:

Lab Assignments	50%
Mid Term Exam	25%
Final Exam	25%

Main References:

1. *Programming in Matlab for Engineers* by Stephen J. Chapman. Cengage, 2011.
2. *A Guide to Matlab* by Brian R. Hunt, Ronald L. Lipsman and others. 2nd edition, Cambridge, 2011.
3. *Insight Through Computing: A MATLAB introduction to Computational Science and Engineering* by Charles F. Van Loan and K. Y. Daisy Fan. SIAM, 2009.
4. *Introducing C++ for Scientists, Engineers and Mathematicians* by D. M. Capper. Springer India, 2001.

Other references:

1. *Mastering Matlab 7* by Duane C. Hanselman and Bruce L. Littlefield. Pearson Education, 2005.
2. *C++ Programming Language* by Bjarne Stroustrup. 3rd edition, Pearson, 2002.
3. *Object Oriented Programming in C++* by R. Lafore. 3rd edition, Galgotia, 2006.

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Syllabus for MAT 620 – Measure and Integration

Credits (Lec:Tut:Lab): 3:1:0 (3 lectures and 1 tutorial weekly)

Prerequisites: MAT 220 (Real Analysis) or equivalent

Overview: This course puts the concept of integration of a real function in its most appropriate setting. It is also a prerequisite for the study of general measures, which is the foundation for a large part of pure and applied mathematics – such as spectral theory, probability, stochastic differential equations, harmonic analysis, Sobolev spaces, and partial differential equations.

Detailed Syllabus:

1. **Review of Set Theory and Real Number System**: Operations with infinite collection of sets, algebras of sets, extended real numbers, sequences of real numbers, open and closed sets of real numbers, Borel sets, continuous functions.

2. **Lebesgue Measure:** Outer measure, measurable sets, Lebesgue measure, measurable functions, pointwise convergence, almost everywhere convergence.

3. **The Lebesgue Integral:** Riemann integral, Lebesgue integral of a bounded measurable function over a set of finite measure, Lebesgue integral of a non-negative and a general measurable function.

4. **Differentiation and Integration:** Differentiation of monotone functions, functions of bounded variation, differentiation of an integral, absolute continuity.

5. **The Classical Banach spaces**: L^p spaces, Minkowski and Hölder inequalities, completeness of L^p spaces, bounded linear functions on L^p spaces.

6. **Topics for Student Presentations:** A non-measurable set, Littlewood's three principles, convergence in measure, absolute continuity, convergence and completeness in L^p spaces, approximation in L^p spaces.

Assessment:

Assignments	20%
Presentations	20%
Midterm	20%
Final	40%

Main Reference:

- *Real Analysis* by H. L. Royden and P. Fitzpatrick. 4th edition, Prentice-Hall India, 2010.

Other References:

- *Measure Theory and Integration* by G. de Barra, New Age International, reprint 2006.
- *Real Analysis : Modern Techniques and their Applications* by G. B. Folland, Wiley, 2nd edition, 1999.
- *Measure Theory* by Paul Halmos, Springer, 1974.

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Syllabus for MAT 622 - Topology

Credits (Lec:Tut:Lab): 3:1:0 (3 lectures and 1 tutorial weekly)

Prerequisites: MAT 220 (Real Analysis) or equivalent

Overview: This course concerns 'General Topology' which can be characterized as the abstract framework in which the notion of continuity can be framed and studied. Thus topology provides the basic language and structure for a large part of pure and applied mathematics.

We will take up the following topics: Open and closed sets, continuous functions, subspaces, product and quotient topologies, connected and path connected spaces, compact and locally compact spaces, Baire category theorem, separability axioms.

Detailed Syllabus:

1. **Review:** Operations with infinite collections of sets, axiom of choice, Zorn's lemma, real line, metric spaces.
2. **Topological Spaces:** Definition and examples of topological spaces, Hausdorff property, fine and coarse topologies, subspace topology, closed sets, continuous functions, homeomorphisms, pasting lemma, product topology, quotient topology.
3. **Connectedness and Compactness:** Connected spaces and subsets, path connectedness, compact spaces and subsets, tube lemma, Tychonoff theorem, local compactness, one-point compactification, Baire category theorem.
4. **Separation Axioms:** First and second countability, separability, separation axioms (T_1 etc.), normal spaces, Urysohn lemma, Tietze extension theorem.
5. **Topics for Student Presentations:** Order topology, quotients of the square, locally (path) connected spaces, sequential and limit point compactness, topological groups, nets, applications of Baire category theorem.

Assessment:

Assignments	20%
Presentations	20%
Midterm	20%
Final	40%

Main Reference:

- *Topology* by James R. Munkres, 2nd Edition. Pearson Education, Indian Reprint, 2001.

Other References:

- *Basic Topology* by M. A. Armstrong. Springer-Verlag, Indian Reprint, 2004.
- *Topology* by K. Jänich. Undergraduate Texts in Mathematics, Springer-Verlag, 1984.
- *Introduction to Topology and Modern Analysis* by G. F. Simmons. International Student Edition. McGraw-Hill, Singapore, 1963.
- *Topology of Metric Spaces* by S. Kumaresan. 2nd edition, Narosa, 2011.

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Syllabus for MAT 626 – Functional Analysis

Credits (Lec:Tut:Lab): 3:1:0 (3 lectures and 1 tutorial weekly)

Prerequisites: MAT 220 (Real Analysis I), Mat 221 (Real Analysis II), MAT 260 (Linear Algebra) or equivalent

Overview: This course introduces the tools of Banach and Hilbert Spaces, which generalize linear algebra and geometry to infinite dimensions. It is a prerequisite for advanced topics like Spectral Theory, Operator Algebras, Operator Theory, Sobolev Spaces, and Harmonic Analysis. Functional Analysis is a vital component of applications of mathematics to areas like Quantum Physics and Information Theory.

Detailed Syllabus:

1. **Banach Spaces**
    a. **Normed Spaces:** Some inequalities, Banach Spaces, finite dimensional spaces, compactness and dimension, quotient spaces, bounded operators, sums of normed spaces.
    b. **Category Theorems:** Baire Category Theorem, Open Mapping Theorem, Closed Graph Theorem, Principle of Uniform Boundedness.
    c. **Dual Spaces:** Hahn-Banach Theorem, Spaces in Duality, Adjoint operator.
    d. **Weak Topologies:** Weak topology induced by seminorms, weakly continuous functionals, Hahn-Banach separation theorem, weak*-topology, Alaouglu's Theorem, Goldstine's Theorem, reflexivity, extreme points, Krein-Milman Theorem.

2. **Hilbert Spaces**
    a. **Inner products:** Inner product spaces, Hilbert spaces, orthogonal sum, orthogonal complement, orthonormal basis, orthonormalization, Riesz Representation Theorem.
    b. **Operators on Hilbert spaces:** Adjoint operators and involution in B(H), Invertible operators, Self adjoint operators, Unitary operators, Isometries.
    c. **Spectrum:** Spectrum of an operator, Spectral mapping theorem for polynomials.

Assessment:

Assignments	20%
Presentations	10%
Midterm	30%
Final	40%

Main References:

1. E. Kreyszig*: Introductory Functional Analysis with Applications*, Wiley India.
2. G. F. Simmons: *Topology and Modern Analysis*, Tata McGraw-Hill, 2004.

Other References:

1. Gert K. Pedersen: *Analysis Now*, Springer, 1988.
2. John B. Conway: *A Course in Functional Analysis*, Springer International Edition, 2010.
3. V. S. Sunder: *Functional Analysis - Spectral Theory*, Hindustan Book Agency, 1997.
4. S. Kesavan: *Functional Analysis*, Hindustan Book Agency, 2009.
5. G. Bachman and L. Narici: *Functional Analysis*, 2nd edition, Dover, 2000.
6. Sterling K. Berberian: *Lectures in Functional Analysis and Operatory Theory*, Springer, 1974.

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Syllabus for MAT 632 – Geometry

Credits: 3 (4 lectures weekly)

Prerequisites: MAT 260 (Linear Algebra) or equivalent

Overview: This course provides a bridge to modern geometry. It provides a unified axiomatic approach leading to a coherent overview of the classical geometries (affine, projective, hyperbolic, spherical), culminating in a treatment of surfaces that sets the stage for future study of differential geometry.

Detailed Syllabus:

1. **Affine geometry –** finite planes, planes over fields, affine transformations, collineations, affine coordinates, triangles and parallelograms, classical theorems of Menelaus and others.
2. **Projective geometry –** finite planes, projective completion of affine planes, homogeneous coordinates, projective transformations, collineations, projective line, poles and polars.
3. **Conics –** affine and projective classifications, group actions.
4. **Euclidean geometry –** isometries, triangles, parallelograms, length minimizing curves, geometry of plane curves.
5. **Hyperbolic geometry –** Poincare upper half plane, Poincare metric, distance function, triangles and area, two-point homogeneity.
6. **Spherical geometry –** Sphere, tangent space, great circles, triangles and area, two-point homogeneity
7. **Surfaces –** Level surfaces, parametrized surfaces, curvature, Gauss theorem, introduction to manifolds.

Assessment:

Assignments	20%
Presentations	20%
Midterm 1	15%
Midterm 2	15%
Final	30%

Main Reference:

- *An Expedition to Geometry* by S Kumaresan and G Santhanam. Hindustan Book Agency, 2005.

Other References:

- *Geometry* by M. Audin. Springer International Edition, Indian reprint, 2004.

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Syllabus for MAT 642 – Graph Theory

Credits: 3 (4 lectures weekly)

Prerequisites: MAT 140 (Discrete Structures), MAT 260 (Linear Algebra) or equivalent

Overview: Combinatorial graphs serve as models for many problems in science, business, and industry. In this course we will begin with the fundamental concepts of graphs and build up to these applications by focusing on famous problems such as the Traveling Salesman Problem, the Marriage Problem, the Assignment Problem, the Network Flow Problem, the Minimum Connector Problem, the Four Color Theorem, the Committee Scheduling Problem , the Matrix Tree Theorem, and the Graph Isomorphism Problem. We will also highlight the applications of matrix theory to graph theory.

Detailed Syllabus:

1. **Fundamentals:** Graphs and Digraphs, Finite and Infinite graphs, Degree of a vertex, Degree Sequence, Walk, Path, Cycles, Clique, Operations on Graphs, Complement, Subgraph, Connectedness, Components, Isomorphism, Special classes of graphs: Regular, Complete, Bipartite, Cyclic and Euler Graphs, Hamiltonian Paths and Circuits. Trees and binary trees.
2. **Connectivity:** Cut Sets, Spanning Trees, Fundamental Circuits and Fundamental Cut Sets, Vertex Connectivity, Edge Connectivity, Separability.
3. Planar graphs, Coloring, Ramsey theory, Covering, Matching, Factorization, Independent sets, Network flows.
4. **Graphs and Matrices:** Incidence matrix, Adjacency matrix, Laplacian matrix, Spectral properties of graphs, Matrix tree theorem, Automorphism group of a graph, vertex, edge and distance transitive graphs, Cayley graphs.
5. **Algorithms and Applications:** Algorithms for connectedness and components, spanning trees, minimal spanning trees of weighted graphs, shortest paths in graphs by DFS, BFS, Kruskal's, Prim's, Dijkstra's algorithms.

Assessment:

Assignments	20%
Presentations	20%
Midterm	20%
Final	40%

Main References:

1. D. West, *Introduction to Graph Theory*, Prentice Hall.
2. Narsingh Deo, *Graph Theory: With Application to Engineering and Computer Science*, PHI, 2003.
3. Chris D. Godsil and Gordon Royle, *Algebraic Graph Theory*, Springer-Verlag, 2001.

Other References:

1. Norman Biggs, *Algebraic Graph Theory*, 2nd edition, Cambridge Mathematical Library.
2. Frank Harary, *Graph Theory*, Narosa Publishing House.
3. J. A. Bondy and U. S. R. Murty, *Graph Theory with Applications*, Addison Wesley.
4. R. J. Wilson*, Introduction to Graph Theory*, 4th Edition, Pearson Education, 2003.
5. Josef Lauri, Raffaele Scapellato, *Topics in Graph Automorphisms and Reconstruction*, London Mathematical Society Student Texts.

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Syllabus for MAT 660 - Linear Algebra

Credits (Lec:Tut:Lab): 3:1:0 (3 lectures and 1 tutorial weekly)

Prerequisites: MAT 240 and 260, or an undergraduate algebra course with basics of groups and fields.

Overview: The theory of vector spaces is an indispensible tool for Mathematics, Physics, Economics and many other subjects. This course aims at providing a basic understanding and some immediate applications of the language of vector spaces and morphisms among such spaces.

Detailed Syllabus:

1. **Familiarity with sets**: Finite and infinite sets; cardinality; Schroeder-Bernstein Theorem; statements of various versions of Axiom of Choice.
2. **Vector spaces**: Fields; vector spaces; subspaces; linear independence; bases and dimension; existence of basis; direct sums; quotients.
3. **Linear Transformations**: Linear transformations; null spaces; matrix representations of linear transformations; composition; invertibility and isomorphisms; change of co-ordinates; dual spaces.
4. **Systems of linear equations:** Elementary matrix operations and systems of linear equations.
5. **Determinants:** Definition, existence, properties, characterization.
6. **Diagonalization:** Eigenvalues and eigenvectors; diagonalizability; invariant subspaces; Cayley-Hamilton Theorem.
7. **Canonical Forms:** The Jordan canonical form; minimal polynomial; rational canonical form.

Assessment:

Assignments	10%
Quizzes	5%
Class performance/seminars	5%
Mid Term Exam	30%
Final Exam	50%

Main References:

- Friedberg, Insel and Spence: *Linear Algebra*, 4th edition, Prentice Hall India
- Hoffman and Kunze: *Linear Algebra*, 2nd edition, Prentice Hall India

Other references:

- Paul Halmos: *Finite Dimensional Vector Spaces*, Springer India
- Sheldon Axler: *Linear Algebra Done Right*, 2nd edition, Springer International Edition
- S. Kumaresan: *Linear Algebra: A Geometric Approach*, Prentice Hall India

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Syllabus for MAT 680 – Numerical Analysis I

Credits: 3 (4 lectures weekly)

Prerequisites: MAT 220 (Real Analysis I), MAT 260 (Linear Algebra) or equivalent

Overview: This course takes up the problems of practical computation that arise in various areas of mathematics such as solving algebraic or differential equations. The focus will be on algorithms for obtaining approximate solutions, and their implementation by computer programs.

Detailed Syllabus:

1. Solution of Linear and Nonlinear Systems
2. Interpolation and Curve Fitting
3. Numerical Integration and Differentiation
4. Numerical Solution of ODE and PDEs

Assessment:

Theoretical Assignments	25%
Practical Assignments	25%
Midterm	25%
Final	25%

Main reference:

- *Numerical Methods using Matlab*, by John H. Mathews and Kurtis D. Fink, 4th edition, PHI, 2009.

Other References:

- *Numerical Analysis*, by Rainer Kress, Springer, 2010.
- *Introduction to Numerical Analysis*, by J. Stoer and R. Bulirsch, 3rd edition, Springer, 2009.

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Syllabus for MAT 684 – Statistics I

Credits (Lec:Tut:Lab): 3:1:0 (3 lectures and 1 tutorial weekly)

Prerequisites: MAT 284 (Probability & Statistics) or equivalent

Overview: This course builds on a standard undergraduate probability and statistics course in two ways. First, it makes probability more rigourous by using the concept of measure. Second, it discusses more advanced topics such as multivariate regression, ANOVA and Markov Chains.

Detailed Syllabus:

1. Probability: Axiomatic approach, conditional probability and independent events
2. Random Variables – Discrete and continuous. Expectation, moments, moment generating function
3. Joint distributions, transformations, multivariate normal distribution
4. Convergence theorems: convergence in probability, Weak law of numbers, Borel- Cantelli lemmas, Strong law of large numbers, Central Limit Theorem
5. Random Sampling & Estimators: Point Estimation, maximum likelihood, sampling distributions
6. Hypothesis Testing
7. Linear Regression, Multivariate Regression
8. ANOVA
9. Introduction to Markov Chains

Assessment:

Assignments and Presentations	30%
Midterm Exam	30%
Final Exam	40%

References:

- *Statistical Inference* by Casella and Berger. Brooks/Cole, 2007. (India Edition)
- *An Intermediate Course in Probability* by Allan Gut. Springer, 1995.
- *Probability: A Graduate Course* by Allan Gut. Springer India.
- *Measure, Integral and Probability* by Capinski and Kopp. 2nd edition, Springer, 2007.

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Syllabus for MAT 799 – Masters Project

Credits: 6 (Over two semesters)

Prerequisites: None

Overview: This is the final year masters project/thesis for students pursuing an MS in Mathematics. The course can take a variety of forms, from a reading course on advanced topics to computational work in an application of mathematics. The work will be presented in a public seminar at the end of the academic year. The grade will also be given at the end of the academic year.

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Syllabus for MAT 800 – Reading Course

Credits: 3

Prerequisites: None

Overview: PhD students can undertake this reading course with the consent of their supervisor, though the course itself may be conducted by other faculty. MAT 800 will be used for reading advanced topics as preparation for starting research.