Board of Studies in Mathematics (UG)
UNIVERSITY OF KERALA

First Degree Programme in MATHEMATICS under Choice Based Credit and Semester System

SYLLABUS
for 2018 admission onwards

Structure of Core Courses

Sem	Course Code	Course title	Instr.hrs. per week	Credit
I	MM 1141	Methods of Mathematics	4	4
II	MM 1221	Foundations of Mathematics	4	3
III	MM 1341	Elementary Number Theory and Calculus – I	5	4
IV	MM 1441	Elementary Number Theory and Calculus – II	5	4
V	MM 1541	Real Analysis – I	5	4
	MM 1542	Complex Analysis – I	4	3
	MM 1543	Abstract Algebra – Group Theory	5	4
	MM 1544	Differential Equations	3	3
	MM 1545	Mathematics Software – LaTeX & SageMath (Practical Examination Only)	4	3
	MM 1551	Open Course	3	2
	——	Project preparation - From selecting the topic to presenting the final report	1	
VI	MM 1641	Real Analysis – II	5	4
	MM 1642	Complex Analysis – II	4	3
	MM 1643	Abstract Algebra – Ring Theory	4	3
	MM 1644	Linear Algebra	5	4
	MM 1645	Integral Transforms	4	3
	MM 1651	Elective Course	3	2
	MM 1646	Project		4

Structure of Open Courses

Sem	Course Code	Course title	Instr.hrs. per week	Credit
V	MM 1551.1	Operations Research	3	2
V	MM 1551.2	Business Mathematics	3	2
V	MM 1551.3	Basic Mathematics	3	2

Structure of Elective Courses

Sem	Course Code	Course title	Instr.hrs. per week	Credit
VI	MM 1661.1	Graph Theory	3	2
VI	MM 1661.2	Linear Programming with SageMath	3	2
VI	MM 1661.3	Numerical Analysis with SageMath	3	2
VI	MM 1661.4	Fuzzy Mathematics	3	2

Structure of the Complementary Courses

Complementary Course in Mathematics for First Degree Programme in Physics

Course Code	Sem.	Title of Course	Contact hrs/week	No. of Credits
MM 1131.1	1	Calculus with applications in Physics – I	4	3
MM 1231.1	2	Calculus with applications in Physics – II	4	3
MM 1331.1	3	Calculus and Linear Algebra	5	4
MM 1431.1	4	Complex Analysis, Special Functions and Probability Theory	5	4

Complementary Course in Mathematics for First Degree Programme in Chemistry

Course Code	Sem.	Title of Course	Contact hrs/week	No. of Credits
MM 1131.2	1	Calculus with applications in Chemistry – I	4	3
MM 1231.2	2	Calculus with applications in Chemistry – II	4	3
MM 1331.2	3	Linear Algebra, Probablity Theory & Numerical Methods	5	4
MM 1431.2	4	Differential Equations, Vector Calculus and Abstsract Algebra	5	4

Complementary Course in Mathematics for First Degree Programme in Geology

Course Code	Sem.	Title of Course	Contact hrs/week	No. of Credits
MM 1131.3	1	Algebra, Geometry and Trigonometry	4	3
MM 1231.3	2	Calculus and Linear Algebra	4	3
MM 1331.3	3	Complex Numbers, Algebra and Calculus	5	4
MM 1431.3	4	Basic Statistics and Differential Equations	5	4

Complementary Course in Mathematics for First Degree Programme in Statistics

Course Code	Sem.	Title of Course	Contact hrs/week	No. of Credits
MM 1131.4	1	Basic Calculus for Statistics	4	3
MM 1231.4	2	Advanced Differential and Integral Calculus	4	3
MM 1331.4	3	Fourier Series, Numerical Methods and ODE	5	4
MM 1431.4	4	Linear Algebra	5	4

Complementary Course in Mathematics for First Degree Programme in Economics

Course Code	Sem.	Title of Course	Contact hrs/week	No. of Credits
MM 1131.5	1	Mathematics for Economics I	3	2
MM 1231.5	2	Mathematics for Economics II	3	3
MM 1331.5	3	Mathematics for Economics III	3	3
MM 1431.5	4	Mathematics for Economics IV	3	3

Syllabus for the First Degree Programme in Mathematics of the University of Kerala

Semester I
Methods of Mathematics

CODE: MM 1141 — Instructional hours per week: 4
No.of credits: 4

In this paper, we quickly review the fundamental methods of solving problems viz. the limiting method, finding the rate of changes through differentiation method, and finding the area under a curve through the integration method.

Module I - Methods of Differential Calculus (36 Hours)
In the beginning of this module, the basic concepts of calculus like limit of functions especially infinite limits and limits at infinity, continuity of functions, basic differentiation, derivatives of standard functions, implicit differentiation etc. should be reviewed with examples.
The above topics which can be found in chapter 2 of text [1] **below are not to be included in the end semester examination.** A maximum of 5 hours should be devoted for the review of the above topics. After this quick review, the main topics to discuss in this module are the following:
Differentiating equations to relate rates, how derivatives can be used to approximate non-linear functions by linear functions, error in local linear approximation, differentials;

Increasing and decreasing functions and their analysis, concavity of functions, points of inflections of a function and applications, finding relative maxima and minima of functions and graphing them, critical points, first and second derivative tests, multiplicity of roots and its geometrical interpretation, rational functions and their asymptotes, tangents and cusps on graphs;

Absolute maximum and minimum, their behaviour on various types of intervals, applications of extrema problems in finite and infinite intervals, and in particular, applications to Economics;

Motion along a line, velocity and speed, acceleration, Position - time curve, Rolle's, Mean Value theorems and their consequences;

Indeterminate forms and L'Hôpital's rule;
The topics to be discussed in this module can be found in chapter 2,3 and 6 of text [1] *below.*

Module II - Methods of Integral Calculus (36 Hours)
The module should begin with revising integration techniques, like integration by substitution, fundamental theorem of calculus, integration by parts, integration by partial fractions, integration by substitition and the concept of definite integrals.

The above topics which can be found in chapter 4 and 7 of text [1] **below are not to be included in the end semester examination.** A maximum of 5 hours should be devoted for the review of the above topics.
After this quick review, the main topics to discuss in this module are the following:
Finding position, velocity, displacement, distance travelled of a particle by integration, analysing the distance-velocity curve, position and velocity when the acceleration is constant, analysing the free-fall motion of an object, finding average value of a function and its applications;

Area, volume, length related concepts : Finding area between two curves, finding volumes of some three dimensional solids by various methods like slicing, disks and washers, cylindrical shells, finding length of a plane curve, surface of revolution and its area;

Work done : Work done by a constant force and a variable force, relationship between work and energy;

Relation between density and mass of objects, center of gravity, Pappus theorem and related problems

Fluids, their density and pressure, fluid force on a vertical surface.

Introduction to Hyperbolic functions and their applications in hanging cables;

Improper integrals, their evaluation, applications such as finding arc length and area of surface.

The topics to be discussed in this module can be found in chapter 4, 5, 6 and 7 of text [1] *below.*

Text 1 – H Anton, I Bivens, S Davis. *Calculus*, 10th Edition, John Wiley& Sons

References

Ref. 1 – G B Thomas, R L Finney. *Calculus*, 9th Edition, Addison-Weseley Publishing Company

Ref. 2 – J Stewart. *Calculus with Early Transcendental Functions*, 7th Edition, Cengage India Private Limited

Semester II

Foundations of Mathematics

CODE: MM 1221 — Instructional hours per week: 4
No.of credits: 3

The rigorous study of mathematics begins with understanding the concepts of sets and functions. After that, one needs to understand the way in which a mathematician formally makes statements and proves or disproves it. We start this course with an introduction to these fundamental concepts. Apart from that, the basic of vector calculus is to be revised before moving to more advanced topics.

Module I - Foundations of Logic and Proof (36 Hours)
The following are the main topics in this module :
Statements, logical connectives, and truth tables, conditional statements and parts of it, tautology and contradiction, using various quantifiers like universal and existential quantifiers in statements, writing negations, determining truth value of statements;

Proof : Various techniques of proof like inductive reasoning, counter examples, deductive reasoning, hypothesis and conclusion, contrapositive statements, converse statements, contradictions, indirect proofs;

Sets and relations: A review of basic set operations like union, intersection, subset, superset concepts, equality of sets, complements, disjoint sets, indexed family of sets and operations on such families, ordered pairs, relations on sets, cartesian products (finite case only), various types of relations (reflexive, symmetric, transitive, equivalence), partitions of sets;

Functions: domain, codomain, range of functions, one-one, onto, bijective functions, image, preimage of functions, composing functions and the order of composition, inverse functions, cardinality of a set, equinumerous (equipotent) sets
The topics to be discussed in this module can be found in chapter 1 and 2 of text [1] *below.*

Module II - Foundations of co-ordinate geometry (18 Hours)
The following are the main topics in this module :
Parametric equations of a curve, orientation of a curve, expressing ordinary functions parametrically, tangent lines to parametric curves, arc length of parametric curves;

Polar co-ordinate systems, converting between polar and rectangular co-ordinate systems, graphs in the polar co-ordinate system, symmetry tests in the polar co-ordinate system, families of lines, rays, circles, other curves, spirals;

Tangent lines to polar curves, arc length of the curve, area, intersections of polar curves;

Conic sections : definitions and examples, equations at standard positions, sketching them, asymptotes of hyperbolas, translating conics, reflections of conics, applications,

rotation of axes and eliminating the cross product term from the equation of a conic, polar equations of conics, sketching them, applications in astronomy such as Kepler's laws, related problems
The topics to be discussed in this module can be found in chapter 10 of text [2] *below.*

Module III - Foundations of vector calculus (18 Hours)
To begin with, the three dimesional rectangular co-ordinate system should be discussed and how distance is to be calculated between points in this sytem. Basic operations on vectors like their addition, cross and dot products should be introduced next. The concept of projections of vectors and the relation with dot product should be given emphasize. Equations of lines determined by a point and vector, vector equations in lines, equatins of planes using vectors normal to be should be discussed. Quadric surfaces which are three dimensinal analogues of conics should be discussed next. Various co-ordinate systems like cylindrical, spherical should be discussed next with the methods for conversion between various co-ordinate systems.
The topics to be discussed in this module can be found in chapter 11 of text [2] *below.*

Texts

Text 1 – S R Lay. *Analysis with an Introduction to Proof*, 5th Edition, Pearson Education Limited

Text 2 – H Anton, I Bivens, S Davis. *Calculus*, 10th Edition, John Wiley & Sons

References

Ref. 1 – J P D'Angelo, D B West. *Mathematical Thinking - Problem Solving and Proofs*, 2nd Edition, Prentice Hall

Ref. 2 – Daniel J Velleman. *How to Prove it : A Structured Approach*, 2nd Edition, Cambridge University Press

Ref. 3 – Elena Nardi, Paola lannonne. *How to Prove it : A brief guide for teaching Proof to Year 1 mathematics undergraduates*, University of East Anglia, Centre for Applied Research in Education

Ref. 4 – G B Thomas, R L Finney. *Calculus*, 9th Edition, Addison-Weseley Publishing Company

Ref. 5 – J Stewart. *Calculus with Early Transcendental Functions*, 7th Edition, Cengage India Private Limited

Semester III

Elementary Number Theory and Calculus – I

CODE: MM 1341 | Instructional hours per week: 5
No.of credits: 4

Towards beginning the study on abstract algebraic structures, this course introduces the fundamental facts in elementary number theory. Apart from that, calculus of vector valued functions and multiple integrals is also discussed.

Module I - Divisibility in integers (18 Hours)
The topic of elementary number theory is introduced for further developing the ideas in abstract algebra. The following are the main topics in this module :
The division algorithm, Pigeonhole principle, divisibility relations, inclusion-exclusion principle, base-b representations of natural numbers, prime and composite numbers, infinitude of primes, GCD, linear combination of integers, pairwise relatively prime integers, the Euclidean algorithm for finding GCD, the fundamental theorem of arithmetic, canonical decomposition of an integer into prime factors, LCM;

Linear Diophantine Equations and existence of solutions, Eulers Method for solving LDE's
The topics to be discussed in this module can be found in chapter 2 and 3 of text [2] *below.*

Module II - Vector valued functions (30 Hours)
Towards going to the calculus of vector valued functions, we define such functions. The other topics in this module are the following :
Parametric curves in the three dimensional space, limits, continuity and derivatives of vector valued functions, geometric interpretation of the derivative, basic rules of differentiation of such functions, derivatives of vector products, integrating vector functions, length of an arc of a parametric curve, change of parameter, arc length parametrizations, various types of vectors that can be associated to a curve such as unit vectors, tangent vectors, binormal vectors, definition and various formulae for curvature, the geometrical interpretation of curvature, motion of a particle along a curve and geometrical interpretation of various vectors associated to it, various laws in astronomy like Kepler's laws and problems
The topics to be discussed in this module can be found in chapter 12 of text [1] *below.*

Module III - Multivariable Calculus (42 Hours)
After introducing the concept of functins of more than one variable, the sketching of them in three dimensinal cases with the help of level curves should be discussed. Countours and level surface plotting also should be discussed. The other topics in this module are the following:
Limits and continuity of Multivariable functions, various results related to finding the limits and establishing continuity, continuity at boundary points, partial derivatives of

functions, partial derivative as a function, its geometrical interpretation, implicit partial differentiation, changing the order of partial differentiation and the equality conditions;

Differentiability of a multivariate function, differentiability of such a function implies its continuity, local linear approximations, chain rules - various versions, directional derivative and differentiability, gradient and its properties, applications of gradients;

Tangent planes and normal vectors to level surfaces, finding tangent lines to intersections of surfaces, extrema of multivariate functions, techniques to find them, critical and saddle points, Lagrange multipliers to solve extremum problems with constrains,
The topics to be discussed in this module can be found in chapter 13 of text [1] *below.*

Texts

Text 1 – H Anton, I Bivens, S Davis. *Calculus*, 10th Edition, John Wiley & Sons

Text 2 – Thomas Koshy. *Elementary Number Theory with Applications*, 2nd Edition, Academic Press

References

Ref. 1 – G B Thomas, R L Finney. *Calculus*, 9th Edition, Addison-Weseley Publishing Company

Ref. 2 – J Stewart. *Calculus with Early Transcendental Functions*, 7th Edition, Cengage India Private Limited

Ref. 3 – G A Jones, J M Jones. *Elementary Number Theory*, Springer

Semester IV

Elementary Number Theory and Calculus – II

CODE: MM 1441 — Instructional hours per week: 5
No.of credits: 4

As in the previous semester, towards beginning the study on abstract algebraic structures, this course introduces the fundamental facts in elementary number theory. Apart from that, calculus of vector valued functions and multiple integrals is also discussed.

Module I - Congruence relations in integers (30 Hours)
Towards defining the congruence classes in $\mathbb{Z}$, we begin with defining the congruence relation. Its various properties should be discussed, and then the result that no prime of the form $4n + 3$ is a sum of two squares should be discussed. The other topics in this module are the following:
Defining congruence classes, complete set of residues, modulus exponentiation, finding reminder of big numbers using modular arithmetic, cancellation laws in modular arithmetic, linear congruences and existence of solutions, solving Mahavira's puzzle, modular inverses, Pollard Rho factoring method;

Certain tests for divisibility - The numbers here to test are powers of 2, 3, 5, 7, 9, 10, 11, testing whether a given number is a square;

Linear system of congruence equations, Chinese Remainder Theorem and some applications;

Some classical results like Wilson's theorem, Fermat's little theorem, Pollard $p - 1$ factoring method, Eulers' theorem,
The topics to be discussed in this module can be found in chapter 2 and 3 of text [2] *below.*

Module II - Multiple integrals (30 Hours)
Here we discuss double and triple integrals and their applications. The main topics in this module are the follwing:
Double integrals: Defining and evaluating double integrals, its properties, double integrals over non rectangular regions, determining limits of integration, revising the order of integration, area and double integral, double integral in polar coordinates and their evaluation, finding areas using polar double integrals, conversion between rectangular to polar integrals, finding surface area, surface of revolution in parametric form, vector valued function in two variables, finding surface area of parametric surfaces;

Triple integrals : Properties, evaluation over ordinary and special regions, determining the limits, volume as triple integral, modifying order of evaluation, triple integral in cylindrical co-ordinates, Converting the integral from one co-ordinate system to other;

Change of variable in integration (single, double, and triple), Jacobians in two variables.
The topics to be discussed in this module can be found in chapter 14 of text [1] *below.*

Module III - Vector Calculus (30 Hours)

After the differentiation of vector valued functions in the last semester, here we introduce the concept of integrating vector valued functions. Some important theorems are also to be discussed here. The main topics are the following :

Vector fields and their graphical representation, various type of vector fields (inverse-square, gradient, conservative), potential functions, divergence, curl, the $\bigtriangledown$ operator, Laplacian;

Integrating a function along a curve (line integrals), integrating a vector field along a curve, defining work done as a line integral, line integrals along piecewise-smooth curves, integration of vector fields and independence of path, fundamental theorem of line integrals, line integrals along closed paths, test for conservative vector fields, Green's theorem and applications;

Defining and evaluating surface integrals, their applications, orientation of surfaces, evaluating flux integrals, The divergence theorem, Gauss' Law, Stoke's theorem, applications of these theorems.

The topics to be discussed in this module can be found in chapter 15 of text [1] *below.*

Texts

Text 1 – H Anton, I Bivens, S Davis. *Calculus*, 10th Edition, John Wiley & Sons

Text 2 – Thomas Koshy. *Elementary Number Theory with Applications*, 2nd Edition, Academic Press

References

Ref. 1 – G B Thomas, R L Finney. *Calculus*, 9th Edition, Addison-Weseley Publishing Company

Ref. 2 – J Stewart. *Calculus with Early Transcendental Functions*, 7th Edition, Cengage India Private Limited

Ref. 3 – G A Jones, J M Jones. *Elementary Number Theory*, Springer

Semester V

Real Analysis – I

Code: MM 1541 — Instructional hours per week: 5
No.of credits: 4

In this course, we discuss the notion of real numbers, the ideas of sequence of real numbers and the concept of infinite summation in a formal manner. Many of the topics discussed in the first two modules of this course were introduced somewhat informally in earlier courses, but in this course, the emphasis is on mathematical rigor. A minimal introduction to the metric space structure of $\mathbb{R}$ is also included so as to serve as a stepping stone into the idea of abstract topological spaces. The course is mainly based on Chapters 1–3 of text [1].

All the chapters mentioned above contains a section titled *Discussions* in the beginning of the chapter. This section is intended only for motivating the students, and so should not be made as a part of the examination process.

Module I (25 Hours)

This module introduces the basic concepts about the real number system with some introduction to sets, functions, and proof techniques. The following are the main topics to be discussed: existence of an irrational number, the axiom of completeness, upper lower bounds of sets in $\mathbb{R}$, consequences of completeness like Archimedian property of real numbers, Density of $\mathbb{Q}$ in $\mathbb{R}$, existence of square roots, countability of $\mathbb{Q}$ and uncountability of $\mathbb{R}$, various cardinality results, Cantor's original proof for uncoubtability of $\mathbb{R}$, and Cantor's theorem on power sets.

The topics to be discussed in this module can be found in chapter 1 of text [1] *below. The first section 1.1 may be briefly discussed and is not meant for examination purposes.*

Module II (40 hours)

Students must have already encountered the idea of infinite series through the example of geometric progression. After discussing the rearrangement concept of infinite series, the following topics are to be introduced rigourously : Limit of a sequence, diverging sequences, examples, algebraic operations on limits, and order properties of sequences and limits, the Monotone Convergence Theorem, Cauchy's condensation test for convergence of a series, various other tests for the convergence series, the Bolzano-Weierstrass theorem, the Cauchy criterion for convergence of a sequence, rearrangement of absolutely convergent series.

The topics to be discussed in this module can be found in chapter 2 of text [1] *below. The first section 2.1 may be briefly discussed and is not meant for examination purposes.*

Module III (25 hours)

This module is intended to be a beginner for learning abstract metric spaces. To motivate the students, the Cantor set should be constructed and shown in the beginning. Then move to the topics open and closed sets in $\mathbb{R}$, and what about their complements, Compactness of sets (defined using sequential convergence), open covers and compactness, perfect and connected sets in $\mathbb{R}$, and finally the Baire's theorem.
The topics to be discussed in this module can be found in chapter 3 of text [1] *below. The first section 3.1 may be briefly discussed and is not meant for examination purposes.*

Texts

Text 1 – Stephen Abbot. *Understanding Analysis*, 2nd Edition, Springer

References

Ref. 1 – R G Bartle, D Sherbert. *Introduction to Real Analysis*, 3rd Edition, John Wiley & Sons

Ref. 2 – W. Rudin. *Principles of Mathematical Analysis*, Second Edition, McGraw-Hill

Ref. 3 – Terrence Tao. *Analysis I*, Hindustan Book Agency

Semester V

Complex Analysis – I

CODE: MM 1542 — Instructional hours per week: 4
No.of credits: 3

Here we go through the basic complex function theory.

Module I (27 Hours)
Complex numbers : The algebra of Complex Numbers, Point Representation of Complex Numbers, Vectors and Polar forms, The Complex Exponential, Powers and Roots, Planar Sets
Analytic Functions : Functions of a complex variable, Limits and Continuity, Analyticity, The Cauchy Riemann Equations, Harmonic Functions
The topics to be discussed in this module can be found in chapter 1, sections 1.1, 1.2, 1.3, 1.4, 1.5, 1.6 and chapter 2, sections 2.1, 2.2, 2.3, 2.4, 2.5 of text [1] *below.*

Module II (15 hours)
Elementary Functions : Polynomials and rational Functions (Proof of the theorem on partial fraction decomposition need not be discussed), The Exponential, Trigonometric and Hyperbolic Functions, The Logarithmic Function, Complex Powers and Inverse Trigonometric Functions.
The topics to be discussed in this module can be found in chapter 3, sections 3.1, 3.2, 3.3, 3.5 of text [1] *below.*

Module III (30)
Complex Integration : Contours, Contour Integrals, Independence of Path, Cauchy's Integral Theorem (Section 4.4a on deformation of Contours Approach is to be discussed, but section 4.4 b on Vector Analysis Approach need not be discussed), Cauchy's Integral Formula and Its Consequences, Bounds of Analytic Functions
The topics to be discussed in this module can be found in chapter 4, sections 4.1, 4.2, 4.3, 4.4a, 4.5 and 4.6 of text [1] *below.*

Texts

Text 1 – Edward B. Saff, Arthur David Snider. *Fundamentals of complex analysis with applications to engineering and science*, 3rd Edition, Pearson Education India

References

Ref. 1 – John H Mathews, Russel W Howell. *Complex Analysis for Mathematics and Engineering*, Jones and Bartlett Publishers

Ref. 2 – Erwin Kreyszig. *Advanced Engineering Mathematics*, 10th Edition, Wiley-India

Ref. 3 – James Brown, Ruel Churchill. *Complex Variables and Applications*, Eighth Edition, McGraw-Hill

Semester V

Abstract Algebra – Group Theory

CODE: MM 1543 | Instructional hours per week: 5
No.of credits: 4

The aim of this course is to provide a very strong foundation in the theory of groups. All the concepts appearing in the course are to be supported by numerous examples mainly from the references provided.

Module I (30 Hours)
The concept of group is to be introduced before rigorously defining it. The symmetries of a square can be a starting point for this. After that, definition of group should be stated and should be clarified with the help of examples. After discussing various properties of groups, finite groups and their examples should be discussed. The concept of subgroups with various characterizations also should be discussed. After introducing the definition of cyclic groups, various examples, and important features of cyclic groups and results on order of elements in such groups should be discussed.
The topics to be discussed in this module can be found in chapter 1, 2 3 and 4 of text [1] *below.*

Module II (24 Hours)
This module starts with defining and analysing various properties permutation groups which forms one of the most important class of examples for non abelian, finite groups. After defining operations on permutations, their properties are to be discussed. To motivate the students, the example of check-digit scheme should be discussed (This section on check-digit scheme is not meant for the examinations). Then we proceed to define the notion of equivalence of groups viz. isomorphisms. Several examples are to be discussed for explaining this notion. The properties of isomorphisms are also to be discussed together with special classes of isomorphisms like automorphisms and inner automorphisms before finishing the module with the classic result of Cayley on finite groups.
The topics to be discussed in this module can be found in chapter 5 and 6 of text [1] *below.*

Module III (18 Hours)
In this module we prove one of the most important results in group theory which is the Langrange's theorem on counting cosets of a finite group. The concept of cosets of a group should be defined giving many examples before proving the Lagrange's theorem. As some of the applications of this theorem, the connection between permutation groups and rotations of cube and soccer ball should be discussed. The section on Rubik's cube and section on internal direct products need not be discussed.
The topics to be discussed in this module can be found in chapter 7 and 9 of text [1] *below.*

Module IV (18 Hours)

Here the concept of group homomorphisms should be defined with sufficient number of examples. After proving the first isomorphism theorem, the fundamental theorem of isomorphism should be introduced and proved. Classifying groups based on the fundamental theorem should be discussed in detail.
The topics to be discussed in this module can be found in chapter 10 and 11 of text [1] *below.*

Texts

Text 1 – Joseph Gallian. *Contemporary Abstract Algebra*, 8th Edition, Cengage Learning

References

Ref. 1 – D S Dummit, R M Foote. *Abstract Algebra*, 3rd Edition, Wiley

Ref. 2 – I N Herstein. *Topics in Algebra*, Vikas Publications

Semester V

Differential Equations

Code: MM 1544 Instructional hours per week: 3
No.of credits: 3

In this course, we discuss how differential equations arise in various physical problems and consider some methods to solve first order differential equations and second order linear equations. For introducing the concepts, text [1] may be used, and for strengthening the theoretical aspects, reference [1] may be used.

Module I - First order ODE (18 hours)
In this module we discuss first order equations and various methods to solve them. Sufficient number of exercises also should be done for understanding the concepts thoroughly. The main topics in this module are the following:
Modelling a problem, basic concept of a differential equation, its solution, initial value problems, geometric meaning (direction fields), seperable ODE, reduction to seperable form, exact ODEs and integrating factors, reducing to exact form, homogeneous and non homogeneous linear ODEs, special equations like Bernoulli equation, orthogonal trajectories, understanding the existence and uniqueness of solutions theorem.
The topics to be discussed in this module can be found in chapter 1 of text [1] *below.*

Module II - Second order ODE (18 hours)
As in the first module, we discuss second order equations and various methods to solve them. Sufficient number of exercises also should be done for understanding the concepts thoroughly. The main topics in this module are the following:
homogeneous linear ODE of second order, initial value problem, basis, and general solutions, finding a basis when one solution is known, homogeneous linear ODE with constant coefficients (various cases that arise depending on the characteristic equation), differential operators, Euler-Cauchy Equations, existence and uniqueness of solutions w.r. to wronskian, solving nonhomogeneous ODE via the method of undetermined coefficients, varius applications of techniques, solution by variation of parameters.
The topics to be discussed in this module can be found in chapter 2 of text [1] *below.*

Texts

Text 1 – Erwin Kreyszig. *Advanced Engineering Mathematics*, 10th Edition, Wiley-India

References

Ref. 1 – G. F. Simmons. *Differential Equations with applications and Historical notes*, Tata McGraw-Hill, 2003

Ref. 2 – H Anton, I Bivens, S Davis. *Calculus*, 10th Edition, John Wiley & Sons

Ref. 3 – Peter V. O' Neil. *Advanced Engineering Mathematics*, Thompson Publications, 2007

Semester V

Mathematics Software – LaTeX & SageMath

Code: MM 1545 Instructional hours per week: 4
No.of credits: 3

Here we introduce two software which are commonly used by people working in Mathematics – a science typesetting software LaTeX, and a mathematical computation and visualization software SageMath. The aim of introducing LaTeX software is to enable students to typeset the project report which is a compulsory requirement for finishing their undergraduate mathematics programme succesfully. The aim of learning SageMath is to enable students to see how the computational techniques they have learned in the previous semesters can be put into action with the help of software so as to reduce human effort. Also, they should be able to use this software for further computations in their own in the forthcoming semester.

Module I - LaTeX for prearing a project report in Mathematics (36 Hours)

Graphical User Interface (GUI)/ Edtitor like Kile or TeXstudio should be used for providing training to the students. The main topics in this module are following:

Typesetting a simple article and compiling it;

How spaces are treated in the document;

Document layout : various options to be included in the `documentclass` command, page styles, splitting files into smaller files, breaking line and page, using boxes (like, `mbox`) to keep text unbroken across lines, dividing document in to parts like frontmatter, mainmatter, backmatter, chapters, sections, etc, cross referencing with and without page number, adding footnotes;

Emphasizing words with `\emph, \texttt, \textsl, \textit,  \underline` etc.

Basic environments like `enumerate, itemize, description, flushleft, flusuright, center, quote, quotation`

Controlling enumeration via the `enumerate` package.

Tables : preparing a table and floating it, the longtable environment;

Typesetting mathematics : basic symbols, equations, operators, the `equation` environment and reference to it, the `displaymath` environment, exponents, arrows, basic functions, limits, fractions, spacing in the mathematics environments, matrices, aligning various objects, multi-equation environments, suppressing numbering for one or more equations, handling long equations, phantoms, using normal text in math mode, controlling font size, typesetting theorems, defintions, lemmas, etc, making text bold in math mode, inserting symbols and environments (`array, pmatrix` etc) using the support of GUIs;

Figures : Including JPG, PNG graphics with `graphicx` package, controlling width, height etc, floating figures, adding captions, the wrapfig package;

Adding references/bibliogrpahy and citing them, using the package `hyperref` to add and control hypertext links, creating presentations with `pdfscreen`, creating new commands;

Fonts : changing font size, various fonts, math fonts,

Spacing : changing line spacing, controlling horizontal, vertical spacing, controlling the margins using the geometry package, fullpage package

Preparing a dummy project with `titlepage`, acknowledgement, certificates, table of contents (using `\tableofcontents`), list of tables, table of figures, chapters, sections, bibliography (using the `thebibliography` environment). This dummy project should contain atleast one example from the each of the topic in the syllabus, and should be submitted for internal evaluation before the end semester practical examination.

Module II - Doing Mathematics with SageMath (36 hours)

Starting SageMath using a browser, how to use the sage cell server `https://sagecell.sagemath.org/`, how to use SageMathCloud, creating and saving a sage worksheet, saving the worksheet to an .sws file, moving it and re-opening it in another computer system;

Using sagemath as a calculator, basic functions (square root, logarithm, numeric value, exponential, trigonometric, conversion between degrees and radians, etc.);

Plotting : simple plots of known functions, controlling range of plots, controlling axes, labels, gridlines, drawing multiple plots on a single picture, *adding* plots, polar plotting, plotting implicit functions, contour plots, level sets, parametric 2D plotting, vector fields plotting, gradients;

Matrix Algebra : Adding, multiplying two matrices, row reduced echelon forms to solve linear system of equations, finding inverses of square matrices, determinants, exponentiation of matrices, computing the kernel of a matrix;

Defining own functions and using it, composing functions, multi variate functions;

Polynomials : Defining polynomials, operations on them like multiplication and division, expanding a product, factorizing a polynomial, finding gcd;

Solving single variable equations, declaring multiple variables, solving multi variable equations, solving system of non linear equations, finding the numerical value of roots of equations;

complex number arithmetic, finding complex roots of equations;

Finding derivatives of functions, higher order derivatives, integrating functions, definite and indefinite integrals, numerical integration, partial fractions and integration,

Combinatorcs & Number theory: Permutations, combinations, finding gcd, lcm, prime factorization, prime counting function, n^{th} prime funcion, divisors of a number, counting divisors, modular arithmetic;

Vector calculus : Defining vectors, operations like sum, dot product, cross product, vector valued functions, divergence, curl, multiple integrals;

Computing Taylor, McClaurins polynomials, minimization and Lagrange multipliers, constrained and unconstrained optimization;

Internal Evaluation : A dummy project report prepared in LaTeX should be submitted as assignment for internal evaluation for 5 marks. Another practical record should be submitted the content of which should be problems and their outputs evaluated using SageMath. This record should be awarded a maximum of 10 marks which is earmarked for the internal evaluation examination.

Problems to be included in the examination:

1. Find all local extrema and inflection points of a function
2. Traffic flow optimization
3. Minimum surface area of packaging
4. Newton's method for finding approximate roots
5. Plotting and finding area between curves using integrals
6. Finding the average of a function
7. Finding volume of solid of revolution
8. Finding solution for a system of linear equations
9. Finding divergence and curl of vector valued functions
10. Using differential calculus to analyze a quintic polynomials features, for finding the optimal graphing window
11. Using Pollard's $p - 1$ Method of factoring integers, to try to break the RSA cryptosystem
12. Expressing gcd of two integers as a combination of the integers (Bezout's identity)

References

Ref. 1 – Tobias Oetiker, Hubert Partl, Irene Hyna and Elisabeth Schlegl. *The (Not So) Short Introduction to LaTeX2e*, Samurai Media Limited (or available online at `http://mirrors.ctan.org/info/lshort/english/lshort.pdf`)

Ref. 2 – Leslie Lamport. *LaTeX: A Document Preparation System*, Addison-Wesley, Reading, Massachusetts, second edition, 1994

Ref. 3 – *LaTeX Tutorials—A Primer*, Indian TeX Users Group, available online at `https://www.tug.org/twg/mactex/tutorials/ltxprimer-1.0.pdf`

Ref. 4 – H. J. Greenberg. *A Simplified introduction to LaTeX*, available online at `https://www.ctan.org/tex-archive/info/simplified-latex/`

Ref. 5 – *Using Kile - KDE Documentation*, `https://docs.kde.org/trunk4/en/extragear-office/kile/quick_using.html`

Ref. 6 – *TeXstudio : user manual*, `http://texstudio.sourceforge.net/manual/current/usermanual_en.html`

Ref. 7 – *The longtable package - TeXdoc.net*, `http://texdoc.net/texmf-dist/doc/latex/tools/longtable.pdf`

Ref. 8 – *wrapfig - TeXdoc.net*, `http://texdoc.net/texmf-dist/doc/latex/wrapfig/wrapfig-doc.pdf`

Ref. 9 – *The geometry package*, `http://texdoc.net/texmf-dist/doc/latex/geometry/geometry.pdf`

Ref. 10 – *The fullpage package*, http://texdoc.net/texmf-dist/doc/latex/preprint/fullpage.pdf

Ref. 11 – *The SageMathCloud*, https://cloud.sagemath.com/

Ref. 12 – Gregory V. Bard. *Sage for Undergraduates*, American Mathematical Society, available online at http://www.gregorybard.com/Sage.html

Ref. 13 – Tuan A. Le and Hieu D. Nguyen. *SageMath Advice For Calculus* available online at http://users.rowan.edu/~nguyen/sage/SageMathAdviceforCalculus.pdf

Semester V

Operations Research (Open Course)

CODE: MM 1551.1 | Instructional hours per week: 3
No. of Credits: 2

Module I – Linear Programming (18 hours)
Formulation of Linear Programming models, Graphical solution of Linear Programs in two variables, Linear Programs in standard form - basic variable - basic solution- basic feasible solution -feasible solution, Solution of a Linear Programming problem using simplex method (Since Big-M method is not included in the syllabus, avoid questions in simplex method with constraints of $\geq$ or $=$ type.)

Module II – Transportation Problems (18 hours)
Linear programming formulation - Initial basic feasible solution (Vogel'sapproximation method/North-west corner rule) - degeneracy in basic feasible solution - Modified distribution method - optimalitytest.

ASSIGNMENT PROBLEMS: Standard assignment problems - Hungarian method for solving an assignment problem.

Module III – Project Management (18 hours)
Activity -dummy activity - event - project network, CPM (solution by network analysis only), PERT.

The topics to be discussed in this course can be found in text [1].

Texts

Text 1 – Ravindran, Philps, Solberg. *Operations Research- Principles and Practice*, 2nd Edition, Wiley India Pvt Ltd

References

Ref. 1 – Hamdy A. Taha. *Operations Research : An Introduction*, 9th Edition, Pearson

Semester V

Business Mathematics (Open Course)

CODE: MM 1551.2 — Instructional hours per week: 3
No. of Credits: 2

Module I – Basic Mathematics of Finance (18 hours)
Nominal rate of Interest and effective rate of interest, Continuous Compounding, force of interest, compound interest calculations at varying rate of interest, present value, interest and discount, Nominal rate of discount, effective rate of discount, force of discount, Depreciation.
(Chapter 8 of Unit I of text [1] - Sections: 8.1, 8.2, 8.3, 8.4. 8.5, 8.6, 8.7, 8.9)

Module II – Differentiation and their applications to Business and Economics (18 hours)
Meaning of derivatives, rules of differentiation, standard results (basics only for doing problems of chapter 5 of Unit 1)
(Chapter 4 of unit I of text [1] - Sections: 4.3, 4.4, 4.5, 4.6)
Maxima and Minima, concavity, convexity and points of inflection, elasticity of demand, Price elasticity of demand
(Chapter 5 of Unit I of text [1] - Sections: 5.1, 5.2, 5.3, 5.4, 5.5. 5.6, 5.7)
Integration and their applications to Business and Economics: Meaning, rules of integration, standard results, Integration by parts, definite integration (basics only for doing problems of chapter 7 of Unit 1 of text)
(Chapter 6 of unit I of text [1] - Sections: 6.1, 6.2, 6.4, 6.10, 6.11)
Marginal cost, marginal revenue, Consumer's surplus, producer's surplus, consumer's surplus under pure competition, consumer's surplus under monopoly
(Chapter 7 of unit I of text [1] - Sections: 7.1, 7.2, 7.3, 7.4, 7.5)

Module III – Index Numbers (18 hours)
Definition, types of index numbers, methods of construction of price index numbers, Laspeyer's price index number, Paasche's price index number, Fisher ideal index number, advantages of index numbers, limitations of index numbers
(Chapter 6 of Unit II of text [1] - Sections: 6.1, 6.3, 6.4, 6.5, 6.6, 6.8, 6.16, 6.17)
Time series: Definition, Components of time series, Measurement of Trend
(Chapter 7 of Unit II of text [1] - Sections: 7.1, 7.2, 7.4)

Texts

Text 1 – B M Agarwal. *Business Mathematics and Statistics*, Vikas Publishing House, New Delhi, 2009

References

Ref. 1 – Qazi Zameeruddin, et al . *Business Mathematics*, Vikas Publishing House, New Delhi, 2009

Ref. 2 – Alpha C Chicny, Kevin Wainwright. *Fundamental methods of Mathematical Economics*, 4th Edition, Mc-Graw Hill

Semester V

Basic Mathematics (Open Course)

CODE: MM 1551.3 | Instructional hours per week: 3
No. of Credits: 2

This course is specifically designed for those students who might have not undergone a mathematics course beyond their secondary school curriculum. The structure of the course is so as to give an exposure to the basic mathematics tools which found a use in day today life, say in the fields general finance and basic sciences.

Module I : Basic arithmetic of whole numbers, fractions and decimals (24 hours)

Place Value of numbers, standard Notation and Expanded Notation, Operations on whole numbers : exponentiation, square roots, order of operations, computing averages, rounding, estimation, applications of estimation, estimating product of numbers by rounding, exponents, square roots, order of operations, computing averages;

Fractions: multiplication and division of fractions, applications, primes and composites, factorization, simplifying fractions to lowest terms, multiplication of fractions, reciprocal of fractions, division of fractions, operations of mixed fractions, LCM,

Decimal notation and rounding of numbers, fractions to decimals, multiplication of decimals, division of decimals, order of operations involving decimals,

Scientific notation of numbers, operations in scientific notations, square and cube roots of numbers, laws of exponents and logarithms
The topics to be discussed in this module can be found in chapters 1–3 of text [1] *and chapters 1 and 2 of* text [2] *below.*

Module II - Ratios, proportions, percents and the relation among them (15 hours)

Ratio and proportions : Simplifying ratios to lowest terms, ratios of mixed numbers, unit rates and cost, ratios and proportion, similar figures;

Percents: Fractions - decimals - percents, converting between these three relation with proportions, equations involving percents, increase and decrease in percent, finding simple and compound interests
The topics to be discussed in this module can be found in chapters 4, 5 of text [1] *below.*

Module III – Basic Statistics, Simple Equations (15 hours)

Basic Statistics : Data and tables, various graphs like bar graphs, pictographs, line graphs, frequency distributions and histograms, circle graphs (pie charts), interpreting them, circle graphs and percents, mean, median, mode, weighted mean

Solving simple equations, quadratic equations (real roots only), cubic equations, arithmetic geometric series, systems of two and three equations, matrices and system of equations

The topics to be discussed in this module can be found in chapters 9 of text [1] *and chapters 2, 3 of* text [2] *below.*

Texts

Text 1 – J Miller, M O'Neil, N Hyde. *Basic College Mathematics*, 2nd Edition, McGraw Hill Higher Education

Text 2 – Steven T Karris. *Mathematics for Business, Science and Technology*, 2nd Edition, Orchard Publications

References

Ref. 1 – Charles P McKeague. *Basic Mathematics*, 7th Edition, Cengage Learning

Semester V

Project preparation - From selecting the topic to presenting the final report

Instructional hours per week: 1

To complete the undergraduate programme, the students should undertake a project and prepare and submit a project report on a topic of their choice in the subject mathematics or allied subjects. The work on the project should start in the beginning of the 5th semester itself, and should end towards the middle of the 6th semester. This course (without any examination in the 5th semester, with a project report submissin and project viva in the 6th semester) is introduced for making the students understand various concepts behind undertaking such a project and preparing the final report. Towards the end of this course the students should be able to choose and prepare topics in their own and they should understand the layout of a project report.

To quickly get into the business, the first chapter of text [1] may be completely discussed. Apart from that, for detailed information, the other chapters in this book may be used in association with the other references given below. The main topics to discuss in this course are the following:

Quick overview : The structure of Dissertation, creating a plan for the Dissertation, planning the results section, planning the introduction, planning and writing the abstract, composing the title, figures, tables, and appendices, references, making good presentations, handling resources like notebooks, library, computers etc., preparing an interim report.

Topics in detail : Planning and Writing the Introduction, Planning and Writing the Results, Figures and Tables, Planning and Writing the Discussion, Planning and Writing the References, Deciding On a Title and Planning and Writing the Other Bits, Proofreading, Printing, Binding and Submission, oral examinations, preparing for viva, Taking the Dissertation to the Viva

Layout : Fonts and Line Spacing, Margins, Headers, and Footers, Alignment of Text, Titles and Headings, Separating Sections and Chapters

Texts

Text 1 – Daniel Holtom, Elizabeth Fisher. *Enjoy Writing Your Science Thesis or Dissertation – A step by step guide to planning and writing dissertations and theses for undergraduate and graduate science students*, Imperial College Press

References

Ref. 1 – Kathleen McMillan, Jonathan Weyers. *How to write Dissertations & Project Reports*, Pearson Education Limited

Ref. 2 – Peg Boyle Single. *Demystifying dissertation writing : a streamlined process from choice of topic to final text*, Stylus Publishing, Virginia

Semester VI

Real Analysis – II

Code: MM 1641 Instructional hours per week: 5
No.of credits: 4

In the second part of the Real Analysis course, we focus on functions on $\mathbb{R}$, their continuity, existence of derivatives, and integrability. The course is mainly based on Chapters 4,5 and 7 of text [1].

All the chapters mentioned above contains a section titled *Discussions* in the beginning of the chapter. These sections are intended only for motivating the students, and so should not be made a part of the examination process.

Module I (35 Hours)

Here we move towards the basic notion of limits of functions and their continuity. Various version of definition of limits are to be discussed here. The algebra of limits of functions and the divergence criterion for functional limits are to be discussed next. The other topics to be discussed in this module are the discontinuity criterion, composition of functions and continuity, continuity and compct sets, results on uniform continuity, the intermediate value theorem, Monotone functions and their continuity.

The topics to be discussed in this module can be found in chapter 4 of text [1] *below. The first section 4.1 may be briefly discussed and is not meant for examination purposes.*

Module II (25 hours)

Here we discuss the derivative concept more rigorously than what was done in the previous calculus courses. After (re)introducing the definition of differentiability of functions, we verify that differentiability implies continuity. Algebra and composing of differentiable functions should be discussed next. The interior extremum theorem and Darboux's theorem should be discussed after that. The mean value theorems should be discussed and proved, and the module ends with L'Hospitals results. A continuous everywhere but notwhere differentiable function should be discussed, but it is not meant for the examination. It may be infact used for student seminars.

The topics to be discussed in this module can be found in chapter 5 of text [1] *below. The sections 5.1 and 5.4 may be briefly discussed and is not meant for examination purposes.*

Module III (30 hours)

In the last module, the theory of Riemann integration is to be discussed. Main topics to be included in this module are defining the Riemann integral using upper, lower Riemann sums, and the integrability criterion, continuity and the existence of integral, algebraic operations on integrable functions, (The results and examples on convergence of sequence of functions and integrability may be omitted), the fundamental theorem of calculus and its proof, Lebesgue's criterion for Riemann integrability.

The topics to be discussed in this module can be found in chapter 7 of text [1] *below. The first section 7.1 may be briefly discussed and is not meant for examination purposes.*

Texts

Text 1 – Stephen Abbot; *Understanding Analysis*, 2nd Edition, Springer

References

Ref. 1 – R G Bartle, D Sherbert ; *Introduction to real analysis*, 3rd Edition, John Wiley & Sons

Ref. 2 – W. Rudin, *Principles of Mathematical Analysis*, Second Edition, McGraw-Hill

Ref. 3 – Terrence Tao; *Analysis I*, Hindustan Book Agency

Semester VI

Complex Analysis – II

CODE: MM 1642 | Instructional hours per week: 4
No.of credits: 3

Module I (32 Hours)
Series Representations for Analytic Functions : Sequences and Series, Taylor Series, Power Series, Mathematical Theory of Convergence, Laurent series, Zeros and Singularities, The point at Infinity. *The topics to be discussed in this module can be found in chapter 5, sections 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7 of* text [1] *below.*

Module II (20 Hours)
Residue Theory : The Residue Theorem, Trigonometric Integrals over $[0, 2\pi]$, Improper integrals of Certain functions over $[-\infty, \infty]$, Improper integrals involving Trigonometric Functions, Indented Contours
The topics to be discussed in this module can be found in chapter 6, sections 6.1, 6.2, 6.3, 6.4, 6.5 of text [1] *below.*

Module III (20 Hours)
Conformal Mapping : Geometric Considerations, Mobius Transformations
The topics to be discussed in this module can be found in chapter 7, sections 7.2, 7.3, 7.4 of text [1] *below.*

Texts

Text 1 – Edward B. Saff, Arthur David Snider. *Fundamentals of complex analysis with applications to engineering and science*, 3rd Edition, Pearson Education India

References

Ref. 1 – John H Mathews, Russel W Howell. *Complex Analysis for Mathematics and Engineering*, 6th Edition, Jones and Bartlett Publishers

Ref. 2 – Murray R Spiegel. *Complex variables: with an introduction to conformal mapping and its applications*, Schaum's outline.

Ref. 3 – Erwin Kreyszig. *Advanced Engineering Mathematics*, 10th Edition, Wiley-India

Ref. 4 – James Brown, Ruel Churchill. *Complex Variables and Applications*, Eighth Edition, McGraw-Hill

Semester VI

Abstract Algebra – Ring Theory

CODE: MM 1643 | Instructional hours per week: 4
No.of credits: 3

After discussing the theory of groups thoroughly in the previous semester, we move towards the next higher algebraic structure rings. As in the last semester, all the new concepts appearing in the course is to be supported by numerous examples mainly from the references provided.

Module I (24 Hours)
The concept of rings, subrings with many examples should be discussed here. Next comes the definition and properties of integral domains, fields, and the characteristic of rings. Ideals, how factor rings are defined using ideals, should be explained next. The definition of prime and maximal ideals with examples should be discused after that.
The topics to be discussed in this module can be found in chapter 12, 13 and 14 of text [1] *below.*

Module II (24 Hours)
After introducing the definition of ring homomorphisms, their properties should be discussed. The field of quotients of an integral domain should be discussed next. The next topic is the definition and various properties of polynomial rings over a commutative ring. Various results on operations on polynomials such as division algorithm, factor theorem, remainder theorem etc should be discussed next. The definition and examples of PID's should be discussed next, before moving to the factorization of polynomials. Tests of irreducibility and reducibility and the unique factorization of polynomials over special rings should be discused. .
The topics to be discussed in this module can be found in chapter 15, 16 and 17 of text [1] *below.*

Module III (24 Hours)
In the last module, we introduce more rigorous topics like various type of integral domains. The divisibility properties of integral domains and definition of primes in a general ring should be introduced. Unique factorization domains and the Euclidean domains should be discussed next with examples. Results on these special integral domains are aslo to be discussed.
The topics to be discussed in this module can be found in chapter 18 of text [1] *below.*

Texts

Text 1 – Joseph Gallian; *Contemporary Abstract Algebra*, 8th Edition, Cengage Learning

References

Ref. 1 – D S Dummit, R M Foote; *Abstract Algebra*, 3rd Edition, Wiley

Ref. 2 – I N Herstein, *Topics in Algebra*, Vikas Publications

Semester VI

Linear Algebra

Code: MM 1644 Instructional hours per week: 5
No.of credits: 4

The main focus of this course is to introduce linear algebra and methods in it for solving practical problems.

Module I (15 Hours)
This module deals with a study on linear equations and their geometry. After introducing the geometrical intrepretation of linear equations, following topics should be discussed: various operations on column vectors, technique of Gaussian elimination, operations involving elementary matrices, interchanging of rows using elementary matrices, triangular factorisation of matrices and finding inverse of matrices by the elimination method.
The topics to be discussed in this module can be found in chapter 1 of text [1] *below. The section 1.7 may be omitted.*

Module II (25 hours)
Towards the study of vector spaces, specifically $\mathbb{R}^n$, we define them with many examples. Subspaces are to be defined next. After discussing the idea of nullspace of a matrix. The solving linear equations (which was one to some extent in the first module) and finding solutions to non-homogeneous systems from the corresponding homogeneous systems. After this, linear independence and dependence of vectors, their spanning, basis for a space, its dimension concepts are to be introduced. The column, row, null, left null spaces of a matrix is to be discussed next. When inverses of a matrix exists related to its column/row rank should be discussed. Towards the end of this module, linear transformations (through matrices) and their properties are to be discussed. Types of transformations like rotations, projections, reflections are to be considered next.
The topics to be discussed in this module can be found in chapter 2 of text [1] *below. The section 2.7 on graphs and networks may be omitted.*

Module III (25 hours)
This module is intended for making the idea and concepts of determinants stronger. Its properties like what happens when rows are interchanged, linearlity of expansion along the first row, etc are to be discussed. Breaking a matrix into triangular, diagonal forms and finding the determinants, expansion in cofactors, their applications like solving system of equations, finding volume etc are to be discussed next.
The topics to be discussed in this module can be found in chapter 4 of text [1] *below.*

Module IV (25 hours)
Here we conclude our analysis of matrices. The problem of finding eigen values a matrix is to be introduced first. Next goal is to diagonalize a matrix. This concept should be

discussed first, and move to the discussion on the use of eigen vectors in diagonalization. Applications of finding the powers of matrices should be discussed next. The applications like the concept of Markov Matrices, Positive Matrices and their applications in Economics should be discussed. Complex matrices and operations on them are to be introduced next. The concept orthoganality of vectors may be required here from one of the previous sections in text [1] and it should be briefly introduced and discussed here. The module ends with similar matrices, and similarity transformation related ideas. How to diagonalize some special matrices like symmetric and Hermitial matrices are also to be discussed in this module.
The topics to be discussed in this module can be found in chapter 5 of text [1] *below. The section 5.4 on applications to differential equations may be omitted*

Texts

Text 1 – Gilbert Strang, *Linear Algebra and Its Applications*, 4th Edition, Cengage Learning

References

Ref. 1 – *Video lectures of Gilber Strang Hosted by MITOpenCourseware* available at `https://ocw.mit.edu/courses/mathematics/18-06-linear-algebra-spring-2010/video-lectures/`

Ref. 2 – Thomas Banchoff, John Wermer; *Linear Algebra Through Geometry*, 2nd Edition, Springer

Ref. 3 – T S Blyth, E F Robertson: *Linear Algebra*, Springer, Second Edition.

Ref. 4 – David C Lay: *Linear Algebra*, Pearson

Ref. 5 – K Hoffman and R Kunze: *Linear Algebra*, PHI

Semester VI

Integral Transforms

CODE: MM 1645 — Instructional hours per week: 4
No.of credits: 3

After completing courses in ordinary differential equations and basic integral calculus, we see here some of its applications.

Module I (38 Hours)
Laplace Transforms : Laplace Transform. Linearity. First Shifting Theorem (s-Shifting), $s-$ Shifting: Replacing s by $s-a$ in the Transform, Existence and Uniqueness of Laplace Transforms, Transforms of Derivatives and Integrals. ODEs, Laplace Transform of the Integral of a Function, Differential Equations, Initial Value Problems, Unit Step Function (Heaviside Function), Second Shifting Theorem ($t-$Shifting) Time Shifting ($t-$Shifting): Replacing t by $t-a$ in $f(t)$, Short Impulses. Diracs Delta Function. Partial Fractions Convolution , Application to Nonhomogeneous Linear ODEs, Differentiation and Integration of Transforms, ODEs with Variable Coefficients, Integration of Transforms, Special Linear ODEs with Variable Coefficients, Systems of ODEs
The topics to be discussed in this module can be found in sections 6.1, 6.2, 6.3, 6.4, 6.5, 6.6, 6.7 of text [1] below.

Module II (34 hours)
Fourier Series, Basic Examples, Derivation of the Euler Formulas, Convergence and Sum of a Fourier Series, Arbitrary Period. Even and Odd Functions. Half-Range Expansions From Period 2π to any Period $P = 2L$, Simplifications: Even and Odd Functions, Half-Range Expansions, Fourier Integral, From Fourier Series to Fourier Integral, Applications of Fourier Integrals, Fourier Cosine Integral and Fourier Sine Integral, Fourier Cosine and Sine Transforms, Linearity, Transforms of Derivatives, Fourier Transform, Complex Form of the Fourier Integral, Fourier Transform and Its Inverse, Linearity. Fourier Transform of Derivatives, Convolution.
The topics to be discussed in this module can be found in Sections 11.1, 11.2, 11.7, 11.8, 11.9 (Excluding Physical Interpretation: Spectrum and Discrete Fourier Transform (DFT),Fast Fourier Transform (FFT)) of text [1] below.

Texts

Text 1 – Erwin Kreyszig. *Advanced Engineering Mathematics*, 10th Edition, Wiley-India

References

Ref. 1 – Peter V. O' Neil, *Advanced Engineering Mathematics*, Thompson Publications, 2007

Ref. 2 – M Greenberg, *Advanced Engineering Mathematics*, 2nd Edition, Prentice Hall

Semester VI

Graph Theory (Elective)

CODE: MM 1661.1 — Instructional hours per week: 3
No. of credits: 2

Overview of the Course: The course has been designed to build an awareness of some of the fundamental concepts in Graph Theory and to develop better understanding of the subject so as to use these ideas skillfully in solving real world problems.

Module I (27 Hours)
Basics : The Definition of a Graph, Graphs as Mathematical Models, other basic concepts and definitions, Vertex Degrees, Subgraphs, Paths and Cycles, The Matrix Representation of Graphs, Fusing graphs (The fusion algorithm for connectedness need not be discussed).

Trees and Connectivity : Definitions and Simple Properties of trees, Bridges, Spanning Trees, Cut Vertices and Connectivity *The topics in this module can be found in Chapter 1, Sections 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7 and 1.8, Chapter 2, Sections 2.1, 2.2, 2.3 and 2.6 of* text [1].

Module II (27 Hours)
Euler Tours and Hamiltonian Cycles : Euler Tours (Fleury's algorithm need not be discussed), The Chinese Postman Problem (Only Statement of the problem is to be discussed) , Hamiltonian Graphs, The Travelling Salesman Problem (Only Statement of the problem is to be discussed, The Two-Optimal Algorithm and The Closest Insertion Algorithm need not be discussed)

Planar Graphs : Plane and Planar Graphs, Euler's Formula, The Platonic Bodies, Kuratowski's Theorem (Without proof).

The topics in this module can be found in Chapter 3, Sections 3.1, 3.2, 3.3 and 3.4, Chapter 5, Sections 5.1, 5.2, 5.3 and 5.4 of text [1].

Texts

Text 1 – John Clark, Derek Allan Holton. *A first look at Graph Theory*, World Scientific

References

Ref. 1 – R Balakrishnan, Ranganatahan. *A Text Book of Graph Theory*, 2nd Edition, Springer

Ref. 2 – V Balakrishnan. *Graph Theory*, Schaums Outline

Ref. 3 – J A Body, U S R Murthy. *Graph Theory with Applications*, The Macmillan Press

Ref. 4 – Robin J Wilson. *Introduction to Graph Theory* 5th edition, Prentice Hall

Semester VI

Linear Programming with SageMath (Elective)

CODE: MM 1661.2 — Instructional hours per week: 3
No. of credits: 2

This course is aimed at providing an introduction to linear programming and solving problems in it using very basic methods.

Note :

1. There should not be any problems to solve using the SageMath software in the End Semester Examination (ESE). The ESE should be based only on the theory and problems to be solved either manually or using a non programmable scientific calculator.
2. Students may be permitted to use non programmable scientific calculator in the end semester examination.
3. One of the internal evaluation examinations should be done using SageMath Software, as a practical examination.

Module I (18 Hours)
This module is aimed at providing a strong introduction to various type of problems that can be solved via linear programming. Main topics in this module are the following:
Introduction to linear programming through problems, basic underlying assumptions like Proportionality, Divisibility, Additivity, Certainty, more general problems, standard form of a linear program, conversion rules to arrive at such a form like Converting unrestricted variables, Converting inequality constraints, Converting maximization to minimization, their examples, standard linear programming terminology, examples on planning, transportation, assignment, workforce scheduling, portfolio optimization, Minimum Cost Flow Problem, Maximum Flow Problem.
The topics to be discussed in this module can be found in chapter 1 of text [1] *below.*

Module II (18 hours)
This module begins with the geometry of linear programming and later proceeds to the Fundamental Theorem of Linear Programming which is a basis for algorithm development for linear programs. The main topics in this module are the following:
Geometry of the Feasible Set, graphically representing the solution space, hyperplane, polyhedron, polytope, convex sets, geometry of optimal solutions, geometric characterisaion of optimality, extreme points and basic feasible solutions, generating basic feasible solutions, resolution theorem, fundamental theorem linear programming.
The topics to be discussed in this module can be found in chapter 2 of text [1] *below.*

Module III (18 hours)

Here we introduce the simplex method, which is an important method to solve linear programming problems. The main topics in this module are the following:
Introducing the simplex method, examples, adjacent basic feasible solutions, checking optimality of a basic feasible solution, direction-step length theorem, its application in developing the steps of simplex method, examples, finite termination under non-degeneracy, generating an initial basic feasible solution using two phase and Big M method, degeneracy and cycling, anti-cycling rules like Bland's rule, and lexicographic rules.
The topics to be discussed in this module can be found in chapter 3 of text [1] *below.*

All the problems in this course should be computationally also solved using the software SageMath. The references provided below, especially text [2] and chapter 4 of text [3] can be used mainly for this.

Texts

Text 1 – Roy H Kwon. *Introduction to Linear Optimization and extensions with MATLAB*, 4th Edition, CRC Press, New York

Text 2 – *Sage Reference Manual: Numerical Optimization, Release 7.6* by the Sage Development Team available online at `http://doc.sagemath.org/pdf/en/reference/numerical/numerical.pdf`

Text 3 – Gregory V. Bard. *Sage for Undergraduates*, American Mathematical Society, available online at `http://www.gregorybard.com/Sage.html`

References

Ref. 1 – Frederick S Hillier, Gerald J Lieberman. *Introduction to operations research*, 10th Edition, McGraw Hill Education

Ref. 2 – Paul R Thie, G. E. Keough. *An introduction to linear programming and game theory*, 3rd Edition, John Wiley & Sons

Ref. 3 – Wayne L Winston, *Operations Research Applications and Algorithms*, 4th Edition, Cengage Learning

Semester VI

Numerical Analysis with SageMath (Elective)

CODE: MM 1661.3 Instructional hours per week: 3
No. of credits: 2

This course is aimed at providing an introduction to Numerical analysis with particular emphasize to finding approximate solutions to problems like finding roots of equations, numerically evaluating differential and integral equations, finding polynomials from values that approximate a given function, solving systems of linear equations etc. SageMath can be used as the software for supporting computations.

Note :

1. There should not be any problems to solve using the SageMath software in the End Semester Examination (ESE). The ESE should be based only on the theory and problems to be solved either manually or using a non programmable scientific calculator.
2. Students may be permitted to use non programmable scientific calculator in the end semester examination.
3. One of the internal evaluation examinations should be done using SageMath Software, as a practical examination.

Module I (27 Hours)
General concepts in Numerical analysis : Introduction, Floating-Point Form of Numbers, Round off, Loss of Significant Digits, Errors of Numeric Results, Error Propagation, Basic Error Principle, Algorithm Stability.

Solution of Equations by Iteration : Fixed-Point Iteration for Solving Equations $f(x) = 0$, Newton's Method for Solving Equations $f(x) = 0$, Order of an Iteration Method Speed of Convergence, Convergence of Newton's Method, Secant Method for Solving $f(x) = 0$.

Interpolation : Lagrange Interpolation, Newton's Divided Difference Interpolation, Equal Spacing: Newton's Forward Difference Formula, Equal Spacing: Newton's Backward Difference Formula, Spline Interpolation,
The topics to be discussed in this module can be found in chapter 19, sections 19.1, 19.2,19.3,19.4 of text [1] *below.*

Module II (27 hours)
Numerical Integration and Differentiation : Rectangular Rule. Trapezoidal Rule, Simpson's Rule of Integration, Adaptive Integration, Gauss Integration Formulas Maximum Degree of Precision, Numeric Differentiation.

Numerical Methods for Ordinary Differential Equations : Methods for First-Order ODEs, Picard's Iteration Method, Euler's method (Numeric Method) , Improved Euler Method, Runge-Kutta Methods (RK Methods) of fourth order.

Numerical Methods in Linear Algebra : Linear Systems: Gauss Elimination, Linear Systems: LU-Factorization, Matrix Inversion, Cholesky's Method, GaussJordan Elimination. Matrix Inversion. Linear Systems: Solution by Iteration, GaussSeidel Iteration Method, Jacobi Iteration
The topics to be discussed in this module can be found in chapter 19 section 1.2 and Problem set 1.7 CAS PROJECT. 6 , Chapter 19 Sections 19.5, Chapter 20, Sections 20.1, 20.2, 20.3, Chapter 21 Sections 21.1, of text [1] *below.*

All the problems in this course should be computationally also solved using the software SageMath. The references provided below, especially text [2] and chapter 4 of text [3] can be used mainly for this.

Texts

Text 1 – Erwin Kreyszig. *Advanced Engineering Mathematics*, 10th Edition, Wiley-India

Text 2 – *Sage Reference Manual: Numerical Optimization, Release 7.6* by the Sage Development Team available online at `http://doc.sagemath.org/pdf/en/reference/numerical/numerical.pdf`

Text 3 – Gregory V. Bard. *Sage for Undergraduates*, American Mathematical Society, available online at `http://www.gregorybard.com/Sage.html`

References

Ref. 1 – Richard L Burden, J Douglas Faires. *Numerical Analysis*, 9th Edition, Cengate Learning

Ref. 2 – E Isaacson, H B Keller. *Analysis of Numerical Methods*, Dover Publications, New York

Ref. 3 – W. Cheney, D Kincaid. *Numerical Mathematics and Computing*, 6th Edition, Thomson Brooks/Cole

Semester VI

Fuzzy Mathematics (Elective)

CODE: MM 1661.4 — Instructional hours per week: 3
No. of credits: 2

Module I (18 hours)
FROM CRISP SETS TO FUZZY SETS: A PARADIGM SHIFT.Introduction-crisp sets: an overview-fuzzy sets: basic types and basic concepts of fuzzy sets, Fuzzy sets versus crisp sets, Additional properties of cuts, Representation of fuzzy sets.

Module II (18 hours)
OPERATIONS ON FUZZY SETS AND FUZZY ARITHMETIC:Operations on fuzzy sets-types of operations, fuzzy complements, fuzzy intersections, t-norms, fuzzy unions, t-conorms. Fuzzy numbers, Linguistic variables, Arithmetic operations on intervals, Arithmetic operations on fuzzy numbers.

Module III (18 hours)
FUZZY RELATIONS :Crisp versus fuzzy relations, projections and cylindric extensions, Binary fuzzy relations, Binary relations on a single set, Fuzzy equivalence relations.

The topics to be discussed in this module can be found in
Chapter 1: Sections 1.1 to 1.4
Chapter 2: Sections 2.1 and 2.2
Chapter 3: Sections 3.1 to 3.4 (proof of theorems 3.7, 3.8, lemma 3.1, 3.2, theorems 3.11,3.12 3.13 need not be discussed)
Chapter 4: Sections 4.1 to 4.4
Chapter 5: Sections 5.1 to 5.5
of text [1] *below.*

Texts

Text 1 – George J Klir, Yuan. *Fuzzy sets and fuzzy logic: Theory and applications*, Prentice Hall of India Pvt. Ltd., New Delhi, 2000

References

Ref. 1 – Klir G J and T Folger. *Fuzzy sets, Uncertainty and Information*, PHI Pvt.Ltd., New Delhi, 1998

Ref. 2 – H J Zimmerman. *Fuzzy Set Theory and its Applications*, Allied Publishers, 1996

Ref. 3 – Dubois D and Prade H. *Fuzzy Sets and Systems: Theory and Applications*, Ac.Press, NY, 1988

University of Kerala
Complementary Course in Mathematics
for First Degree Programme in Physics

Semester I

Mathematics – I
(Calculus with applications in Physics – I)
Code: MM 1131.1

Instructional hours per week: 4 No. of Credits:3

Module 1: Differentiation with applications to Physics (18 Hours)
(*The following topics should be quickly reviewed before going to advanced topics; students should be asked to do more problems from exercises, and these problems should be included in assignments:*) Differentiation of products of functions; the chain rule; quotients; implicit differentiation; logarithmic differentiation; Leibnitz theorem
The following topics in this module should be devoted more attention and time.
Special points of a function (especially, stationary points); curvature; theorems of differentiation – Rolles', Mean Value Theorems
The topics in this module can be found in chapter 2, sections 2.1.2, to 2.1.7, text [1] *(Review of ideas through problems), chapter 2, sections 2.1.8, 2.1.9, 2.1.10,* text [1]
More exercises related to the topics in this module can be found in chapter 2 and chapter 3 of reference [1].

Module 2: Integration with applications to Physics (18 Hours)
Integration by parts; reduction formulae; infinite and improper integrals; plane polar coordinates; integral inequalities; applications of integration (finding area, volume etc)
The topics in this module can be found in chapter 2, sections 2.2.8 to 2.2.13, text [1]
More exercises related to the topics in this module can be found in chapter 4, chapter 5 and chapter 7 of reference [1].

Module 3: Infinite series and limits (18 Hours)
Definition, Summation of series of various types (Arithmetic series; geometric series; arithmetico-geometric series; the difference method; series involving natural numbers; transformation of series) Convergence of infinite series (Absolute and conditional convergence; series containing only real positive terms; alternating series test)
Operations with series (Sum and product)
Power series (Convergence of power series; operations with power series)
Taylor series (Taylors theorem need not be proved, but the statement should be explained through problems); approximation errors; standard Maclaurin series
The topics in this module can be found in chapter 4, sections 4.1 to 4.6, text [1]
More exercises related to the topics in this module can be found in chapter 9 of reference [1] and chapter 1 of reference [2].

Module 4: Vector algebra (18 Hours)
Scalars and vectors, Addition and subtraction of vectors, Multiplication by a scalar, Basis vectors and components, Magnitude of a vector, Multiplication of vectors (Scalar product; vector product; scalar triple product; vector triple product), Equations of lines, planes and spheres, using vectors to find distances (Point to line; point to plane; line to line; line to plane)

The topics in this module can be found in chapter 7, sections 7.1 to 7.8, text [1]
More exercises related to the topics in this module can be found in chapter 11 of reference [1] and chapter 6 of reference [2].

Texts

Text 1 – K F Riley, M P Hobson, S J Bence. *Mathematical Methods for Physics and Engineering*, 3rd Edition, Cambridge University Press

References

Ref. 1 – H Anton, I Bivens, S Davis. *Calculus*, 10th Edition, John Wiley & Sons

Ref. 2 – Mary L Boas. *Mathematics Methods in the Physical Sciences*, 3rd Edition, Wiley

Ref. 3 – George B Arfken, Hans J Weber, Frank E Harris. *Mathematical Methods for Physicists*, 7th Edition, Academic Press

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Semester II

Mathematics – II
(Calculus with applications in Physics – II)

Code: MM 1231.1

Instructional hours per week: 4 No. of Credits: 3

Module 1 : Complex numbers and hyperbolic functions (18 hours)
Basic operations (Addition and subtraction; modulus and argument; multiplication; complex conjugate; division), Polar representation of complex numbers (Multiplication and division in polar form), de Moivers theorem (trigonometric identities; finding the nth roots of unity; solving polynomial equations), Complex logarithms and complex powers, Applications to differentiation and integration, Hyperbolic functions (Definitions; hyperbolictrigonometric analogies; identities of hyperbolic functions; solving hyperbolic equations; inverses of hyperbolic functions;calculus of hyperbolic functions)
The topics in this module can be found in chapter 3, sections 3.1 to 3.7 of text [1]
More exercises related to the topics in this module can be found in chapter 6 of reference [1] and chapter 13 of reference [4].

Module 2 : Partial differentiation (18 Hours)
Basics, The total differential and total derivative, Exact and inexact differentials, theorems of partial differentiation, The chain rule, Change of variables, Taylors theorem for many-variable functions, Stationary values of many-variable functions, Stationary values under constraints
The topics in this module can be found in chapter 5, sections 5.1 to 5.9 of text [1]
More exercises related to the topics in this module can be found in chapter 13 of reference [1].

Module 3 : Multiple integrals (18 Hours)
Double integrals, Triple integrals, Applications of multiple integrals (Areas and volumes), Change of variables in multiple integrals – Change of variables in double integrals; evaluation some special infinite integrals, change of variables in triple integrals; general properties of Jacobians
The topics in this module can be found in chapter 6, sections 6.1 to 6.4 of text [1]
More exercises related to the topics in this module can be found in chapter 14 of reference [1].

Module 4 : Vector differentiation (18 Hours)
Differentiation of vectors , Composite vector expressions; differential of a vector, Integration of vectors, Space curves, Vector functions of several arguments, Surfaces, Scalar and vector fields
Vector operators, Gradient of a scalar field; divergence of a vector field; curl of a vector

field Vector operator formulae, Vector operators acting on sums and products; combinations of grad, div and curl, Cylindrical and spherical polar coordinates
The topics in this module can be found in chapter 10, sections 10.1 to 10.9 of text [1].
More exercises related to the topics in this module can be found in chapter 3 of reference [3].

Texts

Text 1 – K F Riley, M P Hobson, S J Bence. *Mathematical Methods for Physics and Engineering*, 3rd Edition, Cambridge University Press

References

Ref. 1 – H Anton, I Bivens, S Davis. *Calculus*, 10th Edition, John Wiley & Sons

Ref. 2 – Mary L Boas. *Mathematics Methods in the Physical Sciences*, 3rd Edition, Wiley

Ref. 3 – George B Arfken, Hans J Weber, Frank E Harris. *Mathematical Methods for Physicists*, 7th Edition, Academic Press

Ref. 4 – Erwin Kreyszig. *Advanced Engineering Mathematics*, 10th Edition, Wiley-India

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Complementary Course in Mathematics
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Semester III

Mathematics – III
(Calculus and Linear Algebra)

Code: MM 1331.1

Instructional hours per week: 5 No. of Credits: 4

Module 1 : Ordinary Differential Equations (30 Hours)
First-order ordinary differential equations : General form of solution, First-degree first-order equations (Separable-variable equations; exact equations; inexact equations, integrating factors; linear equations; homogeneous equations; isobaric equations; Bernoullis equation; miscellaneous equations) Higher-degree first-order equations (Equations soluble for p; for x; for y; Clairaut's equation)

Higher-order ordinary differential equations : Linear equations with constant coefficients, (Finding the complementary function $y_c(x)$; finding the particular integral $y_p(x)$; constructing the general solution $y_c(x) + y_p(x)$; linear recurrence relations; Laplace transform method) Linear equations with variable coefficients (The Legendre and Euler linear equations; exact equations; partially known complementary function; variation of parameters; Green's functions; canonical form for second-order equations)

General ordinary differential equations – Dependent variable absent; independent variable absent; non-linear exact equations; isobaric or homogeneous equations; equations homogeneous in x or y alone; equations having $y = Ae^x$ as a solution
The topics in this module can be found in chapter 14 and chapter 15 of text [1]
More exercises related to the topics in this module can be found in chapter 1, 2 and 3 of reference [3].

Module 2 : Vector Integration – Line, surface and volume integrals (18 hours)
Evaluating line integrals; physical examples; line integrals with respect to a scalar Connectivity of regions, Greens theorem in a plane, Conservative fields and potentials, Surface integrals, Evaluating surface integrals; vector areas of surfaces; physical examples, Volume integrals, Volumes of three-dimensional regions, Integral forms for grad, div and curl, Green's theorems (without proof); other related integral theorems; physical applications, Stokes theorem and related theorems (without proof), Related integral theorems; physical applications
The topics in this module can be found in chapter 11 of text [1]
More exercises related to the topics in this module can be found in chapter 3 of reference [2].

Module 3 : Fourier series (18 Hours)
Basic definition, Simple Harmonic Motion and Wave Motion; Periodic Functions, Applications of Fourier Series, Average Value of a Function, Fourier Coefficients, Dirichlet Conditions, Complex Form of Fourier Series, Other Intervals, Even and Odd Functions, Parsevals Theorem, Fourier Transforms
The topics in this module can be found in chapter 7 of text [2]

More exercises related to the topics in this module can be found in chapter 11 of reference [3].

Module 4 : Basic Linear Algebra (24 Hours)
Matrices and row reduction, Determinants, Cramer's rule for solving system of equations, vectors, lines and planes, linear combinations, linear functions, linear operators, linear dependence and independence, special matrices like Hermitian matrices and formulas, linear vector spaces, eigen values and eigen vectors, diagonalizing matrices, applications of diagonalization
The topics in this module can be found in chapter 3 of text [2]
More exercises related to the topics in this module can be found in chapter 7 and 8 of reference [3].

Texts

Text 1 – K F Riley, M P Hobson, S J Bence. *Mathematical Methods for Physics and Engineering*, 3rd Edition, Cambridge University Press

Text 2 – Mary L Boas. *Mathematics Methods in the Physical Sciences*, 3rd Edition, Wiley

References

Ref. 1 – H Anton, I Bivens, S Davis. *Calculus*, 10th Edition, John Wiley & Sons

Ref. 2 – George B Arfken, Hans J Weber, Frank E Harris. *Mathematical Methods for Physicists*, 7th Edition, Academic Press

Ref. 3 – Erwin Kreyszig. *Advanced Engineering Mathematics*, 10th Edition, Wiley-India

University of Kerala
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Semester IV

Mathematics – IV
(Complex Analysis, Special Functions, and Probability Theory)

Code: MM 1431.1

Instructional hours per week: 5 — No. of Credits: 4

Module 1 : Advanced Complex Analysis (36 Hours)
Functions of a complex variable, Analytic functions, the Cauchy-Riemann relations, Contour integrals Cauchy's theorem, Cauchy's integral formula, Laurent series, the residue theorem, methods of finding residues, evaluation of definite integrals using residue theorem, residues at infinity, conformal mapping and some of its applications.
The topics in this module can be found in chapter 14 of text [1]
More exercises related to the topics in this module can be found in chapter 14, 15, 16 and 17 of reference [4].

Module 2 : Special functions (18 Hours)
The Factorial Function, Definition of the Gamma Function; Recursion Relation, The Gamma Function of Negative Numbers, Some Important Formulas Involving Gamma Functions, Beta Functions, Beta Functions in Terms of Gamma Functions
The topics in this module can be found in chapter 11 of text [1]
More exercises related to the topics in this module can be found in chapter 13 of reference [3].

Module 3 : Probability and Statistics (36 Hours)
Basics, Sample Space, Probability Theorems, Methods of Counting Random Variables, Continuous Distributions, Binomial Distribution, The Normal or Gaussian Distribution, The Poisson Distribution
The topics in this module can be found in chapter 15, sections 15.1 to 15.9 of text [1]
More exercises related to the topics in this module can be found in chapter 23 of reference [3].

Texts

Text 1 – Mary L Boas. *Mathematics Methods in the Physical Sciences*, 3rd Edition, Wiley

References

Ref. 1 – K F Riley, M P Hobson, S J Bence. *Mathematical Methods for Physics and Engineering*, 3rd Edition, Cambridge University Press

Ref. 2 – H Anton, I Bivens, S Davis. *Calculus*, 10th Edition, John Wiley & Sons

Ref. 3 – George B Arfken, Hans J Weber, Frank E Harris. *Mathematical Methods for Physicists*, 7th Edition, Academic Press

Ref. 4 – Erwin Kreyszig. *Advanced Engineering Mathematics*, 10th Edition, Wiley-India

University of Kerala
Complementary Course in Mathematics
for First Degree Programme in Chemistry

Semester I

Mathematics – I
(Calculus with applications in Chemistry – I)
Code: MM 1131.2

Instructional hours per week: 4 No. of Credits:3

Module 1: Differentiation with applications to Chemistry (18 Hours)
(*The following topics should be quickly reviewed before going to advanced topics; students should be asked to do more problems from exercises, and these problems should be included in assignments:*) Differentiation of products of functions; the chain rule; quotients; implicit differentiation; logarithmic differentiation; Leibnitz theorem
The following topics in this module should be devoted more attention and time.
Special points of a function (especially, stationary points); curvature; theorems of differentiation – Rolles', Mean Value Theorems
The topics in this module can be found in chapter 2, sections 2.1.2, to 2.1.7, text [1] *(Review of ideas through problems), chapter 2, sections 2.1.8, 2.1.9, 2.1.10,* text [1]
More exercises related to the topics in this module can be found in chapter 2 and chapter 3 of reference [1].

Module 2 : Complex numbers and hyperbolic functions (18 hours)
Basic operations (Addition and subtraction; modulus and argument; multiplication; complex conjugate; division), Polar representation of complex numbers (Multiplication and division in polar form), de Moivers theorem (trigonometric identities; finding the nth roots of unity; solving polynomial equations), Complex logarithms and complex powers, Applications to differentiation and integration, Hyperbolic functions (Definitions; hyperbolictrigonometric analogies; identities of hyperbolic functions; solving hyperbolic equations; inverses of hyperbolic functions;calculus of hyperbolic functions)
The topics in this module can be found in chapter 3, sections 3.1 to 3.7 of text [1]
More exercises related to the topics in this module can be found in chapter 6 of reference [1] and chapter 13 of reference [4].

Module 3: Basic vector algebra (18 Hours)
Scalars and vectors, Addition and subtraction of vectors, Multiplication by a scalar, Basis vectors and components, Magnitude of a vector, Multiplication of vectors (Scalar product; vector product; scalar triple product; vector triple product), Equations of lines, planes and spheres, using vectors to find distances (Point to line; point to plane; line to line; line to plane)
The topics in this module can be found in chapter 7, sections 7.1 to 7.8, text [1]
More exercises related to the topics in this module can be found in chapter 11 of reference [1] and chapter 6 of reference [2].

Module 4: Basic integration with applications to Chemistry (18 Hours)
Integration by parts; reduction formulae; infinite and improper integrals; plane polar coordinates; integral inequalities; applications of integration (finding area, volume etc)
The topics in this module can be found in chapter 2, sections 2.2.8 to 2.2.13, text [1]

More exercises related to the topics in this module can be found in chapter 4, 5 and 7 of reference [1].

Texts

Text 1 – K F Riley, M P Hobson, S J Bence. *Mathematical Methods for Physics and Engineering*, 3rd Edition, Cambridge University Press

References

Ref. 1 – H Anton, I Bivens, S Davis. *Calculus*, 10th Edition, John Wiley & Sons

Ref. 2 – Mary L Boas. *Mathematics Methods in the Physical Sciences*, 3rd Edition, Wiley

Ref. 3 – George B Arfken, Hans J Weber, Frank E Harris. *Mathematical Methods for Physicists*, 7th Edition, Academic Press

Ref. 4 – Erwin Kreyszig. *Advanced Engineering Mathematics*, 10th Edition, Wiley-India

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Semester II

Mathematics – II
(Calculus with applications in Chemistry – II)

Code: MM 1231.2

Instructional hours per week: 4 No. of Credits: 3

Module 1 : Partial differentiation (18 Hours)
Basics, The total differential and total derivative, Exact and inexact differentials, theorems of partial differentiation, The chain rule, Change of variables, Taylors theorem for many-variable functions, Stationary values of many-variable functions, Stationary values under constraints
The topics in this module can be found in chapter 5, sections 5.1 to 5.9 of text [1]
More exercises related to the topics in this module can be found in chapter 13 of reference [1].

Module 2: Infinite series and limits (18 Hours)
Definition, Summation of series of various types (Arithmetic series; geometric series; arithmetico-geometric series; the difference method; series involving natural numbers; transformation of series) Convergence of infinite series (Absolute and conditional convergence; series containing only real positive terms; alternating series test)
Operations with series (Sum and product)
Power series (Convergence of power series; operations with power series)
Taylor series (Taylors theorem need not be proved, but the statement should be explained through problems); approximation errors; standard Maclaurin series
The topics in this module can be found in chapter 4, sections 4.1 to 4.6, text [1]
More exercises related to the topics in this module can be found in chapter 9 of reference [1] and chapter 1 of reference [2].

Module 3 : Vector differentiation (18 Hours)
Differentiation of vectors , Composite vector expressions; differential of a vector, Integration of vectors, Space curves, Vector functions of several arguments, Surfaces, Scalar and vector fields
Vector operators, Gradient of a scalar field; divergence of a vector field; curl of a vector field Vector operator formulae, Vector operators acting on sums and products; combinations of grad, div and curl, Cylindrical and spherical polar coordinates
The topics in this module can be found in chapter 10, sections 10.1 to 10.9 of text [1].
More exercises related to the topics in this module can be found in chapter 3 of reference [3].

Module 4 : Multiple integrals (18 Hours)
Double integrals, Triple integrals, Applications of multiple integrals (Areas and volumes), Change of variables in multiple integrals – Change of variables in double integrals; evaluation some special infinite integrals, change of variables in triple integrals; general properties of Jacobians
The topics in this module can be found in chapter 6, sections 6.1 to 6.4 of text [1]

More exercises related to the topics in this module can be found in chapter 14 of reference [1].

Texts

Text 1 – K F Riley, M P Hobson, S J Bence. *Mathematical Methods for Physics and Engineering*, 3rd Edition, Cambridge University Press

References

Ref. 1 – H Anton, I Bivens, S Davis. *Calculus*, 10th Edition, John Wiley & Sons

Ref. 2 – Mary L Boas. *Mathematics Methods in the Physical Sciences*, 3rd Edition, Wiley

Ref. 3 – George B Arfken, Hans J Weber, Frank E Harris. *Mathematical Methods for Physicists*, 7th Edition, Academic Press

Ref. 4 – Erwin Kreyszig. *Advanced Engineering Mathematics*, 10th Edition, Wiley-India

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Complementary Course in Mathematics
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Semester III

Mathematics – III
(Linear Algebra, Probablity Theory & Numerical Methods)

Code: MM 1331.2

Instructional hours per week:5 No. of Credits: 4

Module 1 : Basic Linear Algebra (24 Hours)
Matrices and row reduction, Determinants, Cramer's rule for solving system of equations, vectors, lines and planes, linear combinations, linear functions, linear operators, linear dependence and independence, special matrices like Hermitian matrices and formulas, linear vector spaces, eigen values and eigen vectors, diagonalizing matrices, applications of diagonalization
The topics in this module can be found in chapter 3 of text [2]
More exercises related to the topics in this module can be found in chapter 7 and 8 of reference [3].

Module 2 : Probability and Statistics (36 Hours)
Basics, Sample Space, Probability Theorems, Methods of Counting Random Variables, Continuous Distributions, Binomial Distribution, The Normal or Gaussian Distribution, The Poisson Distribution
The topics in this module can be found in chapter 15, sections 15.1 to 15.9 of text [2]
More exercises related to the topics in this module can be found in chapter 23 of reference [2].

Module 3 : Numerical Methods (30 Hours)
Algebraic and transcendental equations (Rearrangement of the equation; linear interpolation; binary chopping; Newton-Raphson method)
Convergence of iteration schemes, Simultaneous linear equations (Gaussian elimination; Gauss-Seidel iteration; tridiagonal matrices) Numerical integration (Trapezium rule; Simpsons rule; Gaussian integration; Monte Carlo methods), Finite differences, Differential equations (Difference equations; Taylor series solutions; prediction and correction;Runge–Kutta methods; isoclines)
The topics in this module can be found in chapter 27, sections 27.1 to 27.6 of text [1]
More exercises related to the topics in this module can be found in reference [4].

Texts

Text 1 – K F Riley, M P Hobson, S J Bence. *Mathematical Methods for Physics and Engineering*, 3rd Edition, Cambridge University Press

Text 2 – Mary L Boas. *Mathematics Methods in the Physical Sciences*, 3rd Edition, Wiley

References

Ref. 1 – H Anton, I Bivens, S Davis. *Calculus*, 10th Edition, John Wiley & Sons

Ref. 2 – George B Arfken, Hans J Weber, Frank E Harris. *Mathematical Methods for Physicists*, 7th Edition, Academic Press

Ref. 3 – Erwin Kreyszig. *Advanced Engineering Mathematics*, 10th Edition, Wiley-India

Ref. 4 – Richard L Burden, J Douglas Faires. *Numerical Analysis*, 9th Edition, Cengate Learning

University of Kerala
Complementary Course in Mathematics
for First Degree Programme in Chemistry

Semester IV

Mathematics-IV
(Differential Equations, Vector Calculus, and Abstsract Algebra)

Code: MM 1431.2

Module 1 : Ordinary Differential Equations (30 Hours)
First-order ordinary differential equations : General form of solution, First-degree first-order equations (Separable-variable equations; exact equations; inexact equations, integrating factors; linear equations; homogeneous equations; isobaric equations; Bernoullis equation; miscellaneous equations) Higher-degree first-order equations (Equations soluble for p; for x; for y; Clairaut's equation)

Higher-order ordinary differential equations : Linear equations with constant coefficients, (Finding the complementary function $y_c(x)$; finding the particular integral $y_p(x)$; constructing the general solution $y_c(x) + y_p(x)$; linear recurrence relations; Laplace transform method) Linear equations with variable coefficients (The Legendre and Euler linear equations; exact equations; partially known complementary function; variation of parameters; Green's functions; canonical form for second-order equations)

General ordinary differential equations – Dependent variable absent; independent variable absent; non-linear exact equations; isobaric or homogeneous equations; equations homogeneous in x or y alone; equations having $y = Ae^x$ as a solution
The topics in this module can be found in chapter 14 and chapter 15 of text [1]
More exercises related to the topics in this module can be found in chapter 1, 2 and 3 of reference [3].

Module 2 : Vector Integration – Line, surface and volume integrals (18 hours)
Evaluating line integrals; physical examples; line integrals with respect to a scalar Connectivity of regions, Greens theorem in a plane, Conservative fields and potentials, Surface integrals, Evaluating surface integrals; vector areas of surfaces; physical examples, Volume integrals, Volumes of three-dimensional regions, Integral forms for grad, div and curl, Green's theorems (without proof); other related integral theorems; physical applications, Stokes theorem and related theorems (without proof), Related integral theorems; physical applications
The topics in this module can be found in chapter 11 of text [1]
More exercises related to the topics in this module can be found in chapter 3 of reference [2].

Module 3: Abstract Algebra (42 Hours)
Definition of a group; examples of groups, Finite groups, Non-Abelian groups, Permutation groups, Mappings between groups, Subgroups Subdividing a group (Equivalence relations and classes; congruence and cosets; conjugates and classes)

Representation theory, Equivalent representations, Reducibility of a representation, The orthogonality theorem for irreducible representations Characters (Orthogonality property of characters), Counting irreps using characters (Summation rules for irreps), Con-

struction of a character table
The topics in this module can be found in chapter 28 and chapter 29, sections 29.3, 29.4, 29.5, 29.6, 29.7, 29.8 of text [1]
More exercises related to the topics in this module can be found in reference [5].

Texts

Text 1 – K F Riley, M P Hobson, S J Bence. *Mathematical Methods for Physics and Engineering*, 3rd Edition, Cambridge University Press

References

Ref. 1 – H Anton, I Bivens, S Davis. *Calculus*, 10th Edition, John Wiley & Sons

Ref. 2 – Mary L Boas. *Mathematics Methods in the Physical Sciences*, 3rd Edition, Wiley

Ref. 3 – George B Arfken, Hans J Weber, Frank E Harris. *Mathematical Methods for Physicists*, 7th Edition, Academic Press

Ref. 4 – Erwin Kreyszig. *Advanced Engineering Mathematics*, 10th Edition, Wiley-India

Ref. 5 – David M Bishop. *Group theory and Chemistry*, Dover Publications

University of Kerala
Complementary Course in Mathematics
for First Degree Programme in Geology

Semester I
Mathematics-I
(Algebra, Geometry and Trigonometry)

CODE: MM 1131.3 — Instructional hours per week: 4
No. of Credits: 3 credits

Module 1 : Preliminary algebra (20 Hours)
Calculators and approximate numbers, exponents, scientific notation, roots and radicals, addition and subtraction of algebraic expressions, multiplication of algebraic expressions, division of algebraic expressions, solving equations: quadratic equations, solving them by factoring, completing the square, the quadratic formula, the graph of the quadratic function
The above topics can be found in chapter 1 and chapter 7 of text [1]

Module 2 : Plane Geometry (20 Hours)
Geometry : lines and angles, triangles, quadrilaterals, circles, measurement of irregular areas, solid geometric figures; plane analytic geometry : basic definitions, the straight line, the circle, the parabola, the ellipse, the hyperbola
The above topics can be found in chapter 2 and chapter 21 of text [1]

Module 3 : Basic Trigonometry (32 hours)
The trigonometric functions, angles, defining the trigonometric functions, values of the trigonometric functions, the right triangle, applications of right triangles, trigonometric functions of any angle, signs of the trigonometric functions, radians, applications of radian measure, vectors and oblique triangles, introduction to vectors, components of vectors, vector addition by components, applications of vectors, oblique triangles, the law of sines, graphs of $y = a\sin x$ and $y = a\cos x$, graphs of $y = a\sin bx$ and $y = a\cos bx$, graphs of $y = a\sin(bx + c)$ and $y = a\cos(bx + c)$, graphs of $y = \tan x$, $y = \cot x$, $y = \sec x, y = \csc x$, applications of the trigonometric graphs, Composite trigonometric curves
The above topics can be found in chapter 4, 8, 9 and 10 of text [1]

Texts

Text 1 – Allyn J Washington. *Basic technical mathematics with calculus*, 10th edition, Pearson

References

Ref. 1 – H Kruglak et al. *Theory and problems of basic Mathematics with applications to science and technology*, 2nd Edition, Schaum's Outline Series

Ref. 2 – Steven T Karris. *Mathematics for Business, Science, and Technology With MATLAB and Spreadsheet Applications*, 2nd Edition, Orchard Publications

University of Kerala
Complementary Course in Mathematics
for First Degree Programme in Geology

Semester II
Mathematics-II
(Calculus and Linear Algebra)

CODE: MM 1231.3 Instructional hours per week: 4
No. of Credits: 3

Module 1 : Exponential and logarithmic functions (12 Hours)
Exponential functions, logarithmic functions, properties of logarithms , logarithms to the base 10, natural logarithms, exponential and logarithmic equations
The above topics can be found in chapter 13 of text [1]

Module 2 : Basic Linear Algebra (20 hours)
Systems of linear equation; determinants, linear equations, graphs of linear functions, solving systems of two linear equations in two unknowns graphically, solving systems of two linear equations in two unknowns algebraically, solving systems of two linear equations in two unknowns by determinants, solving systems of three linear equations in three unknowns algebraically, solving systems of three linear equations in three unknowns by determinants,
Matrices: definitions and basic operations, multiplication of matrices, finding the inverse of a matrix, matrices and linear equations, gaussian elimination, higher-order determinants.
The above topics can be found in chapter 5 and 16 of text [1]

Module 3 : Sequences and series (10 hours)
Arithmetic sequences, geometric sequences, infinite geometric series, the binomial theorem
The above topics can be found in chapter 19 text [1]

Module 4 : Differentiation (30 hours)
Limits, the slope of a tangent to a curve, the derivative, the derivative as an instantaneous, rate of change, derivatives of polynomials, derivatives of products and quotients of func- tions, the derivative of a power of a function, differentiation of implicit functions, higher derivatives, tangents and normals, newtons method for solving equations, curvilinear motion, related rates, using derivatives in curve sketching, more on curve sketching, applied maximum and minimum problems, differentials and linear approximations Matrices: definitions and basic operations, multiplication of matrices, finding the inverse of a matrix, matrices and linear equations, gaussian elimination, higher-order determi- nants.
The above topics can be found in chapter 23 and 24 of text [1]

Texts

Text 1 – Allyn J Washington. *Basic technical mathematics with calculus*, 10th edition, Pearson

References

Ref. 1 – H Kruglak et al. *Theory and problems of basic Mathematics with applications to science and technology*, 2nd Edition, Schaum's Outline Series

Ref. 2 – Steven T Karris. *Mathematics for Business, Science, and Technology With MATLAB and Spreadsheet Applications*, 2nd Edition, Orchard Publications

University of Kerala
Complementary Course in Mathematics
for First Degree Programme in Geology

Semester III
Mathematics-III
(Complex Numbers, Algebra and Calculus)

CODE: MM 1331.3 — Instructional hours per week: 5
No. of Credits: 4

Module 1 : Complex Analysis (15 Hours)
Complex numbers, basic definitions, basic operations with complex numbers, graphical representation of complex numbers, polar form of a complex number, exponential form of a complex number, products, quotients, powers, and roots of complex numbers
The above topics can be found in chapter 12 of text [1]

Module 2 : Solving equations and inequalities (25 hours)
The remainder and factor theorems, synthetic division, the roots of an equation, rational and irrational roots, inequalities, properties of inequalities, solving linear inequalities, solving nonlinear inequalities, inequalities involving absolute values, graphical solution of inequalities with two variables, linear programming
The above topics can be found in chapter 15 and 17 of text [1]

Module 3 : Integration (30 hours)
Antiderivatives, the indefinite integral, the area under a curve, the definite integral, numerical integration: the trapezoidal rule, simpsons rule, applications of the indefinite integral, areas by integration, volumes by integration, the general power formula, the basic logarithmic form, the exponential form, basic trigonometric forms, other trigonometric forms, inverse trigonometric forms, integration by parts, integration by trigonometric substitution, integration by partial fractions (various cases), integration by use of tables
The above topics can be found in chapter 25, 26 and 28 of text [1]

Module 4 : Expanding functions in series (20 hours)
Infinite series, Maclaurin series, operations with series, computations by use of series expansions, Taylor series, introduction to Fourier series
The above topics can be found in chapter 30 of text [1]

Texts

Text 1 – Allyn J Washington. *Basic technical mathematics with calculus*, 10th edition, Pearson

References

Ref. 1 – H Kruglak et al. *Theory and problems of basic Mathematics with applications to science and technology*, 2nd Edition, Schaum's Outline Series

Ref. 2 – Steven T Karris. *Mathematics for Business, Science, and Technology With MATLAB and Spreadsheet Applications*, 2nd Edition, Orchard Publications

University of Kerala
Complementary Course in Mathematics
for First Degree Programme in Geology

Semester IV
Mathematics-IV
(Basic Statistics and Differential Equations)

CODE: MM 1431 — Instructional hours per week: 5
No. of Credits: 4

Module 1 : Basic Statistics (35 hours)
Probability and sample spaces, probability of success and failure, probability of independent and dependent events, probability of exclusive events, probability of inclusive events, conditional probability. descriptive versus inferential statistics, population and samples, parameters and statistics, quantitative and qualitative data, frequency distributions and graphical representation of the data, bar charts, pie chart, frequency distribution of large data sets, determining the class width, class relative frequency, cumulative frequency, histograms, measurements of central tendency, average or arithmetic mean, weighted mean, median, mode, measures of dispersion, sample range, variance, standard deviation, random variable, normal distribution, empirical rule, converting values into standard units,
The above topics can be found in chapter 21 and 22 of text [1]

Module 2 : Fitting Functions to Data (25 hours)
Curve fitting, linear regression, parabolic regression, covariance, correlation coefficient
The above topics can be found in chapter 12 of text [2]

Module 3 : Differential Equations (30 hours)
Differential equations, solutions of differential equations, separation of variables, integrating combinations, the linear differential equation of the first order, numerical solutions of first-order equations, elementary applications, higher-order homogeneous equations, auxiliary equation with repeated or complex roots, solutions of nonhomogeneous equations, applications of higher-order equations, laplace transforms, solving differential equations.
The above topics can be found in chapter 31 of text [1]

Texts

Text 1 – Allyn J Washington. *Basic technical mathematics with calculus*, 10th edition, Pearson

Text 2 – Steven T Karris. *Mathematics for Business, Science, and Technology With MATLAB and Spreadsheet Applications*, 2nd Edition, Orchard Publications

References

Ref. 1 – H Kruglak et al. *Theory and problems of basic Mathematics with applications to science and technology*, 2nd Edition, Schaum's Outline Series

University of Kerala
Complementary Course in Mathematics
for First Degree Programme in Statistics

Semester I
Mathematics-I
(Basic Calculus for Statistics)

CODE: MM 1131.4 — Instructional hours per week: 4
No. of Credits: 3

Module 1: Differential Calculus for Statistics (24 Hours)

(*The following topics should be quickly reviewed before going to advanced topics; students should be asked to do more problems from exercises, and these problems should be included in assignments:*) Differentiation of products of functions; the chain rule; quotients; implicit differentiation; logarithmic differentiation; Leibnitz theorem

The following topics in this module should be devoted more attention and time.

Special points of a function (especially, stationary points); curvature; theorems of differentiation – Rolles', Mean Value Theorems

The topics in this module can be found in chapter 2, sections 2.1.2, to 2.1.7, text [1] *(Review of ideas through problems), chapter 2, sections 2.1.8, 2.1.9, 2.1.10,* text [1]

More exercises related to the topics in this module can be found in chapter 2 and chapter 3 of reference [1].

Module 2: Infinite series and limits (24 Hours)

Definition, Summation of series of various types (Arithmetic series; geometric series; arithmetico-geometric series; the difference method; series involving natural numbers; transformation of series) Convergence of infinite series (Absolute and conditional convergence; series containing only real positive terms; alternating series test)

Operations with series (Sum and product)

Power series (Convergence of power series; operations with power series)

Taylor series (Taylors theorem need not be proved, but the statement should be explained through problems); approximation errors; standard Maclaurin series

The topics in this module can be found in chapter 4, sections 4.1 to 4.6, text [1]

More exercises related to the topics in this module can be found in chapter 9 of reference [1] and chapter 1 of reference [2].

Module 3: Integral Calculus for Statistics (24 Hours)

Integration by parts; reduction formulae; infinite and improper integrals; plane polar coordinates; integral inequalities; applications of integration (finding area, volume etc)

The topics in this module can be found in chapter 2, sections 2.2.8 to 2.2.13, text [1]

More exercises related to the topics in this module can be found in chapter 4, chapter 5 and chapter 7 of reference [1].

Texts

Text 1 – K F Riley, M P Hobson, S J Bence. *Mathematical Methods for Physics and Engineering*, 3rd Edition, Cambridge University Press

References

Ref. 1 – H Anton, I Bivens, S Davis. *Calculus*, 10th Edition, John Wiley & Sons

Ref. 2 – Mary L Boas. *Mathematics Methods in the Physical Sciences*, 3rd Edition, Wiley

Ref. 3 – George B Arfken, Hans J Weber, Frank E Harris. *Mathematical Methods for Physicists*, 7th Edition, Academic Press

Ref. 4 – Andre I Khuri. *Advanced Calculus with Applications in Statistics*, 2nd Edition, Wiley Interscience

University of Kerala
Complementary Course in Mathematics
for First Degree Programme in Statistics

Semester II
Mathematics-II
(Advanced Differential and Integral Calculus)

CODE: MM 1231.4 — Instructional hours per week: 4
No. of Credits: 3

Module 1 : Partial differentiation (24 Hours)
Basics, The total differential and total derivative, Exact and inexact differentials, theorems of partial differentiation, The chain rule, Change of variables, Taylors theorem for many-variable functions, Stationary values of many-variable functions, Stationary values under constraints
The topics in this module can be found in chapter 5, sections 5.1 to 5.9 of text [1]
More exercises related to the topics in this module can be found in chapter 13 of reference [1].

Module 2 : Multiple integrals (24 Hours)
Double integrals, Triple integrals, Applications of multiple integrals (Areas and volumes), Change of variables in multiple integrals – Change of variables in double integrals; evaluation some special infinite integrals, change of variables in triple integrals; general properties of Jacobians
The topics in this module can be found in chapter 6, sections 6.1 to 6.4 of text [1]
More exercises related to the topics in this module can be found in chapter 14 of reference [1].

Module 3 : Special functions (24 Hours)
The Factorial Function, Definition of the Gamma Function; Recursion Relation, The Gamma Function of Negative Numbers, Some Important Formulas Involving Gamma Functions, Beta Functions, Beta Functions in Terms of Gamma Functions
The topics in this module can be found in chapter 11 of text [2]
More exercises related to the topics in this module can be found in chapter 13 of reference [4].

Texts

Text 1 – K F Riley, M P Hobson, S J Bence. *Mathematical Methods for Physics and Engineering*, 3rd Edition, Cambridge University Press

Text 2 – Mary L Boas. *Mathematics Methods in the Physical Sciences*, 3rd Edition, Wiley

References

Ref. 1 – H Anton, I Bivens, S Davis. *Calculus*, 10th Edition, John Wiley & Sons

Ref. 2 – James Stewart, *Essential Calculus*, Thompson Publications, 2007.

Ref. 3 – Thomas and Finney, *Calculus and Analytic Geometry*, Ninth Edition, Addison-Wesley.

Ref. 4 – George B Arfken, Hans J Weber, Frank E Harris. *Mathematical Methods for Physicists*, 7th Edition, Academic Press

Ref. 5 – Peter V. O' Neil, *Advanced Engineering Mathematics*, ThompsonPublications, 2007

University of Kerala
Complementary Course in Mathematics
for First Degree Programme in Statistics

Semester III
Mathematics-III
(Fourier Series, Numerical Methods and ODE)

CODE: MM 1331.4 Instructional hours per week: 5
No. of Credits: 4

Module 1 : Fourier series (20 Hours)
Basic definition, Simple Harmonic Motion and Wave Motion; Periodic Functions, Applications of Fourier Series, Average Value of a Function, Fourier Coefficients, Dirichlet Conditions, Complex Form of Fourier Series, Other Intervals, Even and Odd Functions, Parsevals Theorem, Fourier Transforms
The topics in this module can be found in chapter 7 of text [2]
More exercises related to the topics in this module can be found in chapter 11 of reference [1].

Module 2 : Ordinary Differential Equations (35 Hours)
First-order ordinary differential equations : General form of solution, First-degree first-order equations (Separable-variable equations; exact equations; inexact equations, integrating factors; linear equations; homogeneous equations; isobaric equations; Bernoullis equation; miscellaneous equations) Higher-degree first-order equations (Equations soluble for p; for x; for y; Clairaut's equation)

Higher-order ordinary differential equations : Linear equations with constant coefficients, (Finding the complementary function $y_c(x)$; finding the particular integral $y_p(x)$; constructing the general solution $y_c(x) + y_p(x)$; linear recurrence relations; Laplace transform method) Linear equations with variable coefficients (The Legendre and Euler linear equations; exact equations; partially known complementary function; variation of parameters; Green's functions; canonical form for second-order equations)

General ordinary differential equations – Dependent variable absent; independent variable absent; non-linear exact equations; isobaric or homogeneous equations; equations homogeneous in x or y alone; equations having $y = Ae^x$ as a solution
The topics in this module can be found in chapter 14 and chapter 15 of text [1]
More exercises related to the topics in this module can be found in chapter 1, 2 and 3 of reference [1].

Module 3 : Numerical Methods (35 Hours)
Algebraic and transcendental equations (Rearrangement of the equation; linear interpolation; binary chopping; Newton-Raphson method)
Convergence of iteration schemes, Simultaneous linear equations (Gaussian elimination; Gauss-Seidel iteration; tridiagonal matrices) Numerical integration (Trapezium rule; Simpsons rule; Gaussian integration; Monte Carlo methods), Finite differences, Differential equations (Difference equations; Taylor series solutions; prediction and correction;Runge–Kutta methods; isoclines)
The topics in this module can be found in chapter 27, sections 27.1 to 27.6 of text [1]
More exercises related to the topics in this module can be found in reference [3].

Texts

Text 1 – K F Riley, M P Hobson, S J Bence. *Mathematical Methods for Physics and Engineering*, 3rd Edition, Cambridge University Press

Text 2 – Mary L Boas. *Mathematics Methods in the Physical Sciences*, 3rd Edition, Wiley

References

Ref. 1 – Erwin Kreyszig. *Advanced Engineering Mathematics*, 10th Edition, Wiley-India

Ref. 2 – H Anton, I Bivens, S Davis. *Calculus*, 10th Edition, John Wiley & Sons

Ref. 3 – Richard L Burden, J Douglas Faires. *Numerical Analysis*, 9th Edition, Cengate Learning

University of Kerala
Complementary Course in Mathematics
for First Degree Programme in Statistics

Semester IV
Mathematics-IV
(Linear Algebra)

CODE: MM 1431.4 Instructional hours per week: 5
No. of Credits: 4

Module 1: Vector Spaces over $\mathbb{R}$

- Vector in 3-space as an ordered triple of real numbers. Addition of two vectors and multiplication of a vector by a scalar. Algebra of vectors involving addition and scalar multiplication. The norm of a vector. The dotproduct and orthogonal vectors. Geometric interpretation of these concepts andtheir connection to the traditional method of representing a vector in terms ofstandard unit vectors.
- The $n-$tuple as a generalisation of ordered triple and the space $\mathbb{R}^n$of all $n-$tuples. Addition of two $n-$tuples and multiplication ofan $n-$tuple by a scalar. Listing of the algebraic properties of $\mathbb{R}^n$ thatmakes it a vector space. Dot product of $n-$tuples and orthogonality. The Cauchy-Schwarz inequality in $\mathbb{R}^n$.
- Sub space of $\mathbb{R}^n$. Geometric meaning of subspaces in $\mathbb{R}^2$.and $\mathbb{R}^3$. Linear dependence and independence of vectors in $\mathbb{R}^n$. Basis anddimension and the standard basis of $\mathbb{R}^n$. Orthogonal and orthonormal bases. Representation of an arbitrary vector in an orthonormal basis. The Gram-Schmidtorthogonalisation process.

Module 2: Theory of Matrices

- (Review only) basic concepts about matrices. Operations involving matrices,different types of matrices. Representation of a system of linear equation inmatrix form. Inverse of a matrix, Cramer's rule.
- The rows and columns of a matrix as elements of $\mathbb{R}^n$ for suitable n. Rank of a matrix as the maximum number of linearly independent rows/columns. Elementary row operations. Invariance of rank under elementary row operations. The Echelon form and its uniqueness. Finding the rank of a matrix by reducing to echelon form.
- Homogeneous and non-homogeneous system of linear equations. Resultsabout the existence and nature of solution of a system of equations in terms ofthe ranks of the matrices involved.
- The eigen value problem. Method of finding the eigen values and eigenvectors of a matrix. Basic properties of eigen values and eigen vectors. Eigen values and eigen vectors of a symmetric matrix. The result that theeigen vectors of a real symmetric matrix form an orthogonal basis of $\mathbb{R}^n$.

- Diagonalisable matrices. Advantages of diagonalisable matrices incomputing matrix powers and solving system of equations. The result that asquare matrix of order n is diagonalisabe (i) if and only if it has $n$linearly independent eigen vectors (ii) if it has n distinct eigen values. Method of diagonalising a matrix. Diagonalisation of real symmetric matrices.

- Quadratic forms in $\mathbb{R}^n$ and matrix of quadratic forms. Canonical formof a quadratic form and the principal axes theorem. Geometric meaning ofprinciple axes theorem for quadratic forms in $\mathbb{R}^2$. Use of these results inidentifying the type of a conic that a general second degree equation mayrepresent.

Module 3: Linear Transformations

- Linear transformations from $\mathbb{R}^n$ into $\mathbb{R}^m$. Matrix of alinear transformation relative to a given pair of bases and linear transformation defined by a matrix. Characterisation of linear transformationsfrom $\mathbb{R}^n$ into $\mathbb{R}^m$.

- Linear transformations from $\mathbb{R}^n$ into $\mathbb{R}^n$ and matix of such tranformations. Matrix representation of simple tranformations such asrotation, reflection, projection etc. on the plane. Relation between matricesof a given transformation relative to two different bases. Method of choosing a suitable basis in which the matrix of a given transformation has the particularly simple form of a diagonal matrix.

The topics for all the above modules in this semester can be found in text [1].

DISTRIBUTION OF INSTRUCTIONAL HOURS:

Module 1: 30 hours; Module 2: 30 hours; Module 3: 30 hours

Texts

Text 1 – David C. Lay, *Linear Algebra*, Thompson Publications, 2007

References

Ref. 1 – T S Blyth and E F Robertson: *Linear Algebra*, 2nd Edition, Springer,

Ref. 2 – Erwin Kreyszig. *Advanced Engineering Mathematics*, 10th Edition, Wiley-India

Ref. 3 – Peter V. O' Neil, *Advanced Engineering Mathematics*, Thompson Publications, 2007

University of Kerala
Complementary Course in Mathematics
for First Degree Programme in Economics

Semester I
Mathematics for Economics-I

CODE: MM 1131.5

Instructional hours per week: 3
No. of Credits: 2

Overview of the course:
The complementary course intended for Economics students lays emphsis on the increased use of mathematical methods in Economics. The first Module of the first semester course discusses the basic concepts of functions, limits and continuity, which is essential to understand what is to follow in subsequent Modules. The second Module is on Differentiation. Applications to Economics abound in this area. The concepts should therefore be carefully motivated with suitable examples.

Module 1: Functions, Limits and Continuity

- Functions: Definition and examples of functions, domain and range of a function, graph of a function, notion of implicit and explicit functions, demand functions and curves, total revenue functions and curves, cost functions and curves, indifference function, indifference curves for flow of income over time.
- Limits and continuity of functions:Notion of the limit of a function with sufficient examples, algebra of limits (No proof), theorems on limits :$\lim_{x\to a}\dfrac{x^n-a^n}{x-a}=nx^{n-1}$, $\lim_{x\to 0}\dfrac{\sin x}{x}=1$,$\lim_{x\to 0}\dfrac{e^x-1}{x}=1$, $\lim_{x\to 0}\dfrac{a^x-1}{x}=\log a$, for $a>0$(No proof), definition and examples of continuous functions, discontinuity, examples, geometrical meaning of continuity

Module 2: Differentiation-I

- Differentiation: Differentiation of functions of one variable, derivative as a rate measure, rules of differentiation, derivative of a function at a point, product rule, quotient rule, function of a function rule, derivatives of standard functions, derivatives and approximate values, geometrical interpretation of the derivative, applications in economics (such as marginal revenue, marginal cost),

Texts

Text 1 - R G D Allen, *Mathematical Analysis for Economics*, AITBS Publishers, D-2/15. Krishnan Nagar, New Delhi

Text 2 - Taro Yamane, *Mathematics for Economists, An Elementary Survey*, PHI, New Delhi.

DISTRIBUTION OF INSTRUCTIONAL HOURS:

Module 1: 27 hours; Module 2: 27 hours

University of Kerala
Complementary Course in Mathematics
for First Degree Programme in Economics

Semester II
Mathematics for Economics-II

CODE: MM 1231.5 — Instructional hours per week: 3

No. of Credits: 3

Overview of the course:
The first module on differentiation discusses differntials, increasing and decreasing functions and maxima and minima, along with several applications. The second module is on partial differentiation. It considers the maxima and minima of functions of two varibles and these are readily applied to problems in Economics.

Module 1: Differentiation-II

- Further differentiation:Successive derivatives of elementary functions, differentials and approximations, increasing and decreasing functions, turning points, points of inflexion, convexity of curves, maxima and minima of functions of one variable, the problem of average and marginal values,problems of monopoly and duopoly in economic theory.

Module 2: Partial Differentiation

- Partial Differentiation: Functions of several variables, Definition and examples partial differentiation of functions of two variables, maxima and minima of functions of many variables, Lagrangian multiplier method of maxima and minima of functions, illustrations from economics, geometrical interpretation of partial derivatives, total differentials, derivatives of implicit functions, higher order partial derivatives, homogeneous functions, applications(maxima and minima problems) in economics,

Texts

Text 1 - R G D Allen, *Mathematical Analysis for Economics*, AITBS Publishers, D-2/15. Krishnan Nagar, New Delhi

Text 2 - Taro Yamane, *Mathematics for Economists, An Elementary Survey*, PHI, New Delhi.

DISTRIBUTION OF INSTRUCTIONAL HOURS:

Module 1: 27 hours; Module 2: 27 hours

University of Kerala
Complementary Course in Mathematics
for First Degree Programme in Economics

Semester III
Mathematics for Economics-III

CODE: MM 1331.5 — Instructional hours per week: 3
No. of Credits: 3

Overview of the course:

The course follows the trends set in the first two semester. Integration techniques, definite integrals and approximate integration are discussed in the first module, highlighting applications to Economics. Various infinite series form the content of the second module.

Module 1: Integration

- Integration : Integral as an antiderivative, integration by substitution, integration by parts, definition of the definite integral, definite integrals and approximate integration (Simpson's rule and trapezoidal rule),total cost, marginal cost, capitalisation of an income flow, law of growth, Domar's models on public debt and national income.

Module 2: Series

- Series: geometric, binomial, exponential and logarithmic series, Taylor's formula, Taylor series, extension to many variables.

Texts

Text 1 - R G D Allen, *Mathematical Analysis for Economics*, AITBS Publishers, D-2/15. Krishnan Nagar, New Delhi

Text 2 - Taro Yamane, *Mathematics for Economists, An Elementary Survey*, PHI, New Delhi.

DISTRIBUTION OF INSTRUCTIONAL HOURS:

Module 1: 27 hours; Module 2: 27 hours

University of Kerala
Complementary Course in Mathematics
for First Degree Programme in Economics

Semester IV
Mathematics for Economics-IV

CODE: MM 1431.5

Instructional hours per week: 3
No. of Credits: 3

Overview of the course

The two modules in this course treat differential equations, the solutions of which are important in most mathematical models. First order differential equations are considered in the first module, whereas second order differenetial equations with constant coefficients, together with the Euler equation are dealt with in the second module.

Module 1: Differential Equations-I

- Differential Equations: Formulation of differential equations, geometrical interpretation of a differential equation representing a family of curves, First order equations, Linear equations, Variables separable, Homogeneous equations.

Module 2: Differential Equations-II

- Differential equations of higher order: Second order differential equations with constant coefficients with RHS as one of $x, e^{ax}, \sin ax, \cos ax$, Euler equations, applications in economics, Domar's capital expansion model, equilibrium of a market and stability of equilibriumof a dynamic market.

Texts

Text 1 - R G D Allen, *Mathematical Analysis for Economics*, AITBS Publishers, D-2/15. Krishnan Nagar, New Delhi

Text 2 - Taro Yamane, *Mathematics for Economists, An Elementary Survey*, PHI, New Delhi.

DISTRIBUTION OF INSTRUCTIONAL HOURS:

Module 1: 27 hours; Module 2: 27 hours