Proposed Syllabus based on NEP - 2020

for

B.Sc. (Hons.) in Mathematics/
B.Sc. (Hons. with Research) in Mathematics

DEPARTMENT OF MATHEMATICS,
SCHOOL OF PHYSICAL SCIENCES,
DOON UNIVERSITY, DEHRADUN-248001, UTTARAKHAND

(w.e.f. ACADEMIC SESSION 2022-2023)

B.Sc. (Hons.) in Mathematics/
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1. **Introduction to Undergraduate Degree course in Mathematics**

   As per the recommendations of the Undergraduate Curriculum Framework 2022 (UGCF 2022), the undergraduate degree course in mathematics is a six/ eight semester course spread over three/ four academic years. The teaching – learning process is student-centric and it involves both theory and practical components. It offers a flexibility of programme structure while ensuring that the student gets a strong foundation in the subject and gains in-depth knowledge. Besides the Discipline Specific Core(DSC) courses, a student can opt courses from the syllabus comprising of Discipline Specific Electives(DSEs), Generic Electives(GEs), Skill Enhancement Courses(SECs), Ability Enhancement courses(AECs) and Value Addition Courses(VACs). Thereby, bringing out the multidisciplinary approach and adherence to innovative ways within the curriculum framework. Moreover, it allows a student maximum flexibility in pursuing his/her studies at the undergraduate level to the extent of having the liberty to eventually design the degree with multiple exit options depending upon the needs and aspirations of the student in terms of his/her goals of life, without compromising on the teaching learning, both in qualitative and quantitative terms. This will suit the present day needs of students in terms of securing their paths towards higher studies or employment.

2. **Courses of Study:**

   Courses of the study indicate pursuance of study in a particular discipline. Every discipline shall offer four categories of courses of study, viz. Discipline Specific Core (DSC) courses, Discipline Specific Electives (DSEs), Skill Enhancement Courses (SECs) and Generic Electives (GEs). Besides these four courses, a student will select Ability Enhancement Courses (AECs) and Value-Added Courses (VACs) from the respective pool of courses offered by the University.

   a) **Discipline Specific Core (DSC):** Discipline Specific Core is a course of study, which should be pursued by a student as a mandatory requirement of his/ her programme of study. In Bachelor of Science (Hons.) Mathematics programme, DSCs are the core credit courses of Mathematics which will be appropriately graded and arranged across the semesters of study, being undertaken by the student, with multiple exit options as per NEP 2020.

   b) **Discipline Specific Elective (DSE):** The Discipline Specific Electives (DSEs) are a pool of credit courses of Mathematics from which a student will choose to study based on his/ her interest.

   c) **Generic Elective (GE):** Generic Electives is a pool of courses offered by various disciplines of study (excluding the GEs offered by the parent discipline) which is meant to provide multidisciplinary or interdisciplinary education to students. In case a student opts for DSEs beyond his/ her discipline specific course(s) of study, such DSEs shall be treated as GEs for that student.

   d) **Ability Enhancement course (AEC), Skill Enhancement Course (SEC) and**

Value Addition Course (VAC): These three courses are a pool of courses offered by all the Departments in groups of odd and even semesters from which a student can choose.

i. **AEC:** AEC courses are the courses based upon the content that leads to knowledge enhancement through various areas of study. They are based on Language and Literature, and Environmental Science which are mandatory for all disciplines.

ii. **SEC:** SECs are skill-based courses in all disciplines and are aimed at providing hands-on training, competencies, proficiency and skills to students. SEC courses may be chosen from a pool of courses designed to provide skill-based instruction.

iii. **VAC:** VACs are common pool of courses offered by different disciplines and aimed towards personality building, embedding ethical, cultural and constitutional values; promote critical thinking, Indian knowledge systems, scientific temperament, communication skills, creative writing, presentation skills, sports and physical education and team work which will help in all round development of students.

3. Programme Duration and Exit Options:

The minimum credit to be earned by a student per semester is 22 credits. The mandatory number of credits which have to be secured for the purpose of award of Undergraduate Certificate/ Undergraduate Diploma/Appropriate Bachelor's Degree in Mathematics are listed in the following Table 1.

*Table 1: **Qualification Type and Credit Requirements***

S. No.	Type of Award	Stage of Exit	Mandatory Credits to be Secured for the Award
1.	Undergraduate Certificate in Mathematics	After successful completion of Semester II	44
2.	Undergraduate Diploma in Mathematics	After successful completion of Semester IV	88
3.	Bachelor of Science (Hons.) in Mathematics	After successful completion of Semester VI	132
4.	Bachelor of Science (Hons. with Research) in Mathematics(Major) and Discipline - 2(Minor)	After successful completion of Semester VIII with minimum 28 GE credits in Discipline- 2 (Minor)	176

a) **Major Discipline (Mathematics):** A student pursuing four-year undergraduate programme in Mathematics (Core course) shall be awarded B.Sc. Honours degree with Major in Mathematics on completion of VIII Semester, if he/she secures in Mathematics at least 50% of the total credits i.e., at least 88 credits in Mathematics out of the total of 176 credits. He/she shall study 20 DSCs and at least 2 DSEs of Mathematics in eight semesters.

b) **Minor Discipline (Discipline - 2):** A student of B.Sc. (Hons.) in Mathematics may be awarded Minor in a discipline, other than Mathematics, on completion of VIII Semester, if he/she earns minimum 28 credits from seven GE courses of that discipline.

4. Programme Objectives:

The undergraduate degree course in Mathematics aims to provide:

a) In-depth knowledge in Mathematics through understanding of key mathematical concepts, principles, theories and their applications.
b) inculcate strong interest in learning mathematics,
c) evolve broad and balanced knowledge and understanding of definitions, key concepts, principles and theorems in Mathematics,
d) enable learners/students to apply the knowledge and skills acquired by them during the programme to solve specific theoretical and applied problems in mathematics,
e) develop in students the ability to apply relevant tools developed in mathematical theory to handle issues and problems in social and natural sciences,
f) provide students with sufficient knowledge and skills that enable them to undertake further studies in mathematics and related disciplines,
g) sufficient subject matter competence and enable students to prepare for various competitive examinations such as IIT-JAM, GATE, GRE, UGC-CSIR, NET/JRF and Civil Services Examinations etc.

5. Programme Outcomes:

The learning outcomes of the undergraduate degree course in Mathematics are as follows:

a) Communicate mathematics effectively by written, computational and graphic means.
b) Create mathematical ideas from basic axioms.
c) Gauge the hypothesis, theories, techniques and proofs provisionally.
d) Utilize mathematics to solve theoretical and applied problems by critical understanding, analysis and synthesis.
e) Identify applications of mathematics in other disciplines and in the real-world, leading to enhancement of career prospects in a plethora of fields and research.

6. Programme Structure:

The detailed framework of undergraduate degree programme in Mathematics is provided in Table 2.

Table 2: Structure of Undergraduate Programme in Mathematics Under UGCF – 2022

Semester	Discipline Specific Core Course	Discipline Specific Elective (DSE)/ Generic Elective(GE)	Ability Enhancement Course (AEC)	Skill Enhancement Course(SEC)/ Project/ Dissertation	Value Addition Course (VAC)	Total Credits earn
I	DSC-1 DSC-2 DSC-3	GE-1	AEC-1	SEC-1	VAC-1	22
II	DSC-4 DSC-5 DSC-6	GE-2	AEC-2	SEC-2	VAC-2	22
III	DSC-7 DSC-8 DSC-9	DSE1/GE-3	AEC-3	SEC-3	VAC-3	22
IV	DSC-10 DSC-11 DSC-12	DSE2 / GE-4	AEC-4	SEC-4	VAC-4	22
V	DSC-13 DSC-14 DSC-15	One DSE-3 and One GE-5		Internship/Apprenticeship /Project/Community Outreach (2-Credits)		22
VI	DSC-16 DSC-17 DSC-18	One DSE-4 and One GE-6		Internship/Apprenticeship/Project/Community Outreach (2-Credits)		22
VII	DSC-19	DSE-5 /GE-7 DSE-6 /GE-8 DSE-7/GE-9		Dissertation/Academic Project (6-Credits)		22
VIII	DSC-20	DSE-8/GE-10 DSE-9/GE-11 DSE-10/GE-12		Dissertation/Academic Project (6-Credits)		22

6.1 Semester-wise Distribution of Discipline Specific Core (DSC) Courses:

A student will study three Discipline Specific Core Courses each in Semesters I to VI and one core course each in semesters VII and VIII. The semester wise distribution of DSC courses over eight semesters is listed in Table 3.

Table 3: Semester-wise Distribution of Discipline Specific Core (DSC) Courses

Discipline Specific Core Courses (4 Credits each)			Contact Hours			Credit
Semester	**Course Code**	**Name Of The Course**	**L**	**T**	**P**	
I	MAC101	Calculus	3	1	0	4
I	MAC102	Algebra	3	1	0	4
I	MAC103	Logic, Sets and Special Functions	3	1	0	4
II	MAC151	Real Analysis-1	3	1	0	4
II	MAC152	Differential Equations	3	1	0	4
II	MAC153	Group Theory-1	3	1	0	4
III	MAC201	Real Analysis-2	3	1	0	4
III	MAC202	PDE and Systems of ODE	3	1	0	4
III	MAC203	Mathematical Transforms	3	1	0	4
IV	MAC251	Numerical Methods	3	0	1	4
IV	MAC252	Riemann Integration and Series of Functions	3	1	0	4
IV	MAC253	Ring Theory	3	1	0	4
V	MAC301	Multivariate Calculus	3	1	0	4
V	MAC302	Group Theory-II	3	1	0	4
V	MAC303	Analytical Geometry	3	1	0	4
VI	MAC351	Metric Spaces	3	1	0	4
VI	MAC352	Linear Algebra	3	1	0	4
VI	MAC353	Linear Programming	3	1	0	4
VII	MAC401	Topology	3	1	0	4
VIII	MAC451	Functional Analysis	3	1	0	4

6.2 Details of Discipline Specific Elective (DSE) Courses:

The Discipline Specific Electives (DSEs) are a pool of credit courses of Mathematics from which a student will choose to study based on his/ her interest. A student of Bachelor of Science (Hons.) Mathematics gets an option of choosing one DSE of Mathematics in each of the semesters III to VI, while the student has an option of choosing a maximum of three DSE courses of Mathematics in semesters VII and VIII. The semester wise distribution of DSE courses over six semesters is listed in Table 4.

Table 4: Semester-wise Distribution of Discipline Specific Elective (DSE) Courses

Discipline Specific Elective Courses (4 Credits each)			Contact Hours			Credit
Semester	**Course Code**	**Name Of The Course**	**L**	**T**	**P**	
III	MAE201	Bio Mathematics	3	1	0	4
III	MAE202	Theory of Equations	3	1	0	4
IV	MAE251	Differential Geometry	3	1	0	4
IV	MAE252	Combinatorial Mathematics	3	1	0	4
V	MAE301	Probability and Statistics	3	1	0	4
V	MAE302	Finite Element Methods	3	1	0	4
V	MAE303	Mechanics	3	1	0	4
VI	MAE351	Graph Theory	3	1	0	4
VI	MAE352	Mathematical Finance	3	1	0	4
VI	MAE353	Cryptography and Network Security	3	1	0	4
VII	MAE401	Finite Field	3	1	0	4
VII	MAE402	Ordinary Differential Equation (ODE)	3	1	0	4
VII	MAE403	Advanced Numerical Analysis	3	1	0	4
VII	MAE404	Mathematical Modelling	3	1	0	4
VIII	MAE451	Complex Analysis	3	1	0	4
VIII	MAE452	Partial Differential Equation (PDE)	3	1	0	4
VIII	MAE453	Measure & Integration	3	1	0	4
VIII	MAE454	Advanced Linear Programming	3	1	0	4
VIII	MAE455	Number Theory	3	1	0	4

In addition to the above proposed courses, students may select courses from the **Swayam.org as MOOCs courses** upto the permissible limit.

6.3 Details of Skill Enhancement Courses (SECs):

To enhance the skills required for advanced studies, research and employability of students various Skill Enhancement Courses will be offered to students as listed in Table 5.

Table 5 : Details of Skill Enhancement Courses

Skill Enhancement Courses (2 Credits each)			Contact Hours			Credit
Semester	**Course Code**	**Name Of The Course**	**L**	**T**	**P**	
I	MAS101	Latex for scientific typesetting	0	0	2	2
I	MAS102	Operating System: Linux	0	0	2	2
II	MAS151	Introduction to Programming with MATLAB	0	0	2	2
II	MAS152	Introduction to Python	0	0	2	2
III	MAS201	Programming with Mathematica	0	0	2	2
IV	MAS251	Computer Graphics	1	0	1	2
IV	MAS252	Financial Accounting	2	0	0	2
V	MAS301	Internship				2
V	MAS302	Apprenticeship				2
V	MAS303	Project				2
V	MAS304	Community Outreach				2
VI	MAS351	Internship				2
VI	MAS352	Apprenticeship				2
VI	MAS353	Project				2
VI	MAS354	Community Outreach				2
VII	MAS401	Dissertation				6
VII	MAS402	Academic Project				6
VIII	MAS451	Dissertation				6
VIII	MAS452	Academic Project				6

In addition to the above proposed courses, students may select courses from the **Swayam.org as MOOCs courses** upto the permissible limit.

6.4 Details of Generic Elective (GE) Courses:

Generic Elective courses provide multidisciplinary or interdisciplinary education to students. Various GE courses offered by the Mathematics Department are listed below in Table 6**.**

Table 6: Details of Generic Elective (GE) Courses

Generic Elective (GE) Courses (4 Credits each)			Contact Hours			Credit
Semester	**Course Code**	**Name Of The Course**	**L**	**T**	**P**	
I	MAG101	Applied Calculus	3	1	0	4
I	MAG102	Programming in C++	3	0	1	4
II	MAG151	Econometrics	3	1	0	4
II	MAG152	Information Security	3	1	0	4
III	MAG201	Applications of Algebra	3	1	0	4
III	MAG202	Bio Mathematics	3	1	0	4
III	MAG203	Theory of Equations	3	1	0	4
IV	MAG251	Numerical Methods	3	1	0	4
IV	MAG252	Differential Geometry	3	1	0	4
IV	MAG253	Combinatorial Mathematics	3	1	0	4
V	MAG301	Probability and Statistics	3	1	0	4
V	MAG302	Finite Element Methods	3	1	0	4
V	MAG303	Mechanics	3	1	0	4
VI	MAG351	Graph Theory	3	1	0	4
VI	MAG352	Mathematical Finance	3	1	0	4
VI	MAG353	Cryptography and Network Security	3	1	0	4
VII	MAG401	Finite Field	3	1	0	4
VII	MAG402	Ordinary Differential Equation (ODE)	3	1	0	4
VII	MAG403	Advanced Numerical Analysis	3	1	0	4
VII	MAG404	Mathematical Modelling	3	1	0	4
VIII	MAG451	Complex Analysis	3	1	0	4
VIII	MAG452	Partial Differential Equation (PDE)	3	1	0	4
VIII	MAG453	Measure & Integration	3	1	0	4
VIII	MAG454	Advanced Linear Programming	3	1	0	4
VIII	MAG455	Number Theory	3	1	0	4

In addition to the above proposed courses, students may select courses from the **Swayam.org as MOOCs courses** upto the permissible limit.

7. Course Details with Course Specific Outcomes:

Discipline Specific Core Course

MAC101: Calculus

Course Prerequisites: Fundamentals of Differentiation and Integration, Limit, Partial fractions, Binomial theorem, Plane geometry, conics, Basic vector algebra

Course outcomes:

a) To introduce fundamentals of the calculus in order to enhance application skill of students and prepare them to pursue higher analytical mathematics.
b) By the completion of the course the students will be able to analysis the relationships between quantities such as rates of changes, area, volume, properties of curves) and their mathematical equivalents.
c) The course will be able to equip the students with the tools of calculus to measure various quantities such as curvature, torsion, point motion in space etc.
d) One of the main objective of the course is to further deepen the fundamentals of analytical mathematics.

Course Contents:

Hyperbolic functions, higher order derivatives, Leibniz rule and its applications to problems of type $e^{ax+b}\sin x$, $e^{ax+b}\cos x$, $(ax+b)^n\sin x$, $(ax+b)^n\cos x$, concavity and inflection points, asymptotes, curve tracing in Cartesian coordinates, tracing in polar coordinates of standard curves, L'Hospital's rule, applications in business, economics and life sciences.

Reduction formulae, derivations and illustrations of reduction formulae of the type $\int \sin nx\,dx$, $\int \cos nx\,dx$, $\int \tan nx\,dx$, $\int \sec nx\,dx$, $\int (\log x)n\,dx$, $\int sinn\ x\ sinm\ x\,dx$, volumes by slicing, disks and washers methods, volumes by cylindrical shells, parametric equations, parameterizing a curve, arc length, arc length of parametric curves, area of surface of revolution. Techniques of sketching conics, reflection properties of conics, rotation of axes and second degree equations, classification into conics using the discriminant, polar equations of conics.

Triple product, introduction to vector functions, operations with vector-valued functions, limits and continuity of vector functions, differentiation and integration of vector functions, tangent and normal components of acceleration, modeling ballistics and planetary motion, Kepler's second law.

Books Recommended

1. G.B. Thomas and R.L. Finney, *Calculus,* 9th Ed., Pearson Education, Delhi, 2005.
2. M.J. Strauss, G.L. Bradley and K. J. Smith, *Calculus,* 3rd Ed., Dorling Kindersley (India) P. Ltd. (Pearson Education), Delhi, 2007.
3. H. Anton, I. Bivens and S. Davis, *Calculus,* 7th Ed., John Wiley and Sons (Asia) P. Ltd., Singapore, 2002.
4. R. Courant and F. John, *Introduction to Calculus and Analysis* (Volumes I & II), Springer-Verlag, New York, Inc., 1989.
5. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAC102: Algebra

Course Prerequisites: An understanding of numbers, matrices, ratios, proportions, the order of operations, equality, algebraic equations and functions.

Course outcomes:

This course will enable the students to:

a) Employ De Moivre's theorem in a number of applications to solve numerical problems.
b) Learn about equivalent classes and cardinality of a set.
c) Use modular arithmetic and basic properties of congruences.
d) Recognize consistent and inconsistent systems of linear equations by the row echelon form of the augmented matrix.
e) Find eigenvalues and corresponding eigenvectors for a square matrix.

Course Contents:

Polar representation of complex numbers, n^{th} roots of unity, De Moivre's theorem for rational indices and its applications.

Equivalence relations, Functions, Composition of functions, Invertible functions, One to one Correspondence and cardinality of a set, Well-ordering property of positive integers, Division algorithm, Divisibility and Euclidean algorithm, Congruence relation between integers, Principles of Mathematical Induction, statement of Fundamental Theorem of Arithmetic.

Systems of linear equations, row reduction and echelon forms, vector equations, the matrix equation Ax=b, solution sets of linear systems, applications of linear systems, linear independence.

Introduction to linear transformations, matrix of a linear transformation, inverse of a matrix, characterizations of invertible matrices. Subspaces of R^n, dimension of subspaces of R^n and rank of a matrix, Eigen values, Eigen Vectors and Characteristic Equation of a matrix.

Books Recommended

1. Titu Andreescu and Dorin Andrica, *Complex Numbers from A to* Z, Birkhauser, 2006.
2. Edgar G. Goodaire and Michael M. Parmenter, *Discrete Mathematics with Graph Theory*, 3rd Ed., Pearson Education (Singapore) P. Ltd., Indian Reprint, 2005**.**
3. David C. Lay, *Linear Algebra and its Applications,* 3rd Ed., Pearson Education Asia, Indian Reprint, 2007.
4. Johnson, L., Riess, D. and Arnold, J., *Introduction to Linear Algebra*, 5^{th} Ed., Pearson India, 2019.
5. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAC103: Logic, Sets and Special Functions

Course Prerequisites: Knowledge of basic concepts of set theory and calculus.

Course Outcomes:

At the end of the course the students will be able to:

a) know the solution of second order differential equations with variable coefficients.
b) find the solution of Legendre's differential equations and know about its properties.
c) determine the solution of Bessel's differential equation.
d) find the solution of Chebyshev differential equations and its properties.
e) Construct proofs of basic set-theoretic identities involving unions, intersections, and cartesian products
f) Formulate the negation, converse, and contrapositive of a quantified implication, both linguistically and in symbolic form.
g) Demonstrate an understanding of the concept of a "counterexample" and be able to provide appropriate instances.
h) Demonstrate an understanding of the Principle of Mathematical Induction.
i) Understand the concepts of propositions, truth table, predicates and quantifiers, relation ,partition etc.

Course Contents:

Introduction, propositions, truth table, negation, conjunction and disjunction. Implications, biconditional propositions, converse, contra positive and inverse propositions and precedence of logical operators. Propositional equivalence: Logical equivalences. Predicates and quantifiers: Introduction, Quantifiers, Binding variables and Negations.

Sets, subsets, Set operations and the laws of set theory and Venn diagrams. Examples of finite and infinite sets. Finite sets and counting principle. Empty set, properties of empty set. Standard set operations. Classes of sets. Power set of a set.

Difference and Symmetric difference of two sets. Set identities, Generalized union and intersections. Relation: Product set, Composition of relations, Types of relations, Partitions, Equivalence Relations with example of congruence modulo relation, Partial ordering relations, nary relations.

Legendre polynomials, Series expansion, Orthogonality and Normalization, A second solution, Rodriquez's formula, Generating function, Recursion relations.
Bessel functions, Series solution of Bessel's equation, Orthogonality of Bessel functions, Orthogonal series of Bessel functions, Generating function, Recursion relations.

Laguerre polynomials, Generating functions, Recurrence relations and differential equations. Orthogonality and expansion of a functions in Laguerre polynomials.

Books Recommended:

1. N. N. Lebedev, *Special Functions and Their Applications*, Dover, 1973.
2. 2. R.P. Grimaldi, *Discrete Mathematics and Combinatorial Mathematics,* Pearson Education, 1998.
3. P.R. Halmos, *Naive Set Theory*, Springer, 1974.

4. *E. Kamke*, Theory of Sets, *Dover Publishers, 1950.*
5. *Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.*

MAC151: Real Analysis-1

Course Prerequisites: Knowledge of Calculus at high school level and number system.

Course Outcomes:

This course will enable the students to:

a) Understand many properties of the real line $\mathbb{R}$, including completeness and Archimedean properties.
b) Learn to define sequences in terms of functions from $\mathbb{N}$ to a subset of $\mathbb{R}$.
c) Recognize bounded, convergent, divergent, Cauchy and monotonic sequences and to calculate their limit superior, limit inferior, and the limit of a bounded sequence.
d) Apply the ratio, root, alternating series and limit comparison tests for convergence and absolute convergence of an infinite series of real numbers.

Course Contents:

Review of Algebraic and Order Properties of *R*, ε-nneighborhood of a point in *R*, Idea of countable sets, uncountable sets and uncountability of *R*. Bounded above sets, Bounded below sets, Bounded Sets, Unbounded sets, Suprema and Infima, The Completeness Property of *R*, The Archimedean Property, Density of Rational (and Irrational) numbers in *R*, Intervals. Limit points of a set, Isolated points, Illustrations of Bolzano-Weierstrass theorem for sets.

Sequences, Bounded sequence, Convergent sequence, Limit of a sequence. Limit Theorems, Monotone Sequences, Monotone Convergence Theorem. Subsequences, Divergence Criteria, Monotone Subsequence Theorem (statement only), Bolzano Weierstrass Theorem for Sequences. Cauchy sequence, Cauchy's Convergence Criterion.

Infinite series, convergence and divergence of infinite series, Cauchy Criterion, Tests for convergence: Comparison test, Limit Comparison test, Ratio Test, Cauchy's n^{th} root test, Integral test, Alternating series, Leibniz test, Absolute and Conditional convergence.

Books Recommended

1. R.G. Bartle and D. R. Sherbert, *Introduction to Real Analysis*, 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.
2. Gerald G. Bilodeau , Paul R. Thie, G.E. Keough, *An Introduction to Analysis*, 2nd Ed., Jones & Bartlett, 2010.
3. Brian S. Thomson, Andrew. M. Bruckner and Judith B. Bruckner, *Elementary Real Analysis*, Prentice Hall, 2001.
4. S.K. Berberian, *A First Course in Real Analysis*, Springer Verlag, New York, 1994.
5. S.C. Malik and S. Arora, *Mathematical Analysis*, New Age International Private Limited, 2017.
6. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAC152: Differential Equations

Course Prerequisites: Knowledge of calculus at high school level.

Course Outcomes:

The course will enable the students to:

a) Learn basics of differential equations and mathematical modeling.
b) Formulate differential equations for various mathematical models.
c) Solve first order non-linear differential equations and linear differential equations of higher order using various techniques.
d) Apply these techniques to solve and analyze various mathematical models.

Course Contents:

Differential equations and mathematical models. General, particular, explicit, implicit and singular solutions of a differential equation. Exact differential equations and integrating factors, separable equations and equations reducible to this form, linear equation and Bernoulli equations, special integrating factors and transformations.

Introduction to compartmental model, exponential decay model, lake pollution model (case study of Lake Burley Griffin), drug assimilation into the blood (case of a single cold pill, case of a course of cold pills), exponential growth of population, limited growth of population, limited growth with harvesting.

General solution of homogeneous equation of second order, principle of super position for homogeneous equation, Wronskian: its properties and applications, Linear homogeneous and non-homogeneous equations of higher order with constant coefficients, Euler's equation, method of undetermined coefficients, method of variation of parameters.

Books Recommended

1. Belinda Barnes and Glenn R. Fulford, *Mathematical Modeling with Case Studies, A Differential Equation Approach using Maple and Matlab,* 2nd Ed., Taylor and Francis group, London and New York, 2009.
2. C.H. Edwards and D.E. Penny, *Differential Equations and Boundary Value problems Computing and Modeling,* Pearson Education India, 2005.
3. S.L. Ross, *Differential Equations,* 3rd Ed., John Wiley and Sons, India, 2004.
4. Martha L Abell, James P Braselton, *Differential Equations with MATHEMATICA,* 3rd Ed., Elsevier Academic Press, 2004.
5. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAC153: Group Theory-I

Course Prerequisites: Knowledge of number system, relation, function, and basic algebra.

Course Outcomes:

The course will enable the students to:

a) Recognize the mathematical objects that are groups, and classify them as abelian, cyclic and permutation groups, etc.
b) Link the fundamental concepts of groups and symmetrical figures.
c) Analyze the subgroups of cyclic groups and classify subgroups of cyclic groups.
d) Explain the significance of the notion of cosets, normal subgroups and factor groups.
e) Learn about Lagrange's theorem and Fermat's Little theorem.
f) Know about group homomorphisms and group isomorphisms.

Course Contents:

Symmetries of a square, Dihedral groups, definition and examples of groups including permutation groups and quaternion groups (illustration through matrices), elementary properties of groups.

Subgroups and examples of subgroups, centralizer, normalizer, center of a group, product of two subgroups.

Properties of cyclic groups, classification of subgroups of cyclic groups. Cycle notation for permutations, properties of permutations, even and odd permutations, alternating group, properties of cosets, Lagrange's theorem and consequences including Fermat's Little theorem.

External direct product of a finite number of groups, normal subgroups, factor groups, Cauchy's theorem for finite abelian groups.

Group homomorphisms, properties of homomorphisms, Cayley's theorem, properties of isomorphisms, First, Second and Third isomorphism theorems.

Books Recommended

1. John B. Fraleigh, *A First Course in Abstract Algebra*, 7th Ed., Pearson, 2002**.**
2. M. Artin, *Abstract Algebra,* 2nd Ed., Pearson, 2011.
3. Joseph A. Gallian, *Contemporary Abstract Algebra,*4th Ed., Narosa Publishing House, New Delhi, 1999.
4. Joseph J. Rotman, *An Introduction to the Theory of Groups,*4th Ed., Springer Verlag, 1995.
5. I.N. Herstein, *Topics in Algebra,* Wiley Eastern Limited, India, 1975.
6. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAC201: Real Analysis-2

Course Prerequisites: Knowledge of number system, calculus and limit.

Course Outcomes:

This course will enable the students to:

a) Have a rigorous understanding of the concept of limit of a function.
b) Learn about continuity and uniform continuity of functions defined on intervals.
c) Understand geometrical properties of continuous functions on closed and bounded intervals.
d) Learn extensively about the concept of differentiability using limits, leading to a better understanding for applications.
e) Know about applications of mean value theorems and Taylor's theorem.

Course Content:

Limits of functions *(ε-δ* approach), sequential criterion for limits, divergence criteria. Limit theorems, one sided limits. Infinite limits and limits at infinity. Continuous functions, sequential criterion for continuity and discontinuity. Algebra of continuous functions. Continuous functions on an interval, intermediate value theorem, location of roots theorem, preservation of intervals theorem. Uniform continuity, non-uniform continuity criteria, uniform continuity theorem.

Differentiability of a function at a point and in an interval, Caratheodory's theorem, algebra of differentiable functions. Relative extrema, interior extremum theorem. Rolle's theorem, Mean value theorem, intermediate value property of derivatives, Darboux's theorem. Applications of mean value theorem to inequalities and approximation of polynomials, Taylor's theorem to inequalities.

Cauchy's mean value theorem. Taylor's theorem with Lagrange's form of remainder, Taylor's theorem with Cauchy's form of remainder, application of Taylor's theorem to convex functions, relative extrema. Taylor's series and Maclaurin's series expansions of exponential and trigonometric functions, $\ln(1 + x)$, $1/ax+b$ and $(1 +x)^n$.

Books Recommended:

1. R. Bartle and D.R. Sherbert, *Introduction to Real Analysis,* John Wiley and Sons, 2003.
2. K.A. Ross, *Elementary Analysis: The Theory of Calculus,* Springer, 2004.
3. A. Mattuck, *Introduction to Analysis,* Prentice Hall, 1999.
4. S.R. Ghorpade and B.V. Limaye, *A Course in Calculus and Real Analysis,* Springer, 2006.
5. S.C. Malik and S. Arora, *Mathematical Analysis,* New Age International Private Limited, 2017.
6. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAC202: PDE and Systems of ODE

Course Prerequisites: Calculus and ODE theory.

Course Outcomes:

The course will enable the students to:

a) Formulate, classify and transform first order PDEs into canonical form.
b) Learn about method of characteristics and separation of variables to solve first order PDE's.
c) Classify and solve second order linear PDEs.
d) Learn about Cauchy problem for second order PDE and homogeneous and nonhomogeneous wave equations.
e) Apply the method of separation of variables for solving many well-known second order PDEs

Course Contents:

Partial Differential Equations - Basic concepts and Definitions, Mathematical Problems. First Order Equations: Classification, Construction and Geometrical Interpretation. Method of Characteristics for obtaining General Solution of Quasi Linear Equations. Canonical Forms of First-order Linear Equations. Method of Separation of Variables for solving first order partial differential equations.

Derivation of Heat equation, Wave equation and Laplace equation. Classification of second order linear equations as hyperbolic, parabolic or elliptic. Reduction of second order Linear Equations to canonical forms.

Systems of linear ordinary differential equations, types of linear systems, differential operators, an operator method for linear systems with constant coefficients, Basic Theory of linear systems in normal form, homogeneous linear systems with constant coefficients: Two Equations in two unknown functions, The method of successive approximations, the Euler method, the modified Euler method, The Runge-Kutta method.

Books Recommended

1. Tyn Myint-U and Lokenath Debnath, *Linear Partial Differential Equations for Scientists and Engineers*, 4th edition, Springer, Indian reprint, 2006.
2. S.L. Ross, *Differential equations,* 3rd Ed., John Wiley and Sons, India, 2004.
3. Martha L Abell, James P Braselton, *Differential equations with MATHEMATICA,* 3rd Ed., Elsevier Academic Press, 2004.
4. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAC203: Mathematical Transforms

Course Prerequisites: Calculus.

Course Outcomes:

The course will enable the students to:

a) determine Laplace transform of functions.
b) determine Fourier and Z-Transforms for various functions.
c) use properties of Fourier and Z-Transforms to solve physical problems.
d) introduce Mellin Transform, its Shifting and scaling properties, Mellin transforms of derivatives and integrals
e) applications of transforms to solve physical problems.

Course Contents:

Laplace Transform: Laplace of some standard functions, Existence conditions for the Laplace Transform, Shifting theorems, Laplace transform of derivatives and integrals, Inverse Laplace transform and their properties, Convolution theorem, Initial and final value theorem, Laplace transform of periodic functions, error functions, Heaviside unit step function and Dirac delta function, Applications of Laplace transform to solve ordinary differential equations (ODEs) and partial differential equations (PDEs).

Fourier Transforms**:** Fourier integrals, Fourier sine and cosine integrals, Complex form of Fourier integral representation, Fourier transform, Fourier transform of derivatives and integrals, Fourier sine and cosine transforms and their properties, Convolution theorem, Application of Fourier transforms to Boundary Value Problems.

Mellin Transform**:** Definition and properties of Mellin transform, Shifting and scaling properties, Mellin transforms of derivatives and integrals, Applications of Mellin transform.

Z-Transform: Z–transform and inverse Z-transform of elementary functions, Shifting theorems, Convolution theorem, Initial and final value theorem, Application of Z-transforms to solve difference equations.

Books Recommended

1. I. N. Sneddon, *Fourier Transforms*, Dover.
2. Joel L. Schiff, *The Laplace Transform: Theory and Applications (Undergraduate Texts in Mathematics)*, Springer.
3. E. Kreyszig, "Advanced Engineering Mathematics**"**, 10th Edition, John & Wiley Sons, U.K., 2016.
4. Ronald N. Bracewell,"The Fourier Transforms and its Applications", 3rd Edition, McGraw Hill Science,1999.
5. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAC251: Numerical Methods

Course Prerequisites: Nil.

Course Outcomes:
The course will enable the students to:

a) Learn some numerical methods to find the zeroes of nonlinear functions of a single variable and solution of a system of linear equations, up to a certain given level of precision.
b) Know about methods to solve system of linear equations, such as Gauss−Jacobi, Gauss−Seidel and SOR methods.
c) Interpolation techniques to compute the values for a tabulated function at points not in the table.
d) Applications of numerical differentiation and integration to convert differential equations into difference equations for numerical solutions.

Course Contents:

Algorithms, Convergence, Errors: Relative, Absolute, Round off, Truncation.

Transcendental and Polynomial equations: Bisection method, Newton's method, Secant method. Rate of convergence of these methods.

System of linear algebraic equations: Gaussian Elimination and Gauss Jordan methods. Gauss Jacobi method, Gauss Seidel method and their convergence analysis.

Interpolation: Lagrange and Newton's methods. Error bounds. Finite difference operators. Gregory forward and backward difference interpolation.

Numerical differentiation: Derivatives using Newton's forward interpolation formula, Derivatives using Newton's backward interpolation formula and Derivatives using Stirling's formula.

Numerical Integration: Trapezoidal rule, Simpson's rule, Simpsons 3/8th rule, Boole's Rule. Midpoint rule, Composite Trapezoidal rule, Composite Simpson's rule.

Ordinary Differential Equations: Euler's method. Runge-Kutta methods of orders two and four.

Note: Use of Scientific Calculator is allowed.

Note: For any of the CAS (Computer aided software) Data types-simple data types, floating data types, character data types, arithmetic operators and operator precedence, variables and constant declarations, expressions, input/output, relational operators, logical operators and logical expressions, control statements and loop statements, Arrays should be introduced to the students.

Books Recommended

1. Brian Bradie, *A Friendly Introduction to Numerical Analysis,* Pearson Education, India, 2007.
2. M.K. Jain, S.R.K. Iyengar and R.K. Jain, *Numerical Methods for Scientific and Engineering Computation,* 6th Ed., New age International Publisher, India, 2007.
3. Uri M. Ascher and Chen Greif, *A First Course in Numerical Methods,* 7th Ed., PHI Learning Private Limited, 2013.
4. John H. Mathews and Kurtis D. Fink, *Numerical Methods using Matlab,* 4th Ed., PHI Learning Private Limited, 2012.
5. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAC252: Riemann Integration and Series of Functions

Course Prerequisites: Real Number system, Concepts of limit, Differentiation methods and theory, Integration, Series and sequences of real numbers and their properties, Convergence tests, plotting of Cartesian curves, asymptotes.

Course outcomes:

(a) The objective of this course is to impart complete constructive and analytical knowledge of the theory of integration.
(b) The students will be able of analysis of the various type of the integrals occurring in engineering and science.
(c) After the completion of the course, the students are expected to gain capability for inquiring about questions relating to the concepts in various fields of mathematics and science.
(d) It is essentially expected that integration theory supported by the knowledge of series and sequences of functions will make a powerful tool to analyze problems of science and technology.

Course Contents:

Riemann integration; inequalities of upper and lower sums; Riemann conditions of integrability.

Riemann sum and definition of Riemann integral through Riemann sums; equivalence of two definitions; Riemann integrability of monotone and continuous functions, Properties of the Riemann integral; definition and integrability of piecewise continuous and monotone functions. Intermediate Value theorem for Integrals; Fundamental theorems of Calculus.

Improper integrals; Convergence of Beta and Gamma functions.

Pointwise and uniform convergence of sequence of functions. Theorems on continuity, derivability and integrability of the limit function of a sequence of functions. Series of functions; Theorems on the continuity and derivability of the sum function of a series of functions; Cauchy criterion for uniform convergence and Weierstrass M-Test.

Limit superior and Limit inferior. Power series, radius of convergence, Cauchy Hadamard Theorem, Differentiation and integration of power series; Abel's Theorem; Weierstrass Approximation Theorem.

Books Recommended

1. K.A. Ross, *Elementary Analysis, The Theory of Calculus,* Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.
2. R.G. Bartle D.R. Sherbert, *Introduction to Real Analysis,* 3rd Ed., John Wiley and Sons (Asia)

Pvt. Ltd., Singapore, 2002.
3. Charles G. Denlinger, *Elements of Real Analysis,* Jones & Bartlett (Student Edition), 2011.
4. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAC253: Ring Theory

Course Prerequisites: MDSC-153: Group theory-I.

Course Outcomes:

The course will enable the students to:

a) Learn about the fundamental concept of rings, integral domains and fields.
b) Know about ring homomorphisms and isomorphisms theorems of rings.
c) Appreciate the significance of unique factorization in rings and integral domains.

Course Contents:

Definition and examples of rings, properties of rings, subrings, integral domains and fields, characteristic of a ring. Ideal, ideal generated by a subset of a ring, factor rings, operations on ideals, prime and maximal ideals.

Ring homomorphisms, properties of ring homomorphisms, Isomorphism theorems I, II and III, field of quotients.

Polynomial rings over commutative rings, division algorithm and consequences, principal ideal domains, factorization of polynomials, reducibility tests, irreducibility tests, Eisenstein criterion, unique factorization in Z[x]. Divisibility in integral domains, irreducibles, primes, unique factorization domains, Euclidean domains.

Books Recommended

1. John B. Fraleigh, *A First Course in Abstract Algebra*, 7th Ed., Pearson, 2002**.**
2. M. Artin, *Abstract Algebra,* 2nd Ed., Pearson, 2011.
3. D.A.R. Wallace, *Groups, Rings and Fields*, Springer Verlag London Ltd., 1998.
4. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.
5. Gallian, J. A., *Contemporary Abstract Algebra*, 4th Ed., Narosa Publishing house, 1999.

MAC301: Multivariate Calculus

Course Prerequisites: The course requires basic knowledge of sets, operations on them, relations, functions, matrix, elementary algebra and elementary calculus(secondary level).

Course Outcome:

The course will enable the students to:

a) Learn the conceptual variations when advancing in calculus from one variable to multivariable discussion.

b) Find partial derivatives and Jacobian of multivariable functions and use them in practical problems, like to find extreme values of functions having two independent variables and to solve constrained optimization problems.

c) Apply Fundamental Theorem of Line Integrals, Green's Theorem, Stokes' Theorem, and Divergence Theorem to evaluate multiple integrals.

d) Understand the maximization and minimization of multivariable functions subject to the given constraints on variables.

e) Learn about inter-relationship amongst the line integral, double and triple integral formulations.

Course Contents:

Functions of several variables, limit and continuity of functions of two variables Partial differentiation, total differentiability and differentiability, sufficient condition for differentiability. Chain rule for one and two independent parameters, directional derivatives, the gradient, maximal and normal property of the gradient, tangent planes, Extrema of functions of two variables, method of Lagrange multipliers, constrained optimization problems, Definition of vector field, divergence and curl

Double integration over rectangular region, double integration over non-rectangular region, Double integrals in polar co-ordinates, Triple integrals, Triple integral over a parallelepiped and solid regions. Volume by triple integrals, cylindrical and spherical co-ordinates.

Change of variables in double integrals and triple integrals. Line integrals, Applications of line integrals: Mass and Work. Fundamental theorem for line integrals, conservative vector fields, independence of path.

Green's theorem, surface integrals, integrals over parametrically defined surfaces. Stoke's theorem, The Divergence theorem.

Note: Use of Scientific calculator is allowed.

Books Recommended

1. G.B. Thomas and R.L. Finney, *Calculus*, 9th Ed., Pearson Education, Delhi, 2005.
2. M.J. Strauss, G.L. Bradley and K. J. Smith, *Calculus*, 3rd Ed., Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2007.

3. E. Marsden, A.J. Tromba and A. Weinstein, *Basic Multivariable Calculus,* Springer (SIE), Indian reprint, 2005.
4. James Stewart, *Multivariable Calculus, Concepts and Contexts,* 2nd Ed., Brooks /Cole, Thomson Learning, USA, 2001.
5. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAC302: Group Theory-II

Course Prerequisites: MDSC-153: Group theory-I

Course Outcomes:

The course shall enable students to:

a) Learn about automorphisms for constructing new groups from the given group.
b) Learn about the fact that external direct product applies to data security and electric circuits.
c) Understand fundamental theorem of finite abelian groups.
d) Be familiar with group actions and conjugacy in S_n.
e) Understand Sylow theorems and their applications in checking nonsimplicity.

Course Contents:

Automorphism, inner automorphism, automorphism groups, automorphism groups of finite and infinite cyclic groups, applications of factor groups to automorphism groups, Characteristic subgroups, Commutator subgroup and its properties.

Properties of external direct products, the group of units modulo n as an external direct product, internal direct products, Fundamental Theorem of finite abelian groups.

Group actions, stabilizers and kernels, permutation representation associated with a given group action, Applications of group actions: Generalized Cayley's theorem, Index theorem.

Groups acting on themselves by conjugation, class equation and consequences, conjugacy in S_n, p-groups, Sylow's theorems and consequences, Cauchy's theorem, Simplicity of A_n for $n > 5$, non-simplicity tests.

Books Recommended

1. John B. Fraleigh, *A First Course in Abstract Algebra,* 7th Ed., Pearson, 2002**.**
2. M. Artin, *Abstract Algebra,* 2nd Ed., Pearson, 2011.
3. Joseph A. Gallian, *Contemporary Abstract Algebra,*4th Ed., Narosa Publishing House, 1999.
4. David S. Dummit and Richard M. Foote, *Abstract Algebra,* 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2004.
5. J.R. Durbin, *Modern Algebra,* John Wiley & Sons, New York Inc., 2000.
6. D. A. R. Wallace, *Groups, Rings and Fields,* Springer Verlag London Ltd., 1998.
7. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAC303: Analytical Geometry

Course Prerequisites: Basic geometry.

Course Outcomes:

This course will enable the students to:

a) introduction to analytical geometry of 2 dimensional.
b) study of lines in 2 and 3 dimension.
c) finding equation in various form of line, circle, ellipse, sphere, cones etc.
d) sketch the graphs of some special curves by using polar coordinates on the plane.

Course Contents:

Techniques for sketching parabola, ellipse and hyperbola. Reflection properties of parabola, ellipse and hyperbola. Classification of quadratic equations representing lines, parabola, ellipse and hyperbola.

Spheres, Cylindrical surfaces. Illustrations of graphing standard quadric surfaces like cone, ellipsoid.

Books Recommended

1. G.B. Thomas and R.L. Finney, *Calculus*, 9th Ed., Pearson Education, Delhi, 2005.
2. H. Anton, I. Bivens and S. Davis, *Calculus*, John Wiley and Sons (Asia) Pvt. Ltd. 2002.
3. S.L. Loney, *The Elements of Coordinate Geometry*, McMillan and Company, London.
4. *R.J.T. Bill*, Elementary Treatise on Coordinate Geometry of Three Dimensions, *McMillan India Ltd., 1994.*
5. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAC351: Metric Spaces

Course Prerequisites: Real analysis.

Course Outcomes:

The course will enable the students to:

a) Learn various natural and abstract formulations of distance on the sets of usual or unusual entities. Become aware one such formulations leading to metric spaces.
b) Analyse how a theory advances from a particular frame to a general frame.
c) Appreciate the mathematical understanding of various geometrical concepts, viz. balls or

connected sets etc. in an abstract setting.

d) Know about Banach fixed point theorem, whose far-reaching consequences haveresulted into an independent branch of study in analysis, known as fixed point theory.

e) Learn about the two important topological properties, namely connectedness and compactness of metric spaces.

Course Contents:

Basic Concepts: Metric spaces: Definition and examples, Sequences in metric spaces, Cauchy sequences, Complete metric space.

Topology of Metric Spaces: Open and closed ball, Neighborhood, Open set, Interior of a set, Limit point of a set, Derived set, Closed set, Closure of a set, Diameter of a set, Cantor's theorem, Subspaces, Dense set.

Continuity & Uniform Continuity in Metric Spaces: Continuous mappings, Sequential criterion and other characterizations of continuity, Uniform continuity, Homeomorphism, Contraction mapping, Banach fixed point theorem.

Connectedness and Compactness: Connectedness, Connected subsets of $\mathbb{R}$, Connectedness and continuous mappings, Compactness, Compactness and boundedness, Continuous functions on compact spaces.

Books Recommended

1. Satish Shirali and Harikishan L. Vasudeva, *Metric Spaces*, Springer, 2009.
2. S. Kumaresan, *Topology of Metric Spaces*, 2nd Ed., Narosa Publishing House, 2011.
3. G.F. Simmons, *Introduction to Topology and Modern Analysis*, McGraw-Hill, 2004.
4. P.K.Jain, K.Ahmad, *Metric Spaces*, Narosa, 3rd Edition, 2019.
5. Mícheál O'Searcoid, *Metric Spaces*, Springer, 2008.
6. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAC352: Linear Algebra

Course Prerequisites: Matrices, sets, relations, functions and the concept of basic algebra.

Course Outcomes:

After studying this course the student will be able to:

a) Learn about the concept of linear independence of vectors over a field, and the dimension of a vector space.

b) Basic concepts of linear transformations, dimension theorem, matrix representation of a linear transformation, and the change of coordinate matrix.

c) Compute the characteristic polynomial, eigenvalues, eigenvectors, and eigenspaces, as well as the geometric and the algebraic multiplicities of an eigenvalue and apply the basic diagonalization result.
d) Compute inner products and determine orthogonality on vector spaces, including Gram−Schmidt orthogonalization to obtain orthonormal basis.

Course Contents:

Vector Spaces: Vector space, subspace, sum of subspaces, linear combination, linear dependence and independence, basis and dimension, examples of infinite dimensional spaces, ordered bases and coordinates.

Linear Transformation: Basic definitions, rank-nullity theorem, matrix representation, algebra of linear transformations, change of basis, linear functional, Dual Spaces.

Canonical Forms: Eigen-values of linear operators, Eigen-space, minimal polynomial, diagonalization, invariant subspaces, Jordan canonical representation, Norm of a matrix, computation of a matrix Exponential.

Inner Product Space: Definition of inner product between two vectors, orthogonal and orthonormal vectors, normed space, Gram-Schmidt process for orthogonalization, projection operator, quadratic forms, positive definite forms, Symmetric, Hermitian, orthogonal, unitary and Normal transformations/matrices.

Books Recommended:

1. Hoffman, K. and Kunze, R., "Linear Algebra", 2nd edition, Pearson Education (Asia) Pvt. Ltd/ Prentice Hall of India 2004.
2. Leon, S.J., "Linear Algebra with Applications", 8th Edition, Pearson 2009.
3. Peter, J. Olever and Shakiban, C., "Applied Linear Algebra", 1st Edition, Prentice Hall 2005.
4. Strang, G., "Linear Algebra and its Applications", 3rd edition, Thomson Learning Asia Pvt Ltd 2003.
5. Sudan L., "Applied Linear Algebra", Prentice Hall 2001.
6. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAC353: Linear Programming

Course Prerequisites: Linear Algebra.

Course Outcomes:

This course will enable the students to:

a) Learn about the graphical solution of linear programming problem with two variables.
b) Learn about the relation between basic feasible solutions and extreme points.

c) Understand the theory of the simplex method used to solve linear programming problems.
d) Learn about two-phase and Big-M methods to deal with problems involving artificial variables.
e) Learn the role of sensitivity analysis in linear programming problem.
f) Learn about the relationships between the primal and dual problems.
g) Solve transportation and assignment problems.
h) Integer programming.

Course Contents:
Introduction to linear programming problem(LPP), Formulation of LPP, Graphical method, Theory of simplex method, optimality and unboundedness, the simplex algorithm, simplex method in tableau format, introduction to artificial variables, two-phase method, Big-M method and their comparison.

Duality, formulation of the dual problem, primal-dual relationships, economic interpretation of the dual.

Sensitivity Analysis, Integer Programming. Transportation problem and its mathematical formulation, northwest-corner method least cost method and Vogel approximation method for determination of starting basic solution, algorithm for solving transportation problem, assignment problem and its mathematical formulation, Hungarian method for solving assignment problem.

Books Recommended

1. Mokhtar S. Bazaraa, John J. Jarvis and Hanif D. Sherali, *Linear Programming and Network Flows*, 2nd Ed., John Wiley and Sons, India, 2004.
2. F.S. Hillier and G.J. Lieberman, *Introduction to Operations Research*, 9th Ed., Tata McGraw Hill, Singapore, 2009.
3. Hamdy A. Taha, *Operations Research, An Introduction*, 8th Ed., Prentice-Hall India, 2006.
4. G. Hadley, *Linear Programming*, Narosa Publishing House, New Delhi, 2002.
5. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAC401: Topology

Course Prerequisites: Real Analysis and Metric Spaces.

Course Outcomes:

After studying this course the student will be able to:
a) The knowledge gained in this subject will make students able to generalize and extend concepts of real/complex analysis to more abstract spaces.
b) It is expected that the critical reasoning ability will be further enhanced and sharpened at the end of the course. Students completing this course will be able to present mathematics clearly and precisely, make vague ideas precise.

c) This course will enable the students to understand the importance and properties of abstract analysis.

Course Contents:

Basics of Metric Spaces: Definitions and examples, Subspaces, Convergent sequences, Continuous and uniformly continuous functions, Completeness, connectedness.

Topological Spaces: Definition and basic concepts, Open bases and open subbases, weak topologies, compact spaces, Finite products, Locally compact spaces. Separability, Separation axioms, T_1-spaces and Hausdorff spaces. Connectedness, component of space, totally disconnected spaces, Locally connected spaces.

The Scope of the course is indicated by the relevant sections of Chapters 2 to 7 of [1].

Books Recommended:

1. G.F. Simmons, Introduction to Topology and Modern Analysis, Tata McGraw Hill Education Pvt. Ltd., New Delhi, 2004.
2. P.K. Jain and K. Ahmad, Metric Spaces, Second Edition, Narosa Publishing House, New Delhi, 2004.
3. J.R. Munkers, Topology, Prentice Hall, 1975.
4. W.J. Pervin, Foundations of General Topology, Academic Press, 1964.
5. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAC451: Functional Analysis

Course Prerequisites: Real Analysis, Linear Algebra and Metric Spaces.

Course Outcomes:

After studying this course the student will be able to:

a) Familiarize with distance and extension of distance as a norm. The student will learn central concepts from functional analysis, including the Hahn-Banach theorem, the open mapping and closed graph theorems and the uniform boundedness theorem.

b) Structural properties of spaces those are constructed with the help of suitable norms. The students will be able to unify the various concepts of calculus and analysis with the help of other concepts from vector spaces, matrix theory and complex variables.

c) The concepts of linear operators, their adjoint operators and properties of bounded linear operators. The significance of orthonormal sequences in the Fourier series and orthonormal expansions.

Course Contents:

Normed Spaces, Banach spaces, properties of normed spaces, Finite dimensional normed spaces and subspaces, Quotient normed spaces, Equivalent norms, Bounded and continuous linear operators, Linear functional, Finite dimensional normed spaces and compactness, Normed spaces of operators, Dual spaces.

Inner product spaces, Hilbert spaces, properties of inner product spaces, orthogonal complements and Projection Theorem, Orthonormal sets and sequences, Total orthonormal sets and sequences.

Representation Theorem for Hilbert spaces, Hilbert adjoint operator, self adjoint, unitary, normal and positive operators.

Hahn Banach theorem for real/complex vector spaces and normed spaces, Adjoint Operators, reflexive spaces.

Baire Category theorem, Uniform boundedness theorem, Open Mapping Theorem (OMT), Closed Graph Theorem.

Books Recommended:

1. E.Kreyszig, Introductory Functional Analysis with Applications, John Wiley & Sons (Asia) Pvt. Ltd., 2006.
2. J.B. Conway, A course in Functional Analysis, Second Edition Springer-Verlag, 2006.
3. P.K. Jain and O.P.Ahuja, Functional Analysis, Second Edition, New Age International Publication New Delhi, 2004.
4. G.F. Simmons, Introduction to Topology and Analysis, Tata McGraw Hill Education Pvt. Ltd., New Delhi, 2004.
5. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

Discipline Specific Elective(DSE)/ Generic Elective(GE)

MAG101: Applied Calculus

Course Prerequisites: Basic calculus.

Course Outcomes:

At the end of the course, students should be able to:

a) Identify functions as linear, exponential, or periodic, compute the change and average rate of change for given functions,
b) Interpret the concept of derivative as the rate of change, and approximate the derivative at a single point,
c) Perform analysis and computation of limits by analytic, graphical and numerical methods, and use limits to investigate continuity of functions.
d) Use techniques of differentiation, including the product, quotient, and chain rules to derive derivatives for polynomials, powers, exponentials, periodic functions and their compositions.
e) Interpret definite integrals as areas, and evaluate them by numerical approximations and by the Fundamental Theorem of Calculus. Derive indefinite integrals by using power rule, exponential rule, logarithm rule, and rules for periodic functions.
f) Use first and second derivatives to determine max/min values and locations for given functions, and to apply them to investigate the behaviors of logistic and surge functions.
g) Understand the concepts of vector triple product, introduction to vector functions, space curves , tensor, tangent plane, normal and envelope analysis, helices, etc.

Course Contents:

Higher order derivatives, Leibniz rule, Curvature, Concavity and inflection points, Cartesian, Spherical, Cylindrical coordinate systems, asymptotes, curve tracing in Cartesian and polar coordinates coordinates. Maxima and Minima. L'Hospital's rule, Mean value theorems, Taylor's formula and their applications in Science, Engineering, business and economics.

Area and volumes by slicing, disks and washers methods, volumes by cylindrical shells, parametric equations, arc length, arc length of parametric curves, area of surface of revolution. Applications in science, engineering and real life.

Vector triple product, introduction to vector functions, vector-valued functions, differentiation and integration of vector functions, tangent and normal components of acceleration, modeling ballistics and planetary motion, Kepler's second law. Gradient, divergence and curl and use in fluid mechanics.

Space curve, Tangent, normal and osculating planes, Length of a curve, Seret-Frenet formulas, Curvature, circle of curvature, torsion. Curve by its intrinsic equations, Helices. Surfaces, Parametric equations of a surface. Tangent plane, Normal and Envelope. Applications.

Books Recommended

1. N. Piskunov, *Differential and Integral Calculus*, Mir Publisher Moscow, CBS Publishers & Distributors India.
2. Deborah Hughes et al., *Applied Calculus,* 5th Edition, Wiley.
3. Shanti Narayan, P. K. Mittal, *Differential Calculus,* S. Chand.
4. J. Stewart, *Calculus: Early Transcendentals,* Nelson Publication Canada.
5. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAG102: Programming in C++

Course Prerequisites: Logics and sets.

Course Outcomes:

After completion of this course, student will be able to:

a) Identify importance of object oriented programming and difference between structured
b) oriented and object oriented programming features.
c) make use of objects and classes for developing programs.
d) use various object oriented concepts to solve different problems.

Course Contents:

OOP Paradigm: Comparison of Programming paradigms, Characteristics of Object-Oriented Programming Languages, Object-based programming languages C++: Brief History of C++,Structure of a C++ program, Difference between C and C++ - cin, cout, new, delete operators, ANSI/ISO Standard C++, Comments, Working with Variables and const Qualifiers. Enumeration, Arrays and Pointer.

Implementing oops concepts in C++ Objects, Classes, Encapsulation, Data Abstraction, Inheritance, Polymorphism, Dynamic Binding, Message Passing, Default Parameter Value,Using Reference variables with Functions.

Abstract data types, Class Component, Object & Class, Constructors Default and Copy Constructor, Assignment operator deep and shallow coping, Access modifiers - private, publicand protected. Implementing Class Functions within Class declaration or outside the Class declaration. instantiation of objects, Scope resolution operator, Working with Friend Functions, Using Static Class members. Understanding Compile Time Polymorphism function overloading Rules of Operator Overloading (Unary and Binary) as member function/friend function, Implementation of operator overloading of Arithmetic Operators, Overloading Output/Input,Prefix/ Postfix Increment and decrement Operators, Overloading comparison operators, Assignment, subscript and function call Operator , concepts of namespaces.

Practicals to be performed in computer lab.

Books Recommended

1. A. R. Venugopal, Rajkumar, and T. Ravishanker, *Mastering C++,* TMH, 1997.
2. S. B. Lippman and J. Lajoie, *C+ + Primer,*3rd Ed., Addison Wesley, 2000.
3. Bruce Eckel, *Thinking in C++,* 2nd Ed., President, Mindview Inc., Prentice Hall.
4. D. Parasons, *Object Oriented Programming with C++,* BPB Publication.
5. Bjarne Stroustrup , *The C++ Programming Language,* 3rd Ed., Addison Welsley.
6. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAG151: Econometrics

Course Prerequisites: The course requires basic knowledge of elementary calculus(secondary level).

Course Outcomes:

At the end of the course the students will be able to:

a) Apply basic statistical concepts like normal distribution, chi square, t, and F distributions, and test- Hypotheses to the data based problems.
b) Apply Simple linear and multilinear regression models with the application of statistical tools for estimating economic relationships, testing economic hypotheses and forecasting.

Course Contents:

Statistical Concepts Normal distribution; chi-square, t and F-distributions; estimation of parameters; properties of estimators; testing of hypotheses: defining statistical hypotheses; distributions of test statistics; testing hypotheses related to population parameters; Type I and Type II errors; power of a test; tests for comparing parameters from two samples.

Simple Linear Regression Model: Two Variable Case Estimation of model by method of ordinary least squares; properties of estimators; goodness of fit; tests of hypotheses; scaling and units of measurement; confidence intervals; Gauss-Markov theorem; forecasting.

Multiple Linear Regression Model Estimation of parameters; properties of OLS estimators; goodness of fit - R2 and adjusted R2 ; partial regression coefficients; testing hypotheses - individual and joint; functional forms of regression models; qualitative (dummy) independent variables.

Violations of Classical Assumptions: Consequences, Detection and Remedies Multicollinearity; heteroscedasticity; serial correlation.

Specification Analysis Omission of a relevant variable; inclusion of irrelevant variable; tests of specification errors.

Books Recommended

1. Jay L. Devore, *Probability and Statistics for Engineers*, Cengage Learning, 2010.
2. John E. Freund, *Mathematical Statistics*, Prentice Hall, 1992.
3. Richard J. Larsen and Morris L. Marx, *An Introduction to Mathematical Statistics and its Applications*,Prentice Hall, 2011.
4. D. N. Gujarati and D.C. Porter, *Essentials of Econometrics*, McGraw Hill, 4th Ed., International Edition, 2009.
5. Christopher Dougherty, *Introduction to Econometrics*, Oxford University Press, 3rd Ed., Indian edition, 2007.
6. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAG152: Information Security

Course Prerequisites:

Course Outcomes:

After the completion of the course, the students will be able to:

a) develop basic understanding of security, cryptography, system attacks and defences against them,
b) Cryptography tools usage
c) understand the methods and techniques for information security,
d) have knowledge of data security and secure system development.

Course Contents:

Overview of Security: Protection versus security; aspects of security-data integrity, data availability, privacy; security problems, user authentication, Orange Book.

Security Threats: Program threats, worms, viruses, Trojan horse, trap door, stack and buffer over flow; system threats- intruders; communication threats- tapping and piracy.

Cryptography: Substitution, transposition ciphers, symmetric-key algorithms-Data Encryption Standard, advanced encryption standards, public key encryption - RSA; Diffie- Hellman key exchange, ECC cryptography, Message Authentication- MAC, hash functions.

Digital signatures: Symmetric key signatures, public key signatures, message digests, public key infrastructures.

Security Mechanisms: Intrusion detection, auditing and logging, tripwire, system-call monitoring.

Books Recommended

1. W. Stallings, *Cryptography and Network Security Principles and Practices,*4th Ed., Prentice-Hall of India, 2006.
2. *C. Pfleeger and S.L. Pfleeger,* Security in Computing,*3rd Ed., Prentice-Hall of India, 2007.*
3. D. Gollmann, *Computer Security*, John Wiley and Sons, NY, 2002.
4. J. Piwprzyk, T. Hardjono and J. Seberry, *Fundamentals of Computer Security,*Springer- Verlag Berlin, 2003.
5. J.M. Kizza, *Computer Network Security,* Springer, 2007.
6. M. Merkow and J. Breithaupt, *Information Security: Principles and Practices,*Pearson Education, 2006.
7. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAG201: Applications of Algebra

Course Prerequisites: The course requires basic knowledge of sets, operations on them, relations, functions, matrix, elementary algebra and elementary calculus(secondary level).

Course Outcomes:

At the end of the course the students will be able to use and apply:

a) Balance incomplete Block design (BIBD), in design of experiments in science, engineering and technology, symmetric theory in development of designs.

b) Coding theory in information technology.

c) Theory of matrices in remote sensing in image processing, and in constraint optimization problems and Theory of linear transformations in Least square method and to find approximate solution of system of linear equations finding inverse of rectangular matrices.

Course Contents:

Balanced incomplete block designs (BIBD): definitions and results, incidence matrix of a BIBD, construction of BIBD from difference sets, construction of BIBD using quadratic residues, difference set families, construction of BIBD from finite fields.

Coding Theory: introduction to error correcting codes, linear cods, generator and parity check matrices, minimum distance, Hamming Codes, decoding and cyclic codes.

Symmetry groups and color patterns: review of permutation groups, groups of symmetry and action of a group on a set; colouring and colouring patterns, Polya theorem and pattern inventory, generating functions for non-isomorphic graphs.

Symmetric matrices and quadratic forms: diagonalization of symmetric matrices, quadratic forms, constrained optimization, singular value decomposition, and applications to image processing and statistics.

Least squares methods: Approximate solutions of system of linear equations, approximate inverse of an $m \times n$ matrix, solving a matrix equation using its normal equation, finding functions that approximate data.

Books Recommended

1. I. N. Herstein and D. J. Winter, *Primer on Linear Algebra,* Macmillan Publishing Company, New York, 1990.
2. S. R. Nagpaul and S. K. Jain, *Topics in Applied Abstract Algebra,* Thomson Brooks and Cole, Belmont, 2005.
3. Richard E. Klima, Neil Sigmon, Ernest Stitzinger, *Applications of Abstract Algebra with Maple,* CRC Press LLC, Boca Raton, 2000.
4. David C. Lay, *Linear Algebra and its Applications.*3rd Ed., Pearson Education Asia, Indian Reprint, 2007.
5. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAE201/MAG202: Bio-Mathematics

Course Prerequisites: The field of biomathematics, sometimes also called mathematical or theoretical biology, is an interdisciplinary field of scientific research which aims to address questions which arise from biological systems using appropriate mathematical and computational theory. students should be aware about MATLAB with numerical methods needed for their area of research.

Course Outcomes:

On completion of the course, a student will be able to

a) Learn the development, analysis and interpretation of bio mathematical models such as population growth, cell division, and predator-prey models.
b) Learn about the mathematics behind heartbeat model and nerve impulse transmission model.
c) Appreciate the theory of bifurcation and chaos.
d) Learn to apply the basic concepts of probability to molecular evolution and genetics.

Course Contents:

Mathematical Biology and the modeling process: an overview. Continuous models: Malthus model, logistic growth, Allee effect, Gompertz growth, Michaelis-Menten Kinetics, Holling type growth, Bacterial growth in a Chemostat, Harvesting a single natural population, Prey predator systems and Lotka Volterra equations, Populations in competitions, Epidemic Models (SI, SIR, SIRS, SIC), Activator-Inhibitor system, Insect Outbreak Model: Spruce Budworm, Numerical solution of the models and its graphical representation. Qualitative analysis of continuous models: Steady state solutions, stability and linearization, multiple species communities and Routh-Hurwitz Criteria, Phase plane methods and qualitative solutions, bifurcations and limit cycles with examples in the context of biological scenario. Spatial Models: One species model with diffusion, Two species model with diffusion, Conditions for diffusive instability, Spreading colonies of microorganisms, Blood flow in circulatory system, Travelling wave solutions, Spread of genes in a population. Discrete Models: Overview of difference equations, steady state solution and linear stability analysis, Introduction to Discrete Models, Linear Models, Growth models, Decay models, Drug Delivery Problem, Discrete Prey-Predator models, Density dependent growth models with harvesting, Host-Parasitoid systems (Nicholson-Bailey model), Numerical solution of the models and its graphical representation. Case Studies: Optimal Exploitation models, Models in Genetics, Stage Structure Models, Age Structure Models.

Books Recommended

1. *L.E. Keshet, Mathematical Models in Biology, SIAM, 1988.*
2. J. D. Murray, *Mathematical Biology,* Springer, 1993.
3. Y.C. Fung, *Biomechanics,* Springer-Verlag, 1990.
4. F. Brauer, P.V.D. Driessche and J. Wu, *Mathematical Epidemiology,* Springer, 2008.
5. M. Kot, *Elements of Mathematical Ecology,* Cambridge University Press, 2001.

6. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAE202/MAG203: Theory of Equations

Course Prerequisites: Nil.

Course Outcomes:

On completion of the course, a student will be able to

a) describe the graphical representation of a polynomial, maximum and minimum values of a polynomial,
b) acquire the concept of symmetric functions,
c) use Newton's theorem to find the sums of power of roots, homogeneous products, limits of the roots of equation,
d) derive Sturm's theorem and its application.

Course Contents:

General properties of polynomials, Graphical representation of a polynomial, maximum and minimum values of a polynomials, General properties of equations, Descarte's rule of signs positive and negative rule, Relation between the roots and the coefficients of equations.

Symmetric functions, Applications of symmetric function of the roots, Transformation of equations. Solutions of reciprocal and binomial equations. Algebraic solutions of the cubic and biquadratic. Properties of the derived functions.

Symmetric functions of the roots, Newton's theorem on the sums of powers of roots, homogeneous products, limits of the roots of equations.

Separation of the roots of equations, Strums theorem, Applications of Strum's theorem, Conditions for reality of the roots of an equation and biquadratic. Solution of numerical equations.

Books Recommended

1. W.S. Burnside and A.W. Panton, *The Theory of Equations,* Dublin University Press, 1954.
2. C. C. MacDuffee, *Theory of Equations,* John Wiley & Sons Inc., 1954.
3. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAG251: Numerical Methods

Course Prerequisites: Nil.

Course Outcome:
The course will enable the students to:

a) Learn some numerical methods to find the zeroes of nonlinear functions of a single variable and solution of a system of linear equations, up to a certain given level of

precision.

b) Know about methods to solve system of linear equations, such as Gauss−Jacobi, Gauss−Seidel methods.
c) Interpolation techniques to compute the values for a tabulated function at points not in the table.
d) Applications of numerical differentiation and integration to convert differential equations into difference equations for numerical solutions.

Course Content:

Difference Operators, Interpolation: Forward, Backward, Shift, Central, Averaging and Differential Operators, Divided difference Operator, Newton-Gregory Forward and Backward Interpolation Formula,Gauss Forward and Gauss backward Interpolation Formula,Bessel's and Stirling's Interpolation Formula,Newton's Divided Difference Interpolation Formula,Lagrange's Interpolation Formula.

Solution of Algebraic & Transcendental Equations: Bisection Method,Fixed Point Iteration,Regula Falsi Method,Secant Method,Newton-Raphson Method,Horner's Method,Graffe's Root squaring Method.

Solution of Simultaneous Linear Equations: Gauss Elimination and Gauss Jordan Methods,LU Decomposition Methods (Crout, Doolittle and Choleski),Gauss Jacobi and Gauss-Seidel Methods

Solution of Ordinary Differential Equations: Picard's Method, Euler's and Modified Euler's Methods, Taylor Series Method, Second order Runge - Kutta Method, Milne's Predictor-Corrector Method

Book Recommended

1. S. S. Sastry, *Introductory Methods of Numerical Analysis, 5th Ed*, PHI India.
2. Yang, Cao, Chung, Morris, *Applied Numerical Methods Using Matlab*, John Wiley & Sons, 2007.
3. Anthony Ralston, Philip Rabinowitz, *A First Course in Numerical Analysis*,Courier Corporation, 2001.

MAE251/MAG252: Differential Geometry

Course Prerequisites: The course requires basic knowledge of elementary calculus(secondary level).

Course Outcomes:

At the end of the course the students will be able to understand:

a) The theory of space curves and plane curves, properties of curves such as curvature, torsion evolutes , and involutes etc.
b) The theory of surfaces, the fundamental quadratic Forms of surfaces, intrinsic and extrinsic geometry of surfaces, and the Gauss-Bonnet theorem.
c) Developable surfaces, Geodesics.
d) Tensors, and their properties.

Course Contents:

Theory of Space Curves: Space curves, Planer curves, Curvature, torsion and Serret-Frenet formulae. Osculating circles, Osculating circles and spheres. Existence of space curves. Evolutes and involutes of curves.

Theory of Surfaces: Parametric curves on surfaces. Direction coefficients. First and second Fundamental forms. Principal and Gaussian curvatures. Lines of curvature, Euler's theorem. Rodrigue's formula, Conjugate and Asymptotic lines.

Developables: Developable associated with space curves and curveson surfaces, Minimal surfaces.

Geodesics: Canonical geodesic equations. Nature of geodesics on a surface of revolution. Clairaut's theorem. Normal property of geodesics. Torsion of a geodesic. Geodesic curvature. Gauss-Bonnet theorem. Surfaces of constant curvature. Conformal mapping. Geodesic mapping. Tissot's theorem.

Books Recommended

1. T.J. Willmore, *An Introduction to Differential Geometry,* Dover Publications, 2012.
2. B. O'Neill, *Elementary Differential Geometry,* 2nd Ed., Academic Press, 2006.
3. C.E. Weatherburn, *Differential Geometry of Three Dimensions,* Cambridge University Press 2003.
4. *D.J. Struik, Lectures on Classical Differential Geometry, Dover Publications, 1988.*
5. *S. Lang, Fundamentals of Differential Geometry, Springer, 1999.*
6. B. Spain, *Tensor Calculus: A Concise Course,* Dover Publications, 2003.
7. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAE252/MAG253: Combinatorial Mathematics

Course Prerequisites: Calculus.

Course outcomes:

Students will develop skills for:

a) problem solving, counting, permutations and combinations, generating functions, recurrence relations, partitions, Binomial theorem etc..
b) Many fundamental mathematical objects, such as sets and functions.
c) Specialized mathematical objects, such as Fibonacci numbers and permutations.

Course Contents:

Basic counting principles, Permutations and Combinations (with and without repetitions), Binomial theorem, Multinomial theorem, Counting subsets, Set-partitions, Stirling numbers

Principle of Inclusion and Exclusion, Derangements, Inversion formulae

Generating functions: Algebra of formal power series, Generating function models, Calculating generating functions, Exponential generating functions.

Recurrence relations: Recurrence relation models, Divide and conquer relations, Solution of recurrence relations, Solutions by generating functions.

Integer partitions, Systems of distinct representatives.

Polya theory of counting: Necklace problem and Burnside's lemma, Cyclic index of a permutation group, Polya's theorems and their immediate applications.

Latin squares, Hadamard matrices, Combinatorial designs: *t*designs, BIBDs, Symmetric designs.

Books Recommended

1. J.H. van Lint and R.M. Wilson, *A Course in Combinatorics,* 2nd Ed., Cambridge University Press, 2001.
2. V. Krishnamurthy, *Combinatorics, Theory and Application*, Affiliated East-West Press 1985.
3. P.J. Cameron, *Combinatorics, Topics, Techniques, Algorithms,* Cambridge University Press, 1995.
4. M. Jr. Hall, *Combinatorial Theory,* 2nd Ed., John Wiley & Sons, 1986.
5. S.S. Sane, *Combinatorial Techniques,* Hindustan Book Agency, 2013.
6. R.A. Brualdi, *Introductory Combinatorics,* 5th Ed., Pearson Education Inc., 2009.
7. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAE301/MAG301: Probability and Statistics

Course Prerequisites: The course requires basic knowledge of sets, operations on them, relations, functions, matrix, elementary algebra and elementary calculus(secondary level).

Course Outcomes:

At the end of the course the students will be able to:

a) Explain the basic concepts of probability, random variables and solve problems using Baye's theorem.
b) Apply probability distributions like Binomial, Poisson, Geometric, Negative binomial, Uniform and Normal distributions, and Law of Large numbers, Central limit theorem, Markov chains, Chapman –Kolmogrov equations to solve statistical problems.

Course Contents:

Sample space, probability axioms, real random variables (discrete and continuous), cumulative distribution function, probability mass/density functions, mathematical expectation, moments, moment generating function, characteristic function, discrete distributions: uniform, binomial, Poisson, geometric, negative binomial, continuous distributions: uniform, normal, exponential.

Joint cumulative distribution function and its properties, joint probability density functions, marginal and conditional distributions, expectation of function of two random variables, conditional expectations, independent random variables, bivariate normal distribution, correlation coefficient, joint moment generating function (jmgf) and calculation of covariance (from jmgf), linear regression for two variables.

Chebyshev's inequality, statement and interpretation of (weak) law of large numbers and strong law of large numbers, Central Limit theorem for independent and identically distributed random variables with finite variance.

Books Recommended

1. Robert V. Hogg, Joseph W. McKean and Allen T. Craig, *Introduction to Mathematical Statistics,* Pearson Education, Asia, 2007.
2. Irwin Miller and Marylees Miller, John E. Freund, *Mathematical Statistics with Applications*, 7th Ed., Pearson Education, Asia, 2006.
3. Sheldon Ross, *Introduction to Probability Models*, 9th Ed., Academic Press, Indian Reprint, 2007.
4. Alexander M. Mood, Franklin A. Graybill and Duane C. Boes, *Introduction to the Theory of Statistics,* 3rd Ed., Tata McGraw- Hill, Reprint 2007.
5. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAE302/MAG302: Finite Element Methods

Course Prerequisites: Differential equation and numerical methods.

Course Outcomes:

At the end of the course, a student will be able to:

a) apply direct stiffness, Rayleigh-Ritz, Galerkin method to solve engineering problems and outline the requirements for convergence.
b) analyze linear 1D problems like bars and trusses; 2D structural problems using CST element and analyse the axi-symmetric problems with triangular elements.
c) write shape functions for 4 and 8 node quadrilateral, 6 node triangle elements and apply numerical integration to solve; 1D and 2D; stiffness integrations.
d) solve linear 2D structural beams and frames problems; 1D heat conduction and convection heat transfer problems.
e) evaluate the Eigenvalues and Eigenvectors for stepped bar and beam, explain nonlinear

geometric and material non linearity.

Course Contents:

Introduction to finite element methods, comparison with finite difference methods, Methods of weighted residuals, collocations, least squares and Galerkin's method.Variational formulation of boundary value problems equivalence of Galerkin and Ritz methods.

Applications to solving simple problems of ordinary differential equations.

Linear, quadratic and higher order elements in one dimensional and assembly, solution of assembled system.

Simplex elements in two and three dimensions, quadratic triangular elements, rectangular elements, serendipity elements and isoperimetric elements and their assembly, discretization with curved boundaries

Interpolation functions, numerical integration, and modeling considerations.

Solution of two dimensional partial differential equations under different Geometric conditions.

Books Recommended

1. J.N. Reddy, *Introduction to the Finite Element Methods,* Tata McGraw-Hill, 2003.
2. K.J. Bathe, *Finite Element Procedures,* Prentice-Hall, 2001**.**
3. R.D. Cook, D.S. Malkus and M.E. Plesha, *Concepts and Applications of Finite Element Analysis,* John Wiley and Sons, 2002.
4. Thomas J.R. Hughes, *The Finite Element Method: Linear Static and Dynamic Finite Element Analysis*, Dover Publication, 2000.
5. George R. Buchanan, *Finite Element Analysis,* McGraw Hill, 1994.
6. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAE303/MAG303: Mechanics

Course Prerequisites: Familiarity with Newton's laws and basic physics concepts such as mass, moments of inertia, length, force and time.

Course Outcomes:

The course will enable the students to:

a) Know about the concepts in statics such as moments, couples, equilibrium in both two and three dimensions.
b) Understand the theory behind friction and center of gravity.
c) Calculate moments of inertia of areas and rigid bodies.
d) Know about conservation of mechanical energy and work-energy equations.
e) Learn about translational and rotational motion of rigid bodies.

Course Contents:

Moment of a force about a point and an axis, couple and couple moment, Moment of a couple about a line, resultant of a force system, distributed force system, free body diagram, free body involving interior sections, general equations of equilibrium, two point equivalent loading, problems arising from structures, static indeterminacy.

Laws of Coulomb friction, application to simple and complex surface contact friction problems, transmission of power through belts, screw jack, wedge, first moment of an area and the centroid, other centers, Theorem of Pappus-Guldinus, second moments and the product of area of a plane area, transfer theorems, relation between second moments and products of area, polar moment of area, principal axes.

Conservative force field, conservation for mechanical energy, work energy equation, kinetic energy and work kinetic energy expression based on center of mass, moment of momentum equation for a single particle and a system of particles, translation and rotation of rigid bodies, Chasles' theorem, general relationship between time derivatives of a vector for different references, relationship between velocities of a particle for different references, acceleration of particle for different references.

Books Recommended

1. I.H. Shames and G. Krishna Mohan Rao, *Engineering Mechanics: Statics and Dynamics*,(4th Ed.), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2009.
2. R.C. Hibbeler and Ashok Gupta, *Engineering Mechanics: Statics and Dynamics*,11th Ed., Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi.
3. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAE351/MAG351: Graph Theory

Course Prerequisites: Nil.

Course Outcomes:

The course will enable the students to:

a) understand the basics of graph theory and learn about social networks, Eulerian and Hamiltonian graphs, diagram tracing puzzles and knight's tour problem.
b) able to formulate problems in graph theoretic terms.
c) understand various versions of connectedness of a graph,
d) be able to formulate applied problems as coloring problems,
e) understand and be able to use different models of random graphs and (random networks).

Course Contents:

Definition, examples and basic properties of graphs, pseudo graphs, complete graphs, bi-partite graphs, isomorphism of graphs, paths and circuits, Eulerian circuits, Hamiltonian cycles, the adjacency matrix, weighted graph, travelling salesman's problem, shortest path, Dijkstra's algorithm, Floyd-Warshall algorithm.Trees, Properties, Spanning Tee, BFS, DFS.

Books Recommended

1. B.A. Davey and H.A. Priestley, *Introduction to Lattices and Order*, Cambridge University Press, Cambridge, 1990.

2. Edgar G. Goodaire and Michael M. Parmenter, *Discrete Mathematics with Graph Theory*,2nd Edition, Pearson Education (Singapore) P. Ltd., Indian Reprint 2003.

3. Rudolf Lidl and Gunter Pilz, Applied Abstract Algebra, 2nd Ed., Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.

4. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAE352/MAG352: Mathematical Finance

Course Prerequisites: Single and multivariable calculus, differential equation, probability and statistics, numerical methods.

Course outcomes:

After completion of this course, student will be able to:

a) Understand the concept of time value of money.
b) Explain and compare different types of interest(simple and compound, discrete and continuous)
c) Understand the relation between a present value, a set of cash flows and interest, as well as understand the interest rate risk (duration, immunisation).
d) Develop formulae for the expected value and variance of the present values of simple insurance and annuity contracts, assuming constant deterministic interest.
e) Employ methods related to these concepts in a variety of financial applications.

Course Contents:

Basic principles: Comparison, arbitrage and risk aversion, Interest (simple and compound, discrete and continuous), time value of money, inflation, net present value, internal rate of return (calculation by bisection and Newton-Raphson methods), comparison of NPV and IRR. Bonds, bond prices and yields, Macaulay and modified duration, term structure of interest rates: spot and forward rates, explanations of term structure, running present value, floating-rate bonds, immunization, convexity, putable and callable bonds.

Asset return, short selling, portfolio return, (brief introduction to expectation, variance,

covariance and correlation), random returns, portfolio mean return and variance, diversification, portfolio diagram, feasible set, Markowitz model (review of Lagrange multipliers for 1 and 2 constraints), Two fund theorem, risk free assets, One fund theorem, capital market line, Sharpe index. Capital Asset Pricing Model (CAPM), betas of stocks and portfolios, security market line, use of CAPM in investment analysis and as a pricing formula, Jensen's index.

Books Recommended

1. David G. Luenberger, *Investment Science,*Oxford University Press, Delhi, 1998.
2. John C. Hull, *Options, Futures and Other Derivatives,* 6th Ed., Prentice-Hall India, Indian reprint, 2006.
3. Sheldon Ross, *An Elementary Introduction to Mathematical Finance,* 2nd Ed., Cambridge University Press, USA, 2003.
4. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAE353/MAG353: Cryptography and Network Security

Course Prerequisites: Nil.

Course Outcomes:

After the course, the student will be able to:

a) Understand the fundamentals of cryptography and computer security attacks.
b) Learn about various ciphers and data encryption standard.
c) Review basic concepts of number theory and finite fields.
d) Learn about advanced encryption standard.
e) Understand the fundamentals of RSA and elliptic curve cryptography.
f) Encrypt and decrypt messages using block ciphers, sign and verify messages using well known signature generation and verification algorithms.

Course Contents:

Public Key Cryptography Principles & Applications, Algorithms: RSA, Message Authentication: One way Hash Functions: Message Digest, MD5, SHA1. Public Key Infrastructure: Digital Signatures, Digital Certificates, Certificate Authorities.

Network Attacks: Buffer Overflow, IP Spoofing, TCP Session Hijacking, Sequence Guessing, Network Scanning: ICMP, TCP sweeps, Basic Port Scans; Denial of Service Attacks: SYN Flood, Teardrop attacks, land, Smurf Attacks.IP security Architecture: Overview, Authentication header, Encapsulating Security Pay Load, combining Security Associations, Key Management. Virtual Private Network Technology: Tunneling using IPSEC.

Requirements, Secure Socket Layer, and Secure Electronic Transactions, Network Management Security: Overview of SNMP Architecture- SNMPV1, SNMPV3.Firewall Characteristics & Design Principles, Types of Firewalls: Packet Filtering Router, Application Level Gateway or

Proxy, Content Filters, Bastion Host.

Books Recommended

1. W. Stallings, *Networks Security Essentials: Application & Standards,*Pearson Education, 2000.
2. TCP/IP Protocol Suite, Behrouz A. Forouzan, *Data Communication and Networking,* Tata McGraw Hill.
3. W. Stallings, *Cryptography and Network Security, Principles and Practice*, Pearson Education, 2000.
4. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAE401/MAG401: Finite Field

Course Prerequisites: Understanding of group theory and ring theory.

Course Outcomes:

After studying this course the student will be able to:

a) identify and construct examples of fields, distinguish between algebraic and transcendental extensions, characterize normal extensions in terms of splitting fields and prove the existence of algebraic closure of a field.
b) characterize perfect fields using separable extensions, construct examples of automorphism group of a field and Galois extensions as well as prove Artin's theorem and the fundamental theorem of Galois theory.
c) classify finite fields using roots of unity and Galois theory and prove that every finite separable extension is simple.
d) use Galois theory of equations to prove that a polynomial equation over a field of characteristic is solvable by radicals iff its group (Galois) is a solvable group and hence deduce that a general quintic equation is not solvable by radicals.

Course Contents:

Introduction of Groups, Rings, Fields, irreducible polynomials, roots of irreducible polynomials, primitive polynomials, construction of irreducible polynomials.

Introduction to Galois Theory. Finite extensions, characterization of finite fields, Algebraic extensions, roots of polynomials, splitting fields.

Separable extensions, Normal extensions, Algebraic closure, composite extensions, roots of unity. Cyclotomic Polynomial, cyclotomic extensions and abelian extensions over Q, representation of elements of finite fields.

Books Recommended:

1. D.S. Dummit and R.M. Foote, Abstract Algebra, John Wiley & Sons Inc., 3rd Ed., 2004.

2. W.W. Peterson and E.J. Weldon, Jr., Error-Correcting Codes. M.I.T. Press, Cambridge, Massachusetts, 1972.
3. S. Lang, Algebra, Springer (India) Pvt. Ltd., 2010.
4. R. Lidl and H. Niederreiter, Introduction to Finite Fields and their Applications, Cambridge University Press, 1994.
5. G.L. Mullen and C.Mummert, Finite Fields and Applications, Student Mathematical library, 41, AMS 2007. http://www.ams.org/bookstore-getitem/isbn=0-8218-4418-0
6. Khanna, V.K., Bhambri, S.K., A Course in Abstract Algebra, 4th Edition, Vikas Publishing House Pvt. Ltd., 2013.
7. Bhattacharya P.B.,Jain S.K. and Hagpaul S.R., Basic Abstract Algebra Cambridge University Press, Second Edition.
8. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAE402/MAG402: Ordinary Differential Equation

Course Prerequisites: MDSC-152-Differential Equations.

Course Outcomes:

After studying this course the student will be able to:

a) know about existence, uniqueness and continuity of solutions of first order ODE's, properties of zeros of solutions of linear second order ODE's, boundary value problems.
b) understandwith eigen values and eigen functions of Sturm−Liouville systems, and the solutions of initial and boundary value problems.
c) be well equipped to undertake any advanced course on ordinary differential equations.

Course Contents:

Introduction of differential Equations: Formation of differential equations. Basic definitions (linearity, homogeneous and non-homogeneous, explicit and implicit solution general solution, &particular solution of First and second order differential equations).
Existence and uniqueness theorem of Initial Value Problems: Picard's and Peano's Theorems, Continuation of solution and maximal interval of existence, continuous dependence.

Linear systems, properties of homogeneous and non-homogeneous systems, behaviour of solutions of nth order linear homogeneous equations.

Systems of ODEs. Phase Plane. Qualitative Methods: Two Dimensional Autonomous Systems: Phase Space Analysis, Constant-Coefficient Systems. Phase Plane Method, Criteria for Critical Points. Stability, Eigen-value, proper and improper nodes, spiral points and saddle points. Asymptotic behavior, stability, Lyapunov methods. Qualitative Methods for Nonlinear Systems, Nonhomogeneous Linear Systems of ODEs.

Series Solution: Power series solution of second order homogeneous ODE, ordinary points, singular points, Frobenius series solution, Legendre and Bessel's equation through examples

Green's Function: Definition, Construction of Green's function for an important special case. Linear integral equations in cause and effect. The influence function. Applications of Green's function. Eigen value problems. Self adjoint form, Sturm-Liouvile problem and itsapplications.

Books Recommended:

1. Simmons, G. F., "Differential Equations", McGraw-Hill, 2nd Edition 1991.
2. Hildebrand F. B., "Methods of Applied Mathematics", Courier Dover Publications 1992.
3. Tenenbaum, M. and Polard, H., "Ordinary Differential Equations", Dover Publications 1985.
4. Sneddon, I. N., "Elements of Partial Differential Equations", McGraw-Hill Book Company 1988.
5. Rao, K. S., "Introduction to Partial Differential Equations", PHI Learning Pvt. Ltd. (2nd Edition) 2010.
6. Amarnath, T., "An Elementary Course in Partial Differential Equations", Narosa Publishing House (2nd Edition) 2012.
7. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAE403/MAG403: Advanced Numerical Analysis

Course Prerequisites: Understanding of basic numerical methods.

Course Outcomes:

The course will enable the students to

a) Learn some numerical methods to find the zeroes of nonlinear functions of a single variable and solution of a system of linear equations, up to a certain given level of precision.
b) Know about methods to solve system of linear equations, such as Gauss−Jacobi, Gauss−Seidel methods.
c) Interpolation techniques to compute the values for a tabulated function at points not in the table.
d) Applications of numerical differentiation and integration to convert differential equations into difference equations for numerical solutions.

Course Contents:

Revisit of root finding methods for nonlinear equations and their order of convergence

System of Non-linear Equations: Newton's method, Quasi-Newton methods, Broyden's method, Applications-coupled reversible chemical reaction, flow distribution in a pipe flow network.

Interpolation: Piecewise interpolation, cubic spline interpolation, Hermite interpolation, Hermite cubic interpolation.

Initial Value Problems: Euler's method, Higher order Tylor's method, Runge-Kutta methods, multistep methods such as Adam-Bashforth and Adam-Moulton methods, Convergence and Stability, Applications-spread of an epidemic, radiative heat transfer to a thin metal plate, geneting switch.

Two-Point Boundary Value Problems: Finite difference methods for linear problems with Dirichlet as well as non-Dirichlet boundary conditions, Applications-flow between parallel plates, the heat pack.

Books Recommended:

4. B. Bradie, A Friendly Introduction to Numerical Analysis, Pearson Education, Inc., 2006.
5. K. Atkinson and W.Han, Elementary Numerical Analysis, third Edition, Willey India (P) Ltd., 2004.
6. C.F. Gerald and P.O. Wheatley, Applied Numerical Analysis, Seventh Edition, Pearson Education, Inc., 2004.
7. Froberg C.E., Introduction to Numerical Analysis Addition Wesley, Second Edition, 1969.
8. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAE404/MAG404: Mathematical Modelling

Course Prerequisites: Basic vector manipulation. Ideas of position vector, velocity, acceleration. Scalar and vector products. Parametrization of a curve; tangent vector, arc length. Parametrization of a surface; normal to a surface. Knowledge of differential equations and their solutions also.

Course Outcomes:

After studying this course the student will be able to:

a) Know the concept of how to develop mathematical models using experimental data and observation data (Discrete and continuous) in the form of difference and differential equations and basic methods to solve them.
b) To develop Models of growth and decay (for problems of aging), Prey Predator (problems of ecology and environment), drugs delivery problem (Medical problems), motion of planets and satellites (Space problems), population dynamics (genetics and microbiology), etc.

Course Contents:

What is Mathematical Modeling? History of Mathematical Modeling, latest development in Mathematical Modeling, Merits and Demerits of Mathematical Modeling. Introduction to

difference equations, Non-linear Difference equations, Steady state solution and linear stability analysis. Introduction to Discrete Models, Linear Models, Growth models, Decay models, Newton's Law of Cooling, Bank Account Problem and mortgage problem.

Compartment model, Drug Delivery Problem, Harrod Model of Economic growth, War Model, Lake pollution model, Alcohol in the bloodstream model, Arm Race models, Linear Prey-Predator models, Density dependent growth models with harvesting, Numerical solution of the models and its graphical representation using EXCEL.

Introduction to Continuous Models, Carbon Dating, Drug Distribution in the Body, Growth and decay of current in a L-R Circuit, Horizontal Oscillations, Vertical Oscillations, Damped Force Oscillation, Dynamics of Rowing, Combat Models, Mathematical Model of Influenza Infection (within host), Epidemic Models (SI, SIR, SIRS, SIC), Spreading of rumor model, Steady State solutions, Linearization and Local Stability Analysis, logistic and gomperzian growth, prey-predator model, Competition models, Numerical solution of the models and its graphical representation using EXCEL.

Mathematical Modelling through Ordinary Differential Equations of Second Order: Planetary Motions- Circular Motion and Motion of Satellites- Mathematical Modelling through Linear Differential Equations of Second Order- Miscellaneous Mathematical Models. Mathematical.

Modelling through Difference Equations: Simple Models- Basic Theory of linear difference equations with constant coefficients- Economics and Finance-Population Dynamics and Genetics-Probability Theory.

Books Recommended:

1. Albright, B., Mathematical Modeling with Excel, Jones and Bartlett Publishers 2010
2. Marotto, F. R., Introduction to Mathematical Modeling using Discrete
3. Dynamical Systems, Thomson Brooks/Cole. 2006
4. Kapur, J. N., Mathematical Modeling, New Age International 2005
5. Barnes, B. and Fulford, G. R., Mathematical Modelling with Case Studies, CRC Press, Taylor and Francis Group. 2009
6. Edsberg, L., Introduction to Computation and Modeling for Differential Equations, John Wiley and Sons. 2008.
7. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAE451/MAG451: Complex Analysis

Course Prerequisite: The role of epsilon-delta definitions in calculus, probably from a basic course in real analysis. In the courses description, it is stated that only multivariable calculus is required to take it.

Course Outcomes:

After studying this course the student will be able to

a) understand analytic function as a mapping on the plane, Mobius transformation and branch of logarithm.
b) understand Cauchy's theorems and integral formulas on open subsets of the plane.
c) understand how to count the number of zeros of analytic function giving rise to open mapping theorem.
d) know about the kind of singularities of meromorphic functions which helps in residue theory and contour integrations.
e) handle integration of meromorphic function with zeros and poles leading to the argument principle and Rouche's theorem.

Course Contents:

Linen of half planes in complex plane, Extended complex plane, Stereographic projection.

Power Series, Analytic functions, Analytic functions as mappings, Conformal mapping, Mobius transformations.

Analytic Continuation: Direct Analytic Continuation, Monodromy theorem, Poisson Integral Formula, Analytical Formula, Analytical Continuation via Reflection.

Taylor series, Power series representation of analytic functions, Zeroes of an analytic function, Index of a closed curve, Cauchy's theorem and integral formula, Homotopic version of Cauchy's theorem and simple connectedness, Counting zeroes, Open mapping theorem.

Classification of singularities, Laurent series, Residues, Cauchy Residue theorem, Contour integration, Application to real integration, Argument principle, Maximum modulus theorem, Schwartz Lemma.

Books Recommended:

1. J. Bak and D.J. Newman, Complex Analysis, Second Edition, Springer, 2011.
2. J.B. Conway, Function of One Complex Variable, Narosa, Delhi.
3. L.V. Ahlfors, Complex Analysis, McGraw Hill Co., New York, 1988.
4. J.W. Brown and R.V. Churchill, Complex Variables and Applications, McGraw Hill International Edition, 2009.
5. S. Lang, Complex Analysis, Springer-Verlag, 2003.
6. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAE452/MAG452: Partial Differential Equation

Course Prerequisites: The course requires basic knowledge of calculus (undergraduate level).

Course Outcomes:

After studying this course the student will be able to

a) Establish a fundamental familiarity with partial differential equations.
b) Distinguish between linear and nonlinear partial differential equations.
c) Find complete integrals of Non-linear first order partial differential equations.
d) Solve second order partial differential equations by method of characteristic equations, and by method of separation of variables (Elliptic, parabolic, and Hyperbolic).

Course Contents:

Introduction: Surfaces and curves. Simultaneous differential equations of the first order and first degree. Integral curves of vector fields. Methods of solution of $dx/P = dy/Q = dz/R$. Orthogonal Trajectories of a system of curves on a surface. Pfaffian differential forms and equations. Solution of Pfaffian differential equations in three variables.

First Order PDE: Partial differential equations, Origins and classification of first order PDE, Initial value problem for quasi-linear first order equations: Existence and uniqueness of solution, Nonexistence and non-uniqueness of solutions. Surfaces orthogonal to a given system of surfaces. Nonlinear PDE of first order, Cauchy method of characteristics, Compatible systems of first order equations, Charpit's method, Solutions satisfying given conditions. Jacobi's method.

Second Order PDE: The origin of second order PDE. Equations with variable coefficients, Classification and canonical forms of second order equations in two variables. Classification of second order equations in n variables. Characteristic curves of second order equations in two variables. Importance of characteristic curves.

Review of Integral Transform and Fourier series.

Hyperbolic Equations: Derivation of one and two dimensional, Wave, Heat equation, diffusion equation in reactions, initial & boundary value problem and their fundamental solution, wave equation: uniqueness, D'Alembert's solution of wave equations.

Elliptic Equations: Laplace equation in Cartesian, polar, spherical and cylindrical coordinates and its solution by Fourier series method, Poisson equation in 2D. weak and strong maximum principle, Dirichlet's principle, existence of solution using Perron's method.
Parabolic Equations: solution of homogeneous and non-homogeneous diffusion equation (1D). Duhamel's principle.

The scope of the course is indicated by the relevant sections of chapter 10, 11, 13 of [1].

Books Recommended:

1. Simmons, G. F. , “Differential Equations " , McGraw-Hill, 2nd Edition 1991.
2. Hildebrand F. B., "Methods of Applied Mathematics", Courier Dover Publications 1992.
3. Tenenbaum, M. and Polard, H., “Ordinary Differential Equations”, Dover Publications 1985.
4. Sneddon, I. N., “Elements of Partial Differential Equations”, McGraw-Hill Book Company 1988.
5. Rao, K. S., “Introduction to Partial Differential Equations", PHI Learning Pvt. Ltd. (2nd Edition) 2010.
6. Amarnath, T., “An Elementary Course in Partial Differential Equations”, Narosa Publishing House (2nd Edition) 2012.
7. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAE453/MAG453: Measure & Integration

Course Prerequisites: Sets theory, real analysis, calculus.

Course Outcomes:

After studying this course the student will be able to

a) verify whether a given subset of P or a real valued function is measurable
b) understand the requirement and the concept of the Lebesgue integral (a generalization of the Reimann integration) along its properties.
c) demonstrate understanding of the statement and proofs of the fundamental integral convergence theorems and their applications.
d) know aboutthe concepts of functions of bounded variations and the absolute continuity of functions with their relations.
e) extend the concept of outer measure in an abstract space and integration with respect to a measure.
f) learn and apply Holder and Minkowski inequalities in L^p-Spaces and understand completeness of L^p-Spaces and convergence in measures.

Course Contents:

Countable sets, uncountable sets, Cardinal numbers of the sets of natural numbers, the set of real numbers and the set of functions, Order relation between these cardinal numbers. Algebra of Cardinal numbers, the extended real numbers, Borel sets, Countably additive measures.

Lebesgue measure: Outer measure, Measurable sets and Lebesgue measure, Non-measurable sets, Introduction to General Measure and Integration: Measure spaces, Measurable functions Integration. Measurable functions, Littlewood’s three principles, Egoroff’s Theorem.Lebesgue measure: Outer measure, Measurable sets and Lebesgue measure, Non-measurable sets, Measurable functions, Littlewood’s three principles, Egoroff’s Theorem.

Lebesgue Integral: Simple functions, integral of a simple function, Lebesgue integral of a bounded measurable function over a set of finite measure, Comparison of Riemann and Lebesgue integrals,

Theorem of bounded convergence, The integral of a non-negative measurable function, Fatou's Lemma, Monotone Convergence theorem, the general Lebesgue integral, Lebesgue's theorem of dominated convergence. Convergence in measure.

Differentiation and Integration: Differential of monotone functions, Functions of bounded variation, Differentiation of an integral, Absolutely continuous functions, theorem that a function is an indefinite integral if and only if it is absolutely continuous.

The L^p-Spaces, Holder and Minkowski inequalities, Completeness of L^p-Spaces.

The Scope of the course is indicated by the relevant sections of Chapters 1 to 6 and 11 of [1].

Books Recommended:

1. H.L.Royden, Real Analysis, (3^{rd} ed.), The Macmillian Company, New York, 1988.
2. G.de Berra, Introduction to Measure Theory, Van Nostrand Reinhold Company, New York, 1974.
3. R.G. Bartle, The Elements of Integration and Lebesgue Measure, John Wiley & Sons, Inc. New York, 1995.
4. P.K.Jain, V.P. Gupta and P. Jain, Lebesgue Measure and Integration, (2^{nd} ed.), New Age International Publishers, New Delhi, 2011.
5. J.N. McDonald and N.A. Weiss, A Course in Real Analysis, Academic Press, New York, 1999.
6. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAE454/MAG454: Advanced Linear Programming

Course Prerequisites: Basics of linear programming.

Course Outcomes:

After studying this course the student will be able to

a) To appropriately formulate Linear Programming models for service and manufacturing systems, and apply operations research techniques and algorithms to solve these LP problems
b) Apply linear programming method to solve two-person zero-sum game problems.
c) To appropriately formulate Network models for service and manufacturing systems, and apply operations research techniques and algorithms to solve these Network problems.
d) To appropriately formulate Queuing and Inventory models for service and manufacturing systems, and apply operations research techniques and algorithms to solve these problems.

Course Contents:

Introduction to LPP (Graphical, simplex, Big-M, Two-Phase, Dual-Simplex methods). Assignment and Transportation Problems, Sequencing problem.

Goal programming, Game Theory: Two-person zero sum games, game with mixed strategies, graphical solution, and solution by linear programming.

Inventory, Features of Inventory system, Inventory Model Building, Deterministic Inventory Models with no shortage, Deterministic Inventory with shortages probabilistic Inventory Control Models: single period probabilistic model without setup cost-single period probabilities Model with setup cost. Queuing theory.

Project Management by PERT/CPM, Network diagram, Rules of construction, Time estimate and critical path analysis, PERT.

Books Recommended:

1. Kanti-Swarup, P.K. Gupta and man-Mohan, Operations Research, S.Chand publication.
2. G.hadley: Linear Programming, Narosa publishing house 1995.
3. F.S. Hiller and G.J. Lieberman, Introduction to Operations Research (6^{th} Ed.), Mc Graw Hill International Ed., 1995.
4. H.A Taha: Operations Research, An Introduction (3^{rd} Ed.) Macmillan Co., New York, 1982.
5. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAE455/MAG455: Number Theory

Course Prerequisites: Familiarity with elementary number theory and Abstract algebra including groups, rings and ideals, fields.

Course Outcomes:

This course will enable the students to:

a) Learn about some fascinating discoveries related to the properties of prime numbers, and some of the open problems in number theory, viz., Goldbach conjecture etc.
b) Know about number theoretic functions and modular arithmetic.
c) Solve linear, quadratic and system of linear congruence equations.
d) Learn about public key crypto systems, in particular, RSA.

Course Contents:

Linear Diophantine equation, prime counting function, statement of prime number theorem, Goldbach conjecture, linear congruences, complete set of residues, Chinese Remainder theorem, Fermat's Little theorem, Wilson's theorem.

Number theoretic functions, sum and number of divisors, totally multiplicative functions, definition and properties of the Dirichlet product, the Mobius Inversion formula, the greatest integer function, Euler's phi-function, Euler's theorem, reduced set of residues, some properties of Euler's phi-function.

Order of an integer modulo n, primitive roots for primes, composite numbers having primitive roots, Euler's criterion, the Legendre symbol and its properties, quadratic reciprocity, quadratic congruences with composite moduli. Public key encryption, RSA encryption and decryption, the equation $x^1 + y^2 = z^2$, Fermat'sLast theorem.

Books Recommended:

1. David M. Burton, *Elementary Number Theory*, 6th Ed., Tata McGraw-Hill, Indian reprint, 2007.
2. Neville Robinns, *Beginning Number Theory*, 2nd Ed., Narosa Publishing House Pvt. Ltd., Delhi, 2007.
3. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

Skill Enhancement Course (SEC)

MAS101: Latex for scientific typesetting

Prerequisites: There are no prerequisites for this course, except knowledge of editing text. The course can be taken by any learner who wants to create documents using LaTeX.

Course Outcome:

a) Handle different types of documents
b) Organize documents into different sections, subsections, etc.
c) Formatting pages (margins, header, footer, orientation)
d) Formatting text
e) Write complex mathematical formulae
f) Include tables and images
g) Cross-referencing, bibliography, and Indexing
h) Read error messages as and when required
i) Create presentations using Beamer

Course Contents:

This topic introduces the learner to LaTeX, its installation, and different IDEs. The learner creates the first document using LaTeX, organizes content into sections using article and book class of LaTeX, different paper sizes, examines packages, formats the page by setting margins, customizing header and footer, changing the page orientation, dividing the document into multiple columns. The topic ends with reading different types of error messages.

This topic concentrates on formatting text (styles, size, alignment), adding colors to text and entire page, and adding bullets and numbered items. It concludes by explaining the process of writing complex mathematics. Creating basic tables, adding simple and dashed borders, merging rows and columns, and handling situations where a table exceeds the size of a page. The sessions then continue to add an image, explore different properties like rotate, scale, etc..

In this topic, the learner learns to add cross-referencing (refer to sections, table, images), add bibliography (references), and create back index. Introduction to creating slides, adding frames, dividing the slide into multiple columns, adding different blocks, etc.

Book Recommended:

1. Stefan Kottwitz: *LaTeX Beginner's Guide: Create visually appealing texts, articles, and books for business and science using LaTeX*, 2nd Edition , Packt Publishing, 2021.
2. Firuza Karmali Aibara *: A short introduction to LaTeX: A book for beginners*, Createspace Independent Publishing Platform, 2019.
3. Dilip Datta*: LaTeX in 24 Hours: A Practical Guide for Scientific Writing* , 1st ed., Springer, 2017.
4. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAS102: Operating System: Linux

Course Prerequisites: Good knowledge of C, Computer Organization and Architecture, x86 Assembly level programming.

Course Outcomes:

On completion of this course, students will be able to understand

a) the objectives and functions of modern operating systems,
b) the basic commands of Linux operating system and can write shell scripts,
c) to create file systems and directories and operate them,
d) to create processes background and fore ground etc.,by fork() system calls,
e) to create shared memory segements, pipes ,message queues and can exercise interprocess communication.

Course Contents:

Linux - The Operating System: Linux history, Linux features, Linux distributions, Linux's relationship to Unix, Overview of Linux architecture, Installation, Start up scripts, system processes (an overview), Linux Security, The Ext2 and Ext3 File systems: General Characteristics of, The Ext3 File system, file permissions. User Management: Types of users, the powers of Root, managing users (adding and deleting): using the command line and GUI tools.

Resource Management in Linux: file and directory management, system calls for files Process Management, Signals, IPC: Pipes, FIFOs, System V IPC, Message Queues, system calls for processes, Memory Management, library and system calls for memory.

Books Recommended

1. Arnold Robbins, *Linux Programming by Examples The Fundamentals,* 2nd Ed., Pearson Education, 2008.
2. Cox K, *Red Hat Linux Administrator's Guide,* PHI, 2009.
3. R. Stevens, *UNIX Network Programming,* 3rd Ed., PHI, 2008.
4. Sumitabha Das, *Unix Concepts and Applications,* 4th Ed., TMH, 2009.
5. Ellen Siever, Stephen Figgins, Robert Love, Arnold Robbins, *Linux in a Nutshell,* 6th Ed., O'Reilly Media, 2009.
6. Neil Matthew, Richard Stones, Alan Cox, *Beginning Linux Programming,* 3rd Ed., 2004.
7. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAS151: Introduction to Programming with MATLAB

Course Prerequisites: None.

Course Outcome:

After the completion of the course, the students will be able to:

a) Understand the basics functions of MATLAB.

b) Plot the 2D, 3D figures.

c) Use basic commands of MATLAB.

d) Solve various differential equations using MATLAB.

Course Content:

Introduction to MATLAB: vector and matrix generation, subscripting and the colon notation, matrix and array operations and their manipulations, introduction to some inbuilt functions related to array operations. m-files: scripts and functions, editing, saving m-files, and interaction between them.

Introduction to builtin functions: related to matrix inversion, eigenvalues, eigenvectors, condition number; for data representation: bar charts, histograms, pie chart, stem plots etc; for solving various type of differential equations; for specialized plotting.

Relational and logical operators: flow control using various statements and loops including If-End statement, If-Else-End statement, nested If-Else-End statement, For-End and While-End loops with Break commands.

Two & three-dimensional graphics: basic plots, change in axes and annotation in a figure, multiple plots in a figure, saving and printing figures, mesh plots, surface plots and their variants e.g., contour plots, sphere, and animations.

Symbolic Math and working with polynomials. Some applications: Numerical solution of ODE using solver, Numerical differentiation and integrations etc.

Books Recommended:

1. Amos Gilat, *MATLAB: An Introduction with Applications*, 4th edition, Wiley; Fourth edition, 2012.
2. Stephen J. Chapman, *MATLAB Programming for Engineers*, Cengage learning; 4th edition, 2012.
3. Rudra Pratap ,*Getting Started with MATLAB: A Quick Introduction for Scientists & Engineers,* Oxford, 2010.
4. V. Dukkipati, Rao, *Matlab: An Introduction With Applications,* New Age International Private Limited; 1st edition, 2009.
5. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAS152: Introduction to Python

Course Prerequisites: None.

Course Outcomes:

After the completion of the course, the students will be able to:

a) To understand why Python is a useful scripting language for developers.
b) To learn how to design and program Python applications.
c) To learn how to use lists, tuples, and dictionaries in Python programs.
d) To learn how to use indexing and slicing to access data in Python programs.
e) To learn how to write loops and decision statements in Python.
f) To learn how to use python to solve mathematical problems.

Course Content:

Introduction to Python Programming, Installation of Python, Application of Python, Writing Python Code, Running Python Programs, Variables, Basic Input-Output Operations, Operators.

Number, String, List, tuple, set, dictionary, Arrays and Vectors, Conditional Statements (if, if-else, if-elif-else), Loops (For loop, while loop).
Writing and Calling Functions, Function Inputs and Outputs, Local and Global Scope of variable, lamda function , Types of Errors.

Library for Mathematics (sympy and numpy), problems on Algebraic expression, ordinary and partial derivatives, integral, limit, Ordinary Differential Equations, Algebra of Matrices, Plotting of functions.

Books Recommended:

1. Harsh Bhasin, *Python For Beginners*. New Age International; 1st Edition,2018.
2. Tim Hall and J-P Stacey, *Python 3 for Absolute Beginners*. Apress, 2009.
3. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAS201: Programming with Mathematica

Course Prerequisites: Knowledge of Functions, Matrices, Basic algebra, Fundamental calculus and Ordinary differential equations (ODEs).

Course Outcomes:

After the completion of the course, the students will be able to:

a) Understand basic principles of programming language.

b) How to solve complex mathematical problems using Mathematica.

Course Content:

User interface**,** Mathematica language and syntax**,** Functions manipulation**,** Plotting mathematical functions and data. Plotting 2D, 3D functions and manipulation**,** Solving algebraic equation**:** Root finding, Transcendental equation**,** Solving ordinary differential equation (ODE)**,** Solving Partial differential equation (PDE)**,** Vectors and matrices**,** Limits, Integration and Differentiation**,** Numerical computation**,** Symbolic manipulation

Books Recommended:

1. Stephen Wolfram ,*The Mathematica Book*, 5th Edition, Wolfram Media Inc, 2003.
2. José Guillermo Sánchez León, *Mathematica Beyond Mathematics:The Wolfram Language in the Real World*, 1st Ed., Chapman and Hall/CRC, 2017.
3. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAS251: Computer Graphics

Course Prerequisites: Knowledge of data structures and algorithm is preferable.

Course Outcomes:

At the end of the course the students will be able to:

a) Implement various geometric algorithms, transformations, area filling, clipping.
b) Describe the importance of viewing and projections.
c) Define the fundamentals of animation, virtual reality and related technologies.
d) Apply mathematics and logic to develop programs for elementary graphic operations.

Course Contents:

Development of computer Graphics: Raster Scan and Random Scan graphics storages, displays processors and character generators, colour display techniques, interactive input/output devices. Points, lines and curves: Scan conversion, line-drawing algorithms, circle and ellipse generation, conic-section generation, polygon filling anti aliasing. Two-dimensional viewing: Coordinate systems, linear transformations, line and polygon clipping algorithms.

Books Recommended

1. D. Hearn and M.P. Baker, *Computer Graphics,*2nd Ed., Prentice-Hall of India, 2004.
2. J.D. Foley, A van Dam, S.K. Feiner and J.F. Hughes, *Computer Graphics: Principals and Practices,*2nd Ed., Addison-Wesley, MA, 1990.
3. D.F. Rogers, *Procedural Elements in Computer Graphics,*2nd Ed., McGraw Hill Book Company, 2001.
4. D.F. Rogers and A.J. Admas, *Mathematical Elements in Computer Graphics,*2nd Ed., McGraw Hill Book Company, 1990.
5. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

MAS252: Financial Accounting

Course Prerequisites: Nil

Course Outcomes:

At the end of the course the students will be able to:

a) understand the basic accounting and financial terminology.
b) Understand how events affect firm value
c) Understand how financial transactions are recorded.
d) Make the participants' comfortable looking through financial statements
e) Develop the ability in participants' to use financial statements to assess a company's performance.

Course Contents:

Introduction to Accounting: Importance and Limitations of accounting. Various concepts of

Accounting Information, Accounting Principles, Conventions and Concepts. Journal, Ledger, Trial Balance, Rectification of Errors, Preparation of Bank Reconciliation, final Accounts with Adjustment entries. Valuation of Stock, Accounting Treatment of Depreciation, Reserve and Provision. Analysis of Financial Statement : Ratio Analysis.

Books Recommended:

1. Narayanswami, R. (2005). Financial Accounting Managerial Perspective. 2 nd Edition. Prentice Hall of India Pvt. Ltd.
2. Mukherjee, A., & Hanif, M., (2003). Financial Accounting. 1st Edition. Tata Mc. Graw Hill.
3. Maheshwari, S.N., & Maheshwari, S. K., (2013). An Introduction to Accountancy. 11 th Edition. Vikas Publishing House.
4. Bhattacharya, A.K., (2011). Essentials of Financial Accounting. 2nd Edition. Prentice Hall of India Pvt. Ltd.
5. Chowdhary A., (2007). Fundamentals of Accounting and Financial Analysis. 1st Edition. Pearson Education.
6. Suggestive digital platforms web links: NPTEL/SWAYAM/MOOCS.

Project

A project may be undertaken in the form of a case study or otherwise and data be collected, if required, as the case may be. The topic of the project be chosen in consultation with the assigned supervisor and the candidate should prepare a summary/synopsis of the proposed project related to some topic in Mathematics. The candidate needs to collect data/related literature on any particular aspect of the identified topic and shall prepare the report of the project from historical point of view, or as a survey or unification of different aspects.

Dissertation (based on some scientific problem)

Any topic in mathematics may be picked up by a candidate in consultation with the assigned supervisor. An in-depth study of the topic in a specific direction be made leading to the identification of a problem. The derivation of full/partial answer to the problem be written in the form of a thesis. The investigation be made either to give birth to another proof of an existing result or a new technique be proposed in lieu of an existing technique or a novel finding.