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UNIVERSITY OF CALCUTTA · CCF (NEP 2020) UG SYLLABUS

Mathematics Major (Honours) Syllabus

Complete syllabus · 4-Year Major · DSCC and SEC papers

What this file contains

- Course structure, credits and programme outcomes
- All DSCC papers, Semester 1 to 8
- Skill Enhancement Courses (SEC-1, SEC-2.1, SEC-3)
- Research Methodology and research track papers
- Question patterns for every paper
- Internship, project and dissertation guidelines

Source and note

The pages that follow are taken unchanged from the official University of Calcutta syllabus for Mathematics under the Curriculum and Credit Framework for Undergraduate Programmes (CCF, NEP 2020). PALMATHS has only selected the pages for this programme and semester and added this cover so students can find them quickly. Always check the University of Calcutta website (caluniv.ac.in) for later notifications, corrections or changes in paper options. PALMATHS is an independent coaching centre and is not part of, or endorsed by, the University of Calcutta.

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Ground Floor, Boral Co-operative Bank, near Sitala Mandir, Garia, Kolkata (2 min from Kavi Nazrul Metro)

More semester-wise syllabus files and question papers: palmaths.com/cu-pyqs/

University of Calcutta



Syllabus for four-year (Eight Semester) B. Sc. Honours and Honours with Research Course with Mathematics Major

&

Mathematics as a Minor subject

and

Syllabus for three-year (Six Semester) Multidisciplinary Course with Mathematics

Under

Curriculum and Credit Framework (CCF)

Odd Semester : July to December

Even Semester : January to June

The syllabus for the 4 Year B.A./B.Sc. Honours and Honours with Research Course with Mathematics Major is effective from the academic year **2023-24**.

The syllabus for the 3 Year Multidisciplinary Course with Mathematics is effective from the academic year **2023-24**.

Distribution of Credits and Marks for
4-year B.A./B.Sc. Honours & Honours with Research, with Mathematics Major

	DSCC/ Core (Major)	**Minor** (m1 & m2)	**IDC**	**AEC**	**SEC**	**CVAC**	**Summer Intern-ship***	**Research Internship/ Dissertation**	**Total Credit**
Sem.	$22 \times 4 = 88$	$8 \times 4 = 32$	$3 \times 3 = 9$	$4 \times 2 = 8$	$3 \times 4 = 12$	$4 \times 2 = 8$	$1 \times 3 = 3$	$(1 \times 4 = 4)+$ $(1 \times 8 = 8) = 12$	**172**
I	$1 \times 4 = 4$ 3Th + 1TU	$1 \times 4 = 4$(m1) 3Th + 1P/TU	$1 \times 3 = 3$ 2Th + 1P/TU	$1 \times 2 = 2$ 2Th + 0P/TU	$1 \times 4 = 4$	$2 \times 2 = 4$			**21**
II	$1 \times 4 = 4$ 3Th + 1TU	$1 \times 4 = 4$(m1) 3Th + 1P/TU	$1 \times 3 = 3$ 2Th + 1P/TU	$1 \times 2 = 2$ 2Th + 0P/TU	$1 \times 4 = 4$	$2 \times 2 = 4$			**21**
III	$2 \times 4 = 8$ 2×(3Th + 1TU)	$1 \times 4 = 4$(m2) 3Th + 1P/TU	$1 \times 3 = 3$ 2Th + 1P/TU	$1 \times 2 = 2$ 2Th + 0P/TU	$1 \times 4 = 4$				**21**
IV	$4 \times 4 = 16$ 4×(3Th + 1TU)	$1 \times 4 = 4$(m2) 3Th + 1P/TU		$1 \times 2 = 2$ 2Th + 0P/TU					**22**
V	$4 \times 4 = 16$ 4×(3Th + 1TU)	(m1 or m2) $2 \times 4 = 8$ 2×(3Th + 1P/TU)							**24**
VI	$3 \times 4 = 12$ 3×(3Th + 1P/TU)	(m1 or m2) $2 \times 4 = 8$ 2×(3Th + 1P/TU)							**20**
VII	$5 \times 4 = 20$ 5×(3Th + 1TU)								**20**
VIII	**Honours**								**20**
	$5 \times 4 = 20$ 5×(3Th + 1P/TU)								
	Honours with Research								
	$2 \times 4 = 8$ (RM) 2× (3Th+1VV)							$(1 \times 4 = 4)+$ $(1 \times 8 = 8) = 12$	
Credit	$25 \times 4 = 100$ / $22 \times 4 = 88$	$8 \times 4 = 32$	$3 \times 3 = 9$	$4 \times 2 = 8$	$3 \times 4 = 12$	$4 \times 2 = 8$	$1 \times 3 = 3$	/ $(1 \times 4 = 4)+$ $(1 \times 8 = 8) = 12$	$169 + 3$ **=172**
Marks	$25 \times 100 = 2500$ / $22 \times 100 = 2200$	$8 \times 100 = 800$	$3 \times 75 = 225$	$4 \times 50 = 200$	$3 \times 100 = 300$	$4 \times 50 = 200$	$3 \times 25 = 75$	/ $(1 \times 100)+$ $(1 \times 200) = 300$	**=4300**

DSCC - Discipline Specific Core Course; **IDC -** Inter Disciplinary Course; **AEC -** Ability Enhancement Course; **SEC -** Skill Enhancement Course; **CVAC -** Common Value Added Course; **RM -** Research Methodology. Th - Theory, P - Practical, TU - Tutorial, VV - Viva Voce.
***The summer Internship should be completed either after Semester II / Semester IV / Semester VI.**

4-yr Credit Distribution | MDC Credit Distribution | Course Overview
Major | Minor | MDC | Question Pattern

Semesterwise Courses at a glance

Semester	Course	Paper Code	Name of Paper	Credit	Page
ONE (I)	MAJOR	MTHM-DSCC 1	Calculus, Geometry & Vector Analysis	3TH+1TU = 4	10
	MAJOR	MTHM-SEC 1	C language with Mathematical Applications	3TH+1TU = 4	73
	MINOR	MMTH-MN1	Calculus, Geometry & Vector Analysis	3TH+1TU = 4	10
	MDC	MMTH-MDC-CC1	Calculus, Geometry & Vector Analysis	3TH+1TU = 4	10
	MDC	MMTH-SEC	C language with Mathematical Applications	3TH+1TU = 4	73
	IDC	MTHD-IDC	Mathematics in Daily Life	2TH+1TU = 3	92
TWO (II)	MAJOR	MTHM-DSCC 2	Basic Algebra	3TH+1TU=4	12
	MAJOR	MTHM-SEC 2.1 or MTHM-SEC 2.2	Python Programming and Introduction to Latex or Artificial Intelligence	3TH+1TU=4	75
	MINOR	MMTH-MN2	Basic Algebra	3TH+1TU=4	12
	MDC	MMTH-MDC-CC2	Basic Algebra	3TH+1TU=4	12
	MDC	MMTH-SEC	C language with Mathematical Applications	3TH+1TU=4	73
	IDC	MTHD-IDC	Mathematics in Daily Life	2TH+1TU=3	92
THREE (III)	MAJOR	MTHM-DSCC 3	Real Analysis	3TH+1TU=4	14
	MAJOR	MTHM-DSCC 4	Ordinary Differential equations - I & Group Theory - I	3TH+1TU=4	16
	MAJOR	MTHM-SEC 3	Linear Programming & Rectangular Games	3TH+1TU=4	78
	MINOR	MMTH-MN1	Calculus, Geometry & Vector Analysis	3TH+1TU=4	10
	MDC	MMTH-MDC-CC3	Ordinary Differential equations & Group Theory	3TH+1TU=4	80
	MDC	MMTH-SEC	C language with Mathematical Applications	3TH+1TU=4	73
	MDC	MMTH-MDC-mn1	Calculus, Geometry & Vector Analysis	3TH+1TU=4	10
	IDC	MTHD-IDC	Mathematics in Daily Life	2TH+1TU=3	92
FOUR (IV)	MAJOR	MTHM-DSCC 5	Theory of Real Functions	3TH+1TU=4	18
	MAJOR	MTHM-DSCC 6	Mechanics - I	3TH+1TU=4	20
	MAJOR	MTHM-DSCC 7	Multivariate Calculus - I & Partial Differential Equation - I	3TH+1TU=4	22
	MAJOR	MTHM-DSCC 8	Group Theory - II & Ring Theory - I	3TH+1TU=4	25
	MINOR	MMTH-MN2	Basic Algebra	3TH+1TU=4	12
	MDC	MMTH-MDC-CC4	Mechanics	3TH+1TU=4	82
	MDC	MMTH-MDC-CC5	Advanced Calculus	3TH+1TU=4	84
	MDC	MMTH-MDC-mn2	Basic Algebra	3TH+1TU=4	12
FIVE (V)	MAJOR	MTHM-DSCC 9	Probability & Statistics	3TH+1TU=4	27
	MAJOR	MTHM-DSCC 10	Ring Theory - II & Linear Algebra - I	3TH+1TU=4	29
	MAJOR	MTHM-DSCC 11	Riemann Integration & Series of Functions	3TH+1TU=4	31
	MAJOR	MTHM-DSCC 12	Mechanics - II	3TH+1TU=4	33
	MINOR	MMTH-MN3	Ordinary Differential equations & Group Theory	3TH+1TU=4	80
	MINOR	MMTH-MN4	Mechanics	3TH+1TU=4	82
	MDC	MMTH-MDC-CC6	Statistics & Numerical Analysis	3TH+1TU=4	86
	MDC	MMTH-MDC-CC7	Mathematical Methods	3TH+1TU=4	88
	MDC	MMTH-MDC-mn3	Ordinary Differential equations & Group Theory	3TH+1TU=4	80
	MDC	MMTH-MDC-mn4	Mechanics	3TH+1TU=4	82
SIX (VI)	MAJOR	MTHM-DSCC 13	Metric Space & Complex Analysis - I	3TH+1TU=4	35
	MAJOR	MTHM-DSCC 14	Multivariate Calculus - II & Applications of Calculus	3TH+1TU=4	37
	MAJOR	MTHM-DSCC 15	Numerical Analysis	3TH+1P=4	39
	MINOR	MMTH-MN3	Ordinary Differential equations & Group Theory	3TH+1TU=4	80
	MINOR	MMTH-MN4	Mechanics	3TH+1TU=4	20
	MDC	MMTH-MDC-CC7	Mathematical Methods	3TH+1TU=4	88
	MDC	MMTH-MDC-CC8	Discrete Mathematics	3TH+1TU=4	90
	MDC	MMTH-MDC-mn5	Advanced Calculus	3TH+1TU=4	84
	MDC	MMTH-MDC-mn6	Statistics & Numerical Analysis	3TH+1TU=4	86

Semester	Course	Paper Code	Name of Paper	Credit	Page
SEVEN (VII)	MAJOR	MTHM-DSCC 16	Group Theory - III & Linear Algebra - II	3TH+1TU=4	41
	MAJOR	MTHM-DSCC 17	Complex Analysis - II & Measure Theory - I	3TH+1TU=4	43
	MAJOR	MTHM-DSCC 18	Generalised functions, Integral Transforms Integral Equations	3TH+1TU=4	45
	MAJOR	MTHM-DSCC 19	Topology - I	3TH+1TU=4	47
	MAJOR	MTHM-DSCC 20	Functional Analysis - I	3TH+1TU=4	49
EIGHT (VIII)		**Honours without Research**			
	MAJOR	MTHM-DSCC 21	Ordinary Differential Equation - II & Partial Differential Equation - II	3TH+1TU=4	51
	MAJOR	MTHM-DSCC 22	Graph Theory	3TH+1TU=4	53
	MAJOR	MTHM-DSCC 23.1	Mechanics - III	3TH+1TU=4	55
		or	or		
	MAJOR	MTHM-DSCC 23.2	Measure Theory - II	3TH+1TU=4	57
	MAJOR	MTHM-DSCC 24.1	Operations Research & Stochastic Process	3TH+1TU=4	59
		or	or		
	MAJOR	MTHM-DSCC 24.2	Differential Geometry	3TH+1TU=4	61
	MAJOR	MTHM-DSCC 25.1	Fluid Mechanics & Computational Mathematics	3TH+1P=4	63
		or	or		
	MAJOR	MTHM-DSCC 25.2	Functional analysis - II & Topology - II	3TH+1TU=4	66
		Honours with Research			
	MAJOR	MTHM-RM1	Research Methodology - I	3TH +1Viva =4	68
	MAJOR	MTHM-RM2	Research Methodology - II	3TH +1Viva =4	70
	MAJOR		Research Internship	4	107
	MAJOR		Dissertation/Project	8	108

Note.

1. MMTH-MN3 and MMTH-MN4 (both) shall be studied in either Semester Five or in Semester Six.
2. If Mathematics is chosen as Core Course 2 in MDC then only CC6 (Statistical & Numerical Analysis) will be taught in Semester Five and the papers CC7 (Mathematical Methods) and CC8 (Discrete Mathematics) will be taught in Semester Six.
3. **Refer to Notification No. CSR/36/2023 and Notification No. CSR/35/2024 for the Syllabus and Question Pattern for the paper "Artificial Intelligence".**
4. Marks for Tutorial will be awarded on the basis of Internal Assessment through evaluation of internal assignments for SEC papers and internal examinations for Core, Minor and IDC papers.

4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Course Structure for
4-year B.A./B.Sc. Honours & Honours with Research, with Mathematics Major

Semester	Paper Code	Name of Paper	Credit	Page No.
I	MTHM-DSCC 1	Calculus, Geometry & Vector Analysis	3TH+1TU = 4	10
	MTHM-SEC 1	C language with Mathematical Applications	3TH+1TU = 4	73
II	MTHM-DSCC 2	Basic Algebra	3TH+1TU=4	12
	MTHM-SEC 2.1 or MTHM-SEC 2.2	Python Programming & Introduction to Latex or *Artificial Intelligence	3TH+1TU=4	75
III	MTHM-DSCC 3	Real Analysis	3TH+1TU=4	14
	MTHM-DSCC 4	Ordinary Differential equations - I & Group Theory - I	3TH+1TU=4	16
	MTHM-SEC 3	Linear Programming & Rectangular Games	3TH+1TU=4	78
IV	MTHM-DSCC 5	Theory of Real Functions	3TH+1TU=4	18
	MTHM-DSCC 6	Mechanics - I	3TH+1TU=4	20
	MTHM-DSCC 7	Multivariate Calculus–I & Partial Differential Equation - I	3TH+1TU=4	22
	MTHM-DSCC 8	Group Theory - II & Ring Theory - I	3TH+1TU=4	25
V	MTHM-DSCC 9	Probability & Statistics	3TH+1TU=4	27
	MTHM-DSCC 10	Ring Theory - II & Linear Algebra - I	3TH+1TU=4	29
	MTHM-DSCC 11	Riemann Integration & Series of Functions	3TH+1TU=4	31
	MTHM-DSCC 12	Mechanics - II	3TH+1TU=4	33
VI	MTHM-DSCC 13	Metric Space & Complex Analysis-I	3TH+1TU=4	35
	MTHM-DSCC 14	Multivariate Calculus II & Applications of Calculus	3TH+1TU=4	37
	MTHM-DSCC 15	Numerical Analysis	3TH+1P=4	39
VII	MTHM-DSCC 16	Group Theory-III & Linear Algebra-II	3TH+1TU=4	41
	MTHM-DSCC 17	Complex Analysis - II & Measure Theory - I	3TH+1TU=4	43
	MTHM-DSCC 18	Generalised functions, Integral Transforms Integral Equations	3TH+1TU=4	45
	MTHM-DSCC 19	Topology - I	3TH+1TU=4	47
	MTHM-DSCC 20	Functional Analysis - I	3TH+1TU=4	49
VIII		**Honours**		
	MTHM-DSCC 21	Ordinary Differential Equation - II & Partial Differential Equation - II	3TH+1TU=4	51
	MTHM-DSCC 22	Graph Theory	3TH+1TU=4	53
	MTHM-DSCC 23.1 or MTHM-DSCC 23.2	Mechanics - III or Measure Theory - II	3TH+1TU=4 3TH+1TU=4	55 57
	MTHM-DSCC 24.1 or MTHM-DSCC 24.2	Operations Research & Stochastic Process or Differential Geometry	3TH+1TU=4 3TH+1TU=4	59 61
	MTHM-DSCC 25.1 or MTHM-DSCC 25.2	Fluid Mechanics & Computational Mathematics or Functional analysis - II & Topology - II	3TH+1P=4 3TH+1TU=4	63 66
		Honours with Research		
	MTHM-RM1	Research Methodology - I	3TH +1Viva =4	68
	MTHM-RM2	Research Methodology - II	3TH +1Viva =4	70
		Research Internship	4	107
		Dissertation/Project	8	108

***Refer to Notification No. CSR/36/2023 and Notification No. CSR/35/2024 for the Syllabus and Question Pattern for the paper "Artificial Intelligence".**

4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Program Specific Outcome of

B. Sc. with Mathematics as a Major or a Minor subject

The Programme Specific Outcomes (POs) are the broader, expected outcomes that students should demonstrate upon completion of a program and the program is designed in such a fashion that it corroborates the basic aim of the National Education Policy, 2020 to nurture well-rounded individuals who can contribute to society by fostering critical thinking, creativity, and problem-solving skills. It also aims to foster the holistic development of students, encompassing their intellectual, social, physical, emotional, and moral capacities.

PSO1 The basic objective of studying Mathematics Major/ Minor course is to develop the mathematical reasoning power of the students and logical support behind an assumption. Throughout the entire course the students learn different branches of mathematics with which they are not only equipped with solution of different types of problems by framing a proper mathematical model but they can logically justify the model and the computational procedures with proper mathematical reasoning.

PSO2 Another objective of cultivating Mathematics Major/ Minor course is to enhance the power of critical thinking of the students by solving varieties of unsolved Mathematical problems and this programme will provide a very strong foundation in Mathematiccal concepts, problem-solving skills and the ability to apply mathematical knowledge in various fields.

PSO3 The entire syllabus for Undergraduate Course is framed in such a way that after successful completion of three year / four year courses phase by phase the students will be able to solve the mathematical problems with minimum error and the students will be equipped with mathematical skills and techniques which they can apply in both academic and non-academic areas in work. The Students will be able to translate real-world problems into mathematical models and analyze these models to draw conclusions by developing critical thinking skills to evaluate mathematical arguments.

PSO4 The students will develop strong understanding and good grasp over the areas of Algebra, Analysis, Metric spaces and Complex analysis, Geometry, Calculus and advanced calculus, Ordinary and Partial differential equations, Mechanics, Mathematical methods and computational skill using computer languages. The theory and its applications will motivate the students for critical thinking towards further specialisation and to pursue research in mathematics in India and abroad including literature survey, data analysis, critical thinking and formulating research questions.

PSO5 The students will develop a comprehensive knowledge of all the classical and applied fields of mathematics and they will be able to apply mathematical knowledge to problems in other disciplines, such as computer science, economics, and different engineering biomedical fields.

PSO6 It offers a flexibility of programme structure while ensuring that the student gets a strong foundation in the subject and gains in-depth knowledge over the subject. The students will be employable for teaching in educational Institutes and to serve in different consultancy services, Bank, Research and Development wings of different service sectors.

Calculus, Geometry & Vector Analysis

Semester : I	Paper Code : MTHM-DSCC 1-TH MMTH-MN1-TH MMTH-MDC-CC1-TH
Semester : III	Paper Code : MMTH-MN1-TH MMTH-MDC-mn1-TH
Credit : 4	Full Marks : 100 (Theory : 75 & Tutorial : 25)
Minimum number of classes required : 60	

4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Course Outcome

CO1 : To understand and compute higher-order derivatives, apply Leibniz's rule and its applications, and use L'Hospital's rule to evaluate limits.

CO2 : To develop proficiency in solving problems involving higher-order derivatives, Leibniz's rule, and L'Hospital's rule.

CO3 : To learn reduction formulae and apply them to determine the arc length of a curve, the area under a curve, and the area and volume of surfaces of revolution.

CO4 : To study the classification of conic sections, reduce them to canonical form, and determine equations of tangents, normals, and polars.

CO5 : To acquire detail knowledge of spheres, cylindrical surfaces, central conicoids, different quadric surfaces.

CO6 : To apply vector equations to problems in geometry and mechanics, and to perform differentiation and integration of vector functions.

Group A : Calculus [Marks : 20] [16 classes]

- Differentiability of a function at a point and in an interval. Meaning of sign of derivative. Differentiating Hyperbolic functions, higher order derivatives, Leibnitz rule and its applications to functions of type $e^{ax+b}\sin x$, $e^{ax+b}\cos x$, $(ax+b)^n\sin x$, $(ax+b)^n\cos x$. Indeterminate forms. L'Hospital's rule (statement and example).
- Reduction formulae, derivations and illustrations of reduction formulae of the type $\int \sin^n x dx$, $\int \cos^n x dx$, $\int \tan^n x dx$, $\int \sec^n x dx$, $\int (\log x)^n dx$, $\int \sin^n x \sin mx\, dx$, $\int \sin^n x \cos^m x\, dx$. Parametric equations, parametrizing a curve, arc length of a curve, arc length of parametric curves, area under a curve, area and volume of surface of revolution.

Group B : Geometry [Marks : 35] [28 classes]

- Rotation of axes and second degree equations, classification of conics using the discriminant, reduction to canonical form, tangent and normal, polar equations of conics.
- Spheres, Cylindrical surfaces. Central conicoids, paraboloids, plane sections of conicoids, generating lines, identification of quadric surfaces like cone, cylinder, ellipsoid, hyperboloid, classification of quadrics.

Group C : Vector Analysis [Marks : 20] [16 classes]

- Triple product, vector equations, applications to geometry and mechanics — concurrent forces in a plane, theory of couples, system of parallel forces. Introduction to vector functions, operations with vector-valued functions, limits and continuity of vector functions, differentiation and integration of vector functions of one variable.

References

[1] H. Anton, I. Bivens and S. Davis, Calculus, 10th Ed., John Wiley and Sons (Asia) P. Ltd., Singapore, 2015.

[2] T. Apostol, Calculus, Volumes I and II, Wiley and Sons, 1969.

[3] R. Courant and F. John, Introduction to Calculus and Analysis (Volumes I & II), Springer-Verlag, New York, Inc., 1989.

[4] R. R. Goldberg, Methods of Real analysis, Oxford and IBH Publishing, 2020.

[5] M. J. Strauss, G. L. Bradley and K. J. Smith, Calculus, 3rd Ed., Dorling Kindersley (India) P. Ltd. (Pearson Education), Delhi, 2022.

[6] G. B. Thomas and R. L. Finney, Calculus, 14th Ed., Pearson Education, Delhi, 2018.

[7] Robert J. T. Bell, Co-ordinate Geometry of Three Dimensions, Macmillan and Co. Ltd., London, 2018.

[8] S. L. Loney, Co-ordinate Geometry, 6th Ed., Arihant Publications, 2016.

[9] J. Marsden and Tromba, Vector Calculus, W. H. Freeman and Co., 6th Ed., 2011.

[10] M. R. Speigel, Schaum's outline of Vector Analysis, Tata McGraw Hill, 2011.

4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Basic Algebra

Semester : II	Paper Code : MTHM-DSCC 2-TH MMTH-MN2-TH MMTH-MDC-CC2-TH
Semester : IV	Paper Code : MMTH-MN2-TH MMTH-MDC-mn2-TH
Credit : 4	Full Marks : 100 (Theory : 75 & Tutorial : 25)
Minimum number of classes required : 60	

4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Course Outcome

CO1 : To study exponential, logarithmic, trigonometric, and hyperbolic functions of a complex variable.

CO2 : To develop the ability to solve cubic and biquadratic equations.

CO3 : To acquire knowledge of equivalence relations, partial order relations, linear order relations, and composition of mappings.

CO4 : To understand the well-ordering property of positive integers, the division algorithm, and congruence relations among integers.

CO5 : To learn about the existence and uniqueness of solutions to systems of linear equations, including row reduction and echelon forms.

CO6 : To study the algebraic and geometric properties of vectors in n-dimensional space, including linear independence and its algebraic and geometric characterizations.

Group A [Marks : 25] [20 classes]

- Polar representation of complex numbers, n-th roots of unity, De Moivre's theorem for rational indices and its applications. Exponential, logarithmic, trigonometric and hyperbolic functions of complex variable.
- Theory of equations : Relation between roots and coefficients, transformation of equation, Descartes rule of signs, application of Sturm's theorem, cubic equation (solution by Cardan's method) and biquadratic equation (solution by Ferrari's method).
- Inequalities : The inequality involving $AM \geq GM \geq HM$, Cauchy-Schwartz inequality.

Group B [Marks : 25] [20 classes]

- Relation : equivalence relation, equivalence classes & partition, partial order relation, poset, linear order relation.
- Mapping : composition of mappings, relation between composition of mappings and various set theoretic operations. Meaning and properties of $f^{-1}(B)$, for any mapping $f : X \to Y$ and $B \subseteq Y$.
- Well-ordering property of positive integers, Principles of Mathematical induction, equivalence of Well-ordering property and Principles of Mathematical induction (statement only), division algorithm, divisibility and Euclidean algorithm. Prime numbers and their properties, Euclid's theorem. Congruence relation between integers. Fundamental Theorem of Arithmetic. Chinese remainder theorem. Arithmetic functions, some arithmetic functions such as φ, τ, σ and their properties.

Group C [Marks : 25] [20 classes]

- Systems of linear equations, homogeneous and non-homogeneous systems. Existence and uniqueness of solution. The matrix equation $Ax = b$, row reduction and echelon forms, uniqueness of reduced echelon form. Rank of a matrix and characterization of invertible matrices, Pivot positions, basic and free variables, parametric description of the solution set. Existence and uniqueness theorem.
- Vectors in $\mathbb{R}^n$, algebraic and geometric properties of the vectors. Vector form of a linear system and the column picture. Existence of solutions and linear combination of vectors. Geometry of linear combination and subsets spanned by some vectors. Uniqueness of solution and Linear independence of vectors. Algebraic and geometric characterizations of linearly independent subsets.

References

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[2] W. S. Burnside and A.W. Panton, Theory of equations, Dublin University Press Series, S. Chand & Co., Pvt. Ltd., 1986.

[3] Edgar G. Goodaire and Michael M. Parmenter, Discrete Mathematics with Graph Theory, 3rd Ed., Pearson Education (Singapore) P. Ltd., Indian Reprint, 2005.

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[6] David C. Lay, Linear Algebra and its Applications, 3rd Ed., Pearson Education Asia, Indian Reprint, 2007.

[7] Gilbert Strang, Introduction to Linear Algebra, 5th Ed., Wellesley-Cambridge Press, 2019.

4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Real Analysis

Semester : III	Paper Code : MTHM-DSCC 3-TH
Credit : 4	Full Marks : 100 (Theory : 75 & Tutorial : 25)
Minimum number of classes required : 60	

4-yr Credit Distribution | MDC Credit Distribution | Course Overview
Major | Minor | MDC | Question Pattern

Course Outcome

CO1 : To understand the concepts of countable and uncountable sets, as well as bounded and unbounded sets.

CO2 : To learn the concepts of interior points, open sets, limit points, closed sets, dense sets, and related topological ideas.

CO3 : To study real sequences, their convergence, and the concept of subsequences.

CO4 : To study infinite series and apply various tests to determine their convergence.

Group A [Marks : 30] [24 classes]

- Intuitive idea of real numbers. Mathematical operations and usual order of real numbers revisited with their properties (closure, commutative, associative, identity, inverse, distributive). Idea of countable sets, uncountable sets and uncountability of $\mathbb{R}$. Concept of bounded and unbounded sets in $\mathbb{R}$. L.U.B. (supremum), G.L.B. (infimum) of a set and their properties. L.U.B. axiom or order completeness axiom. Archimedean property of $\mathbb{R}$. Density of rational (and Irrational) numbers in $\mathbb{R}$.
- Intervals. Neighbourhood of a point. Interior point. Open set. Union, intersection of open sets. Limit point and isolated point of a set. Bolzano-Weirstrass theorem for sets. Existence of limit point of every uncountable set as a consequence of Bolzano-Weirstrass theorem. Derived set. Closed set (defined as Complement of open set). Union and intersection of closed sets as a consequence. No nonempty proper subset of $\mathbb{R}$ is both open and closed. Expressing an open set of $\mathbb{R}$ as countable union of disjoint open intervals (statement only). Dense set in $\mathbb{R}$ as a set having non-empty intersection with every open interval. $\mathbb{Q}$ and $\mathbb{R} \setminus \mathbb{Q}$ are dense in $\mathbb{R}$.

Group B [Marks : 35] [28 classes]

- Real sequence. Bounded sequence. Convergence and non-convergence. Examples. Boundedness of convergent sequence. Uniqueness of limit. Algebra of limits.
- Relation between the limit point of a set and the limit of a convergent sequence of distinct elements. Monotone sequences and their convergence. Sandwich rule. Nested interval theorem. Limit of some important sequences : $\left\{n^{\frac{1}{n}}\right\}_n$, $\{a^n\}_n$, $\left\{a^{\frac{1}{n}}\right\}_n$, $\{x_n\}_n$ with $\frac{x_{n+1}}{x_n} \to l$ and $|l| < 1$, $\left\{\left(1+\frac{1}{n}\right)^n\right\}_n$, $\left\{1+\frac{1}{1!}+\frac{1}{2!}+\cdots+\frac{1}{n!}\right\}_n$, $\{a^{x_n}\}_n$ $(a > 0)$. Cauchy's first and second limit theorems.
- Subsequence. Subsequential limits, $\limsup$ as the L.U.B. and $\liminf$ as the G.L.B of a set containing all the subsequential limits. Alternative definition of limsup and liminf of a sequence using inequality or as $\limsup x_n = \inf_n \sup\{x_n, x_{n+1}, \dots,\}$ and $\liminf x_n = \sup_n \inf\{x_n, x_{n+1}, \dots,\}$ [Equivalence between these definitions is assumed]. A bounded sequence $\{x_n\}$ is convergent if and only if $\limsup x_n = \liminf x_n$. Every sequence has a monotone subsequence. Bolzano-Weirstrass theorem for sequence. Cauchy sequence. Cauchy's general principle of Convergence.

Group C [Marks : 10] [8 classes]

- Infinite series, convergence and non-convergence of infinite series, Cauchy criterion, tests for convergence - comparison test, limit comparison test, ratio test, Cauchy's n-th root test, Kummer's test (statement and problems), Raabe's test (statement and problems), Gauss test (statement and problems). Alternating series, Leibniz test. Absolute and conditional convergence, Riemann's rearrangement theorem (statement and problems).

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4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Ordinary Differential Equations - I & Group Theory - I

Semester : III	Paper Code : MTHM-DSCC 4-TH
Credit : 4	Full Marks : 100 (Theory : 75 & Tutorial : 25)
Minimum number of classes required : 60	

4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Course Outcome

CO1 : To understand the formation of differential equations and the methods for solving them.

CO2 : To learn techniques for solving first-order, first-degree, and higher-degree differential equations.

CO3 : To study methods for solving higher-order linear and nonlinear differential equations.

CO4 : To study the algebraic structure of groups, including elementary properties, subgroups, order of a group, cyclic groups, alternating groups, and related concepts.

Group A : Ordinary Differential Equations - I [Marks : 45] [36 classes]

- Formation of differential equations, order and degree of a differential equation. First order and first degree differential equations. Homogeneous and exact differential equations, conditions for an equation of the first order to be exact. Integrating factors. Rules for finding integrating factors. Linear equations and Bernoulli equations.
- First order higher degree differential equations solvable for x, y and p. Clairaut's forms. Singular solutions. Equations of tac-locus, nodal locus and cuspidal locus.
- Higher order linear and non-linear equations. Concept of Wronskian and its properties. Complementary functions, particular integrals. Linear homogeneous and non-homogeneous equations with constant coefficient. Method of undetermined coefficients. Method of variation of parameters. Simultaneous linear differential equations.
- Higher order linear equations with variable coefficients reducible to linear equations with constant coefficients (Euler's equation). Condition for exactness of higher order linear equations. Integrating factors. Equations of the form $\frac{d^n y}{dx^n} = f(y)$ $(n \geq 2)$.

Group B : Group Theory - I [Marks : 30] [24 classes]

- Definition of a group, examples of groups including permutation groups, dihedral groups and quaternion groups (through matrices), elementary properties of groups, examples of commutative and non-commutative groups. Subgroups and examples of subgroups, necessary and sufficient condition for a nonempty subset of a group to be a subgroup. Normalizer, centralizer, center of a group, product of subgroups.
- Order of an element of a group, order of a group. Cyclic groups. Properties of cyclic groups, classification of subgroups of cyclic groups. Permutation, cycle notation for permutations, properties of permutation, even and odd permutations. Alternating group. Properties of cosets. Lagrange's theorem and consequences including Fermat's Little theorem.

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4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Theory of Real Functions

Semester : IV	Paper Code : MTHM-DSCC 5-TH
Credit : 4	Full Marks : 100 (Theory : 75 & Tutorial : 25)
Minimum number of classes required : 60	

4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Course Outcome

CO1 : To develop a thorough understanding of limits and continuity of functions.

CO2 : To acquire knowledge of bounded functions, types of discontinuities, and uniform continuity.

CO3 : To study Rolle's Theorem, the Mean Value Theorems, and Taylor's Theorem, along with their applications, including the existence of local extrema of a function on an interval.

Group A : Limit & Continuity of functions [Marks : 45] [36 classes]

- Limits of functions ($\epsilon - \delta$ approach), sequential criterion for limits. Cauchy's criterion of existence of limit (statement only). Limit theorems, one sided limits. Infinite limits and limits at infinity. Important limits like $\frac{\sin x}{x}$, $\frac{\log(1+x)}{x}$, $\frac{a^x-1}{x}$ $(a > 0)$ as $x \to 0$.
- Continuity of a function on an interval and at an isolated point. Sequential criteria for continuity. Concept of oscillation of a function at a point. A function is continuous at x if and only if its oscillation at x is zero. Familiarity with the figures of some well known functions : $y = x^a\,(a = 2, 3, \frac{1}{2}, -1)$, $|x|$, $[x]$, $\sin x$, $\cos x$, $\tan x$, $\log x$, e^x. Algebra of continuous functions as a consequence of algebra of limits. Continuity of composite functions. Examples of continuous functions. Continuity of a function at a point does not necessarily imply the continuity in some neighbourhood of that point.
- Bounded functions. Neighbourhood properties of continuous functions regarding boundedness and maintenance of same sign. Continuous function on a closed interval $[a, b]$ is bounded and attains its bounds therein. Bolzano's theorem, Intermediate value theorem.
- Discontinuity of functions, types of discontinuity. Step functions. Piecewise continuity. Monotone functions. Monotone functions can have only jump discontinuity. Monotone functions can have atmost countably many points of discontinuity. Monotone bijective function from an interval to an interval is continuous and its inverse is also continuous.
- Uniform continuity. Functions continuous on a closed and bounded interval is uniformly continuous. A necessary and sufficient condition under which a continuous function on a bounded open interval I will be uniformly continuous on I. A sufficient condition under which a continuous function on an unbounded open interval I will be uniformly continuous on I(statement only). Lipschitz condition and uniform continuity.

Group B : Differentiability of functions [Marks : 30] [24 classes]

- Darboux theorem, Rolle's theorem, Mean value theorems of Lagrange and Cauchy — as an application of Rolle's theorem. Taylor's theorem on closed and bounded interval with Lagrange's and Cauchy's form of remainder. Expansion of e^x, $\log(1+x)$, $(1+x)^m$, $\sin x$, $\cos x$ with their range of validity (assuming relevant theorems). Application of Taylor's theorem to inequalities.

- Point of local extremum (maximum, minimum) of a function in an interval. Sufficient condition for the existence of a local maximum/minimum of a function at a point (statement only). Application of the principle of maximum/minimum in geometrical problems.

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4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Mechanics - I

Semester : IV	Paper Code : MTHM-DSCC 6-TH
Credit : 4	Full Marks : 100 (Theory : 75 & Tutorial : 25)
Minimum number of classes required : 60	

4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Course Outcome

CO1 : To understand the principles of forces, including resultant forces, resultant couples, and coplanar force systems.

CO2 : To study rectilinear motion and simple harmonic motion.

CO3 : To develop the ability to solve problems related to work, power, and energy.

CO4 : To study impulsive forces and the collision of elastic bodies.

CO5 : To develop the ability to solve problems involving the motion of a particle in two dimensions.

Statics - I

- Idea about Physical Independence, Principle of Forces, Principle of transmissibility of a force, Principle of action and reaction and Principle of parallelogram law of forces, Composition and resolution of forces, Concurrent forces in a plane, Composition and resolution of forces, Equilibrium of three forces acting at a point, Lami's theorem, Moment of a force about a point and an axis, Varignon's theorem, Resultant forces and resultant couple, Coplanar forces: Its reduction and conditions of equilibrium. [8 classes]

Particle Dynamics - I

- Law of gravitation, Concept of inertial frame, Newton's laws of motion, Concept of equation of motion of a particle, Rectilinear motion in a given force field, Simple harmonic motion, damped and forced oscillations, Concept of resonance, motion of elastic strings, Rectilinear motion under uniform gravity, Rectilinear motion in a resisting medium where resistance is proportional to velocity. [18 classes]
- Work, power, energy, Conservative forces, Potential energy, Existence of Potential energy function, Conservative field and Principle of conservation of energy.
  . [6 classes]
- Impulse of a force, Impulsive force, Principle of conservation of linear momentum, Collision of elastic bodies: Coefficient of restitution, Newton's law of collision, Direct and oblique impact of a smooth sphere with a fixed plane, Direct and oblique impact of two smooth spheres. [8 classes]
- Motion of a particle in a plane (2D Cartesian): Angular velocity and angular acceleration, Expressions for components of velocity and acceleration, Tangential and normal components of velocity and acceleration, Motion of a projectile in a resisting medium under gravity. Motion of a particle in a plane (2D Polar): Expressions for components of velocity and acceleration, Central forces and central orbits, Motion under inverse square law, Times of describing the arcs of central orbits for a particle moving under inverse square law, Kepler's laws on planetary motion, Motion of artificial satellites, Tangential and normal components of velocity and acceleration, Constrained motion of a particle on smooth curve. [20 classes]

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4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Multivariate Calculus - I and Partial Differential Equations - I

Semester : IV	Paper Code : MTHM-DSCC 7-TH
Credit : 4	Full Marks : 100 (Theory : 75 & Tutorial : 25)
Minimum number of classes required : 60	

4-yr Credit Distribution | MDC Credit Distribution | Course Overview
Major | Minor | MDC | Question Pattern

Course Outcome

CO1 : To learn the concepts of limits, continuity, differentiability, and partial derivatives of functions of two or more variables.

CO2 : To learn how to compute directional derivatives, gradients, tangent planes, and higher-order partial derivatives.

CO3 : To study homogeneous functions and implicit functions.

CO4 : To determine extrema of functions of two variables and evaluate multiple and repeated integrals.

CO5 : To understand the classification of partial differential equations (PDEs), and learn methods for solving quasilinear and semilinear equations, including Charpit's general method for nonlinear first-order PDEs.

Group A : Multivariate Calculus - I [Marks : 60] [50 classes]

- Concept of neighbourhood of a point in $\mathbb{R}^n$ $(n > 1)$, interior point, limit point, open set and closed set in $\mathbb{R}^n$ $(n > 1)$.
- Functions from R^n $(n > 1)$ to $\mathbb{R}$, limit and continuity of functions of two or more variables. Partial derivatives, related mean value theorem, sufficient condition for continuity. Differentiability, sufficient condition for differentiability.
- Directional derivatives, the gradient, maximal and normal property of the gradient, tangent planes.
- Partial derivatives of higher order, sufficient condition for equality of mixed order partial derivatives (Schwarz's and Young's theorems), differentials of higher orders, total differential for function of functions, Chain rule for one and two independent parameters.
- Euler's theorem on homogeneous functions of two and three variables, change of variables – simple problems. Taylor's theorem of two variables.
- Implicit functions, statement of the existence theorem, derivative of implicit functions – simple problems. Jacobians – elementary properties (statements only) and simple problems.
- Extrema of functions of two variables, constrained optimization problems, method of Lagrangian multipliers for two variables.
- Multiple integral: Concept of upper sum, lower sum, upper integral, lower integral and double integral (no rigorous treatment is needed). Statement of existence theorem for continuous functions.
- Iterated or repeated integral, Statement of Fubini's theorem. Change of order of integration. Areas of plane regions.
- Triple integral. Cylindrical and spherical coordinates.

- Change of variables in double integrals and triple integrals. Transformation of double and triple integrals (problems only).
- Determination of volume and surface area by multiple integrals (problems only).
- Differentiation under the integral sign, Leibnitz's rule (problems only).

Group B : Partial Differential Equations - I [Marks : 15] [10 classes]

- Definition, order and degree of PDE, classification of PDE (linear, quasilinear, semilinear and nonlinear), derivation of partial differential equations (by elimination of arbitrary constants/functions). Examples of PDEs that are central to the study of different problems in science and technology (e.g. Heat equation, Wave equation, Laplace equation, KDV equation).
- First order equations: Solution of quasi linear equations, Lagrange's method of solution. Cauchy problem for quasi linear PDE, The method of characteristics, method of characteristics for linear, semilinear equations. Solution via method of characteristics. Local existence and uniqueness theorem (statement and examples).
- Nonlinear first order partial differential equations, Charpit's general method of solution.

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4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Group Theory - II & Ring Theory - I

Semester : IV	Paper Code : MTHM-DSCC 8-TH
Credit : 4	Full Marks : 100 (Theory : 75 & Tutorial : 25)
Minimum number of classes required : 60	

4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Course Outcome

CO1 : To understand normal subgroups, quotient groups, group homomorphisms, and properties of isomorphisms.

CO2 : To learn about automorphisms, external and internal direct products, and Abelian groups.

CO3 : To acquire knowledge of ring theory, including subrings, integral domains, fields, subfields, ideals, ring homomorphisms, and congruence relations on rings.

Group A : Group theory - II [Marks : 40] [32 classes]

- Normal subgroup and its properties. Quotient group. Group homomorphisms, properties of homomorphisms, correspondence theorem and one-one correspondence between the set of all normal subgroups of a group and the set of all congruences on that group, Cayley's theorem, properties of isomorphisms. First, Second and Third isomorphism theorems.
- Automorphism, inner automorphism, automorphism groups, automorphism groups of finite and infinite cyclic groups, applications of factor groups to automorphism groups.
- External direct product and its properties, the group of units modulo n as an external direct product, internal direct product, converse of Lagrange's theorem for finite abelian group, Cauchy's theorem for finite abelian group.

Group B : Ring theory- I [Marks : 35] [28 classes]

- Definition and examples of rings, properties of rings, subrings, necessary and sufficient condition for a nonempty subset of a ring to be a subring, integral domains and fields, subfield, necessary and sufficient condition for a nonempty subset of a field to be a subfield, characteristic of a ring. Ideal, ideal generated by a subset of a ring, factor rings, operations on ideals, prime and maximal ideals. Ring homomorphisms, properties of ring homomorphisms. First, second and third isomorphism theorems, Correspondence theorem, congruence on rings, one-one correspondence between the set of ideals and the set of all congruences on a ring.

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4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Probability & Statistics

Semester : V	Paper Code : MTHM-DSCC 9-TH
Credit : 4	Full Marks : 100 (Theory : 75 & Tutorial : 25)
Minimum number of classes required : 60	

4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Course Outcome

CO1 : To understand random experiments, probability axioms, conditional probability, and joint probability.

CO2 : To study distribution functions of random variables, their properties, and probability mass and density functions.

CO3 : To learn about joint distributions of discrete and continuous random variables and their properties.

CO4 : To understand populations and samples, sampling distributions, and sample characteristics.

CO5 : To learn methods for estimating parameters, including the method of maximum likelihood.

CO6 : To acquire knowledge of bivariate frequency distributions and the construction of confidence intervals.

CO7 : To study hypothesis testing, including Type I and Type II errors.

Group A : Probability [Marks : 45] [35 classes]

- Random experiment, equally likely outcomes, Sample space, Events, σ-field, Probability as a set function, Probability axioms, Probability space. Conditional probability. The multiplication rule, The law of total probability and Bayes' theorem. Independence of events and trials. Joint probability, Bernoulli trial and binomial law, Poisson approximation of binomial law.
- Real random variables (discrete and continuous), distribution function of a random variable. Properties of distribution function. Probability mass / density functions and properties. Discrete distributions: Binomial, Poisson. Continuous distributions: Uniform, Normal, Exponential. Transformation of a random variable. Mathematical expectation, Mean, Variance, Moments, Quantiles, Skewness, Kurtosis, Median, Mode. Moment generating function, Characteristic function.
- Multivariate random variables, Joint distribution of discrete and continuous random variables and their properties, Joint probability mass / density functions, Marginal and Conditional distributions, Independent random variables. Conditional expectations, Expectation of function of two random variables, Moments, Covariance, Correlation coefficient, linear regression for two variables, regression curves. Bivariate normal distribution. Distribution of the sums of independent discrete / continuous random variables, Product of two random variables. Chi-square, t and F-distributions.
- Chebyshev's inequality, Convergence in Probability, Statement of weak law of large numbers and strong law of large numbers. Statement of Central limit theorem. Statement of De Moivre Laplace limit theorem, Normal approximation of the binomial distribution. Statement of Uniqueness theorem of Characteristic functions.

Group B : Statistics [Marks : 30] [25 classes]

- Populations and Samples, Random Sample, Sampling and Sampling Distributions, Distribution of the sample, Simple random sampling with and without replacement, Sample Statistic, Sample characteristics - Sample moments, Sample variance, Sampling from the normal distributions.
- Estimation of parameters: Point estimation, Interval Estimation, Mean-squared error, Properties of good estimators - unbiasedness, consistency, sufficiency, Minimum-Variance Unbiased Estimator (MVUE), Unbiased estimators for expectation and variance;
- Method of Maximum likelihood: The maximum likelihood principle, Likelihood function and Loglikelihood function, Maximum likelihood estimators for discrete and continuous models, Properties of maximum likelihood estimators.
- Bivariate frequency Distribution: Bivariate data, Correlation and covariance, Linear Regression, principle of least squares and fitting of polynomials and exponential curves.
- Confidence intervals: General principle. Confidence intervals for the mean of Normal population — for known variance and unknown variance; Confidence interval for variance of Normal population.
- Statistical hypothesis: Simple and composite hypotheses, null hypotheses, alternative hypotheses, one sided and two-sided hypotheses, The critical region and test statistic, type I error and type II error, level of significance, Power function of a test, most powerful test, Neyman-Pearson lemma (Statement only), Likelihood-ratio tests. Tests on the Mean of a Normal Distribution, Variance Known. Tests on the Mean of a Normal Distribution, Variance unknown; Tests on a Population Proportion, Chi-square test for goodness of fit.

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4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Ring Theory - II & Linear Algebra - I

Semester : V	Paper Code : MTHM-DSCC 10-TH
Credit : 4	Full Marks : 100 (Theory : 75 & Tutorial : 25)
Minimum number of classes required : 60	

4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Course Outcome

CO1 : To understand principal ideal domains, principal ideal rings, and Euclidean domains.

CO2 : To acquire knowledge of polynomial rings, factorization domains, ring embeddings, quotient fields, regular rings, and ideals in regular rings.

CO3 : To study vector spaces, subspaces, quotient spaces, linear span, basis and dimension, full-rank factorization, and rank inequalities.

CO4 : To learn about linear transformations, the algebra of linear transformations, isomorphisms, eigenvalues, and eigenvectors.

Group A : Ring Theory - II [Marks : 40] [32 classes]

- Principal ideal ring, principal ideal domain, prime element, irreducible element, greatest common divisor (gcd), least common multiple (lcm), expression of gcd, examples of a ring R and a pair of elements $a, b \in R$ such that $\gcd(a, b)$ does not exist, Euclidean domain, relation between Euclidean domain and principal ideal domain.
- Polynomial rings, division algorithm and consequences, factorization domain, unique factorization domain; irreducible and prime elements in a unique factorization domain; relation between principal ideal domain, unique factorization domain, factorization domain and integral domain; polynomial ring over unique factorization domain, Eisenstein criterion and unique factorization in $\mathbb{Z}[x]$.
- Ring embedding and quotient field, regular rings and their examples, properties of regular ring, ideals in regular rings.

Group B : Linear Algebra - I [Marks : 35] [28 classes]

- Vector spaces, subspaces, algebra of subspaces, quotient spaces, linear combination of vectors, linear span, linear independence, basis and dimension, dimension of subspaces. Subspaces of $\mathbb{R}^n$, dimension of subspaces of $\mathbb{R}^n$. Geometric significance of a subspace upto $\mathbb{R}^3$. Four fundamental subspaces associated with a matrix. The dimension of the solution space of $Ax = 0$ and the rank of A. Full rank factorization, rank inequalities, Sylvester's rank inequality.
- Linear transformations, null space, range, rank and nullity of a linear transformation, matrix representation of a linear transformation, change of coordinate matrix. Algebra of linear transformations. Isomorphisms. Isomorphism theorems, invertibility and isomorphisms. Eigen values, eigen vectors and characteristic equation of a matrix (over $\mathbb{C}$). Cayley-Hamilton theorem and its use in finding the inverse of a matrix.

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4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Riemann Integration & Series of Functions

Semester : V Credit : 4	Paper Code : MTHM-DSCC 11-TH Full Marks : 100 (Theory : 75 & Tutorial : 25)
Minimum number of classes required : 60	

4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Course Outcome

CO1 : To understand Riemann's definition of integrability, necessary and sufficient conditions for Riemann integrability, and the properties of Riemann integrable functions.

CO2 : To study improper integrals, Cauchy's principal value of improper integrals, and convergence tests.

CO3 : To learn about sequences of functions, including pointwise and uniform convergence, and the boundedness, continuity, integrability, and differentiability of the limit function under uniform convergence.

CO4 : To study series of functions, including pointwise and uniform convergence, and the boundedness, continuity, integrability, and differentiability of a series under uniform convergence.

CO5 : To learn power series and Fourier series and their applications.

Group A : Riemann integration [Marks : 50] [40 classes]

Riemann integration [32 classes]

- Partition of a closed and bounded interval and refinement of partition. Upper Darboux sum $U(P, f)$ and lower Darboux sum $L(P, f)$ and associated results. Upper integral and lower integral. Darboux's theorem. Darboux's definition of integration over a closed and bounded interval. Riemann's definition of integrability. Equivalence with Darboux definition of integrability (statement only). Necessary and sufficient condition for Riemann integrability.
- Concept of negligible set (or zero set) defined as a set covered by countable number of open intervals sum of whose lengths is arbitrary small. Examples of negligible sets : any subset of a negligible set, finite set, countable union of negligible sets. A bounded function on closed and bounded interval is Riemann integrable if and only if the set of points of discontinuity is negligible (Statement only). Example of Riemann integrable functions.
- Integrability of sum, scalar multiple, product, quotient, modulus of Riemann integrable functions. Properties of Riemann integrable functions arising from the above results.
- Function defined by definite integral $\int_a^x f(t)dt$ and its properties. Antiderivative (primitive or indefinite integral).
- Fundamental theorem of Integral Calculus. First Mean Value theorem of integral calculus. Weierstrass & Bonnet's form of second mean value theorems (statement only).

Improper integral [8 classes]

- Range of integration, finite or infinite. Necessary and sufficient condition for convergence of improper integral in both cases. Cauchy's principal value of improper integral.

- Tests of convergence : Comparison and μ-test. Absolute and non-absolute convergence and inter-relations. Statement of Abel's and Dirichlet's test for convergence of the integral of product of two functions.
- Convergence and working knowledge of Beta and Gamma function and their interrelation (statement only) [$\Gamma(n)\Gamma(1-n) = \frac{\pi}{\sin n\pi}, 0 < n < 1$, to be assumed]. Computation of the integrals $\int_0^{\pi/2} \sin^n x dx$, $\int_0^{\pi/2} \cos^n x dx$, $\int_0^{\pi/2} \tan^n x dx$ when they exist (using Beta and Gamma function).

Group B : Series of functions [Marks : 25] [20 classes]

- Sequence of functions defined on a set, Pointwise and uniform convergence. Cauchy criterion of uniform convergence. Weirstrass' M-test. Boundedness, continuity, integrability and differentiability of the limit function of a sequence of functions in case of uniform convergence.
- Series of functions defined on a set, Pointwise and uniform convergence. Cauchy criterion of uniform convergence. Weierstrass' M-test. Passage to the limit term by term. Boundedness, continuity, integrability, differentiability of a series of functions in case of uniform convergence. Dini's Theorem.
- Power series : Fundamental theorem of power series. Cauchy-Hadamard theorem. Determination of radius of convergence. Uniform and absolute convergence of power series. Properties of sum function. Differentiation and integration of power series. Abel's limit theorems. Uniqueness of power series having sum function.
- Fourier series : Trigonometric series. Statement of sufficient condition for a trigonometric series to be a Fourier series. Fourier coefficients for periodic functions defined on $[-\pi, \pi]$. Statement of Dirichlet's condition of convergence. Statement of Fourier's theorem on sum of Fourier series.

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[2] S. K. Berberian, a First Course in Real Analysis, Springer Verlag, New York, 1994.

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4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Mechanics - II

Semester : V	Paper Code : MTHM-DSCC 12-TH
Credit : 4	Full Marks : 100 (Theory : 75 & Tutorial : 25)
Minimum number of classes required : 60	

4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Course Outcome

CO1 : To develop the ability to solve problems related to friction and virtual work.

CO2 : To understand the concepts of stable, unstable, and neutral equilibrium.

CO3 : To learn how to determine the equations of equilibrium for an arbitrary system of forces in three dimensions.

CO4 : To solve problems involving the motion of a particle on a rough curve and the motion of particles with varying mass.

CO5 : To learn the dynamics of systems of particles and rigid bodies in detail.

Statics - II

- **Friction:** Laws of static friction, Limiting friction, Angle of friction and Cone of friction. Positions of equilibrium of a particle constrained to rest on a (i) rough plane curve and (ii) rough surface. [4 classes]
- **Virtual work:** Degrees of Freedom, Constraints, Virtual Displacement, Virtual Work, Workless Constraints, Forces which do not appear in the equation of virtual work, Forces which appear in the equation of virtual work, Principle of virtual work for any system of coplanar forces acting on a rigid body and deduction of conditions of equilibrium from the Principle of virtual work. [6 classes]
- **Stable and unstable equilibrium:** Field of forces, Conservative field, Potential energy of a system, Concepts of Stable, Unstable and Neutral equilibrium, Energy test of stability for a system having one degree of freedom, Stability when gravity is the only external force, Condition of stability of equilibrium of two heavy bodies resting one upon another, the bodies being rough enough to prevent sliding. [6 classes]
- **Arbitrary force system in three dimensions:** Axis of a couple, Resultant of any number of couples acting on a rigid body, Reduction of a system of forces acting on a rigid body, Equilibrium equations, Reduction to wrench intensity and pitch of a wrench, Poinsot's central axis, Equation of the central axis of a given system of forces, Invariants of a given system of forces. [6 classes]

Dynamics of a Particle - II

- Stability of nearly circular orbits, Disturbed orbits, Motion of a particle on rough curve, Expressions for components of velocity and acceleration referred to a set of rotating axes, Motion of a particle of varying mass including problems of mass addition (Rain-drop Problem) and mass reduction (Rocket Problem). . [8 classes]
- Dynamics of a system of particles: General theorems (Emphasis should be given on theoretical discussion only in this part): Configuration of a mechanical system and its degrees of freedom, External forces, Internal forces and two assumptions connected with these forces, Mass of a system, Centre of mass of a system and its motion, Linear momentum of a system and principle of conservation of linear momentum, Angular momentum of a system about a point and an axis, Angular momentum principle about the centre of mass, Conservation of angular momentum about a point and an axis, Kinetic energy (K.E.) of a system, The energy principle and Conservation of energy. [4 classes]

Dynamics of a rigid body

- Vector angular velocity and its existence, particle velocities in a rigid body. [2 classes]
- Moments and Products of Inertia, Moment of inertia of a body about any line through the origin of a coordinate frame, Radius of gyration, Equimomental systems, Principal axis and Momental ellipsoid, theorems of parallel and perpendicular axes (statements only). [4 classes]
- **General motion:** Deduction of the equations: $M\frac{d\vec{V}}{dt} = \vec{F}$, $\frac{d\vec{L_G}}{dt} = \vec{K_G}$ from linear and angular momentum principle, Deductions of equations of motions from D'Alembert's Principle, Independence of the motion of centre of inertia and the motion relative to the centre of inertia, Angular momentum of a rigid body and the kinetic energy of a rigid body rotating about a fixed axis, Motion of a rigid body about a fixed axis, Compound pendulum, Interchangeability of the point of suspension and centre of oscillation. [10 classes]
- **Motion of a rigid body in two dimensions:** Equations of motion of a rigid body in two dimensions in the form $M\frac{dV_x}{dt} = F_x$, $M\frac{dV_y}{dt} = F_y$, $I\frac{d\omega}{dt} = K_G$. Expressions for K.E. and angular momentum about the origin, Condition of pure rolling and sliding. [6 classes]
- **Motion under impulsive forces:** Equation of motion for impulsive forces for two dimensions, Statements of the conservation of linear and angular momentum. Problems of impulse applied to a free rod and a rod constrained to rotate about a fixed axis. [4 classes]

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4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Metric Space & Complex Analysis - I

Semester : VI Credit : 4	Paper Code : MTHM-DSCC 13-TH Full Marks : 100 (Theory : 75 & Tutorial : 25)
Minimum number of classes required : 60	

4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Course Outcome

CO1 : To understand concepts such as open balls, open sets, closed sets, bounded sets, uniform continuity, and isometries.

CO2 : To learn about convergent sequences and completeness of metric spaces.

CO3 : To learn about compactness, connectedness, and the contraction mapping principle.

CO4 : To study limits, continuity, and differentiability of functions of a complex variable.

CO5 : To understand analytic functions and elementary functions of a complex variable.

CO6 : To learn bilinear transformations and their properties.

CO7 : To study power series, including their convergence and representation of analytic functions.

CO8 : To understand properties of harmonic functions and the Milne-Thomson method.

Group A : Metric space [Marks : 45] [35 classes]

- Definition and examples of metric spaces. Open ball. Open set. Closed set defined as complement of open set. Interior point and interior of a set. Limit point and closure of a set. Boundary point and boundary of a set. Properties of interior, closure and boundary. Bounded set and diameter of a set. Distance between two sets. Subspace of a metric space.
- Continuous mappings. Uniform continuity. Isometry.
- Convergent sequence. Sequential criterion of continuity. Cauchy sequence. Every convergent sequence is Cauchy and bounded, but the converse is not true. Completeness. Cantor's intersection theorem. $\mathbb{R}$ is a complete metric space. $\mathbb{Q}$ is not complete. Completion of metric spaces. Nowhere dense set, Baire Category theorem.
- Compactness, Sequential compactness. Concept of Lebesgue number. Lebesgue covering lemma. Equivalence of compactness and sequential compactness of a metric space. Heine-Borel theorem in $\mathbb{R}$. Total boundedness and its properties. A metric space is compact if and only if the space is complete and totally bounded (statement only).
- Concept of connectedness and some examples of connected metric spaces, connected subsets of $\mathbb{R}, \mathbb{C}$.
- Contraction mappings, Banach Fixed point Theorem and its applications.

Group B : Complex Analysis - I [Marks : 30] [25 classes]

- Stereographic projection. Regions in the complex plane. Limits, limits involving the point at infinity. Continuity of functions of a complex variable.

- Derivatives, differentiation formulae, Cauchy-Riemann equations, sufficient conditions for differentiability. Analytic function, entire function, exponential function, logarithmic function, trigonometric functions, hyperbolic functions.
- Möbius transformation and its properties.
- Power series : Cauchy-Hadamard theorem. Determination of radius of convergence. Uniform and absolute convergence of power series. Analytic functions represented by power series. Uniqueness of power series.
- Harmonic functions and its properties, Milne Thompson method.

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[1] P. K. Jain and K. Ahmad, Metric Spaces, Narosa Publishing House.

[2] S. Kumaresan, Topology of Metric Spaces, 2nd Ed., Narosa Publishing House, 2011.

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4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Multivariate Calculus - II & Applications of Calculus

Semester : VI	Paper Code : MTHM-DSCC 14-TH
Credit : 4	Full Marks : 100 (Theory : 75 & Tutorial : 25)
Minimum number of classes required : 60	

4-yr Credit Distribution | MDC Credit Distribution | Course Overview
Major | Minor | MDC | Question Pattern

Course Outcome

CO1 : To understand the continuity and differentiability of functions of several variables.

CO2 : To learn how to compute double and triple integrals.

CO3 : To study the divergence and curl of vector fields and apply line integrals.

CO4 : To understand and apply Green's Theorem, Stokes' Theorem, and the Divergence Theorem.

CO5 : To learn curvature, concavity, points of inflection, envelopes, rectilinear asymptotes, curve tracing.

Group A : Multivariate Calculus - II [Marks : 45] [35 classes]

- Functions from $\mathbb{R}^n$ $(n > 1)$ to $\mathbb{R}^m$ $(m \geq 1)$. Continuity and differentiability of such functions. Jacobian matrix. A function $f : \mathbb{R}^n \to \mathbb{R}^m$ is differentiable if and only if its every component is differentiable,
- Inverse function theorem (statement only), implicit function theorem (statement only).
- Level sets, tangent spaces.
- Definition of vector field, divergence and curl, the Laplacian, vector identities.
- **Integrals over curves and surfaces :** Line integrals, fundamental theorem for line integrals - simply connected domains, conservative fields, the potential function, irrotational fields, independence of path, oriented surfaces, parametrised surfaces, area of a surface, surface integrals, volume integrals.
- **Integral theorems of vector analysis :** Green's theorem in plane, Stoke's theorem, Gauss' Divergence theorem. (Emphasis should be given on problem solving instead of rigorous theoretical treatment)

Group B : Applications of Calculus [Marks : 30] [25 classes]

- Tangents and normals, pedal equation of a curve, pedal of a curve.
- Curvature (Cartesian, Polar and pedal form). Curvature at the origin - Newton's theorem. Radius of curvature, Centre of curvature, evolute of a curve.
- Rectilinear asymptotes of a curve (Cartesian & parametric form only).
- Concavity, Convexity and points of inflection of a curve.
- Envelopes (Cartesian coordinates only and up to two parameters) of families of straight lines and curves.
- Singular points – nodes, cusps.
- Curve tracing in Cartesian and polar coordinates of standard curves.

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[1] T. Apostol, Mathematical Analysis, Narosa Publishing House, 1969.

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4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Numerical Analysis

Semester : VI	Paper Code : MTHM-DSCC 15-TH&P
Credit : 4	Full Marks : 100 (Theory : 75 & Practical : 25)
Minimum number of classes required : Theory 45 + Practical 15	

4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Course Outcome

CO1 : To understand polynomial approximation, interpolation, and numerical methods for differentiation and integration.

CO2 : To learn various techniques for solving transcendental and polynomial equations.

CO3 : To study methods for solving systems of linear algebraic equations.

CO4 : To learn techniques for matrix inversion and the Power Method for finding the dominant eigenvalue and eigenvector.

CO5 : To study numerical methods for solving ordinary differential equations.

- **Representation of numbers and errors in Numerical Analysis:** Machine Numbers - floating point and fixed point, Sources of Errors, Rounding of numbers, Absolute and Relative Error, Significant digits and Error Propagation in machine arithmetic operations. Numerical Algorithms - stability and convergence.
- **Approximation:** Classes of approximating functions, polynomial approximation, The Weierstrass' polynomial approximation theorem (statement only).
- **Interpolation:** Prerequisite -Divided difference:Definition of n-th divided difference $f[x_0, x_1, ..., x_n]$ and simple properties. Finite difference operators Δ, ∇. E, μ, δ - definitions and simple relations among them. Principle of interpolation, polynomial interpolation, existence and uniqueness of interpolating polynomial. Lagrange's interpolation polynomial, Newton's divided difference interpolation polynomial, Error in polynomial interpolation. Interpolation based on evenly spaced points: Difference table, Newton's forward and backward interpolation formulae, error terms. Central Interpolation: Statements of Stirling's and Bessel's formulae. Different interpolation zones, Error estimation. Statement of Hermite's interpolation formula, its uniqueness and error (only statement).
- **Numerical differentiation:** Basic principle, Methods based on Lagrange's, Newton's forward and backward interpolation formulae.
- **Numerical Integration:** Newton-Cotes formula (deduction of closed type), Trapezoidal rule and Simpson's $\frac{1}{3}$ rule - composite form. Statement of Weddle's rule and composite Weddle's rule. Error formulae (only statements), Degree of precision.
- Numerical solution of non-linear equations: Bisection method, Secant method, Regula-falsi method, fixed point iteration, Newton-Raphson method. Condition of convergence (if any), Order of convergence, Rate of convergence of these methods. Advantages and disadvantages of the methods.
- Numerical solution of system of linear equations: Direct methods-Gaussian elimination and Gauss-Jordan methods, partial pivoting strategies, operational count. Iterative methods- Gauss-Jacobi method, Gauss-Seidel method and their convergence analysis, Advantages and disadvantages of the methods.
- **Matrix inversion** by Gaussian elimination.
- **Algebraic eigenvalue problem:** The Power method.

- **Numerical solution of initial value problems for ordinary differential equations:** Single-step difference equation methods–idea of local truncation error, consistency and convergence. Euler's method, Modified Euler method, Higher order Taylor methods, Runge-Kutta method of order four, Picard's method of successive approximation.

Problems for Practical (using C programming language)

1. Interpolation by Lagrange's formula.
2. Interpolation by Newton's forward formula.
3. Interpolation by Newton's backward formula.
4. Integration by composite Trapezoidal rule.
5. Integration by composite Simpson's $\frac{1}{3}$ rule.
6. Integration by composite Weddle's rule.
7. Solution of equation by Bisection method.
8. Solution of equation by Newton-Raphson method.
9. Solution of equation by Regula-falsi method.
10. Solution of a system of linear equations by Gaussian elimination method.
11. Solution of a system of linear equations by Gauss-Seidel method.
12. Matrix inversion by Gaussian elimination method.
13. Finding largest eigen-pair of a matrix Power method.
14. Solution of ordinary differential equation by modified Euler method.
15. Solution of ordinary differential equation by fourth order Runge-Kutta method.

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[1] U. M. Ascher and C. Greif, A First Course in Numerical Methods, 7th Ed., PHI Learning Private Limited, 2013.

[2] K. E. Atkinson, An Introduction to Numerical Analysis, John Wiley & Sons, 1978.

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4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Group Theory - III & Linear Algebra - II

Semester : VII Credit : 4	Paper Code : MTHM-DSCC 16-TH Full Marks : 100 (Theory : 75 & Tutorial : 25)
Minimum number of classes required : 60	

4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Course Outcome

CO1 :

Group A : Group Theory - III [Marks : 35] [28 classes]

- Finite Abelian group, Fundamental theorem of finite Abelian groups, classification of all non-isomorphic Abelian groups of a given finite order, finitely generated free Abelian groups, structure of finitely generated free Abelian groups, torsion of a group.
- Group actions, permutation representation of group action, orbit, stabilizer, Applications of group actions - Generalized Cayley's theorem (extended Cayley's theorem), Index theorem, Burnside theorem.
- Groups acting on themselves by conjugation, conjugacy classes, class equation and consequences, conjugacy in S_n, Cauchy's theorem on finite groups, p-group, Centre of p-groups, Sylow's theorems, some applications of Sylow's theorems, simple groups, non-simplicity of groups of order $p^n\,(n > 1), pq, p^2q, p^2q^2$ (p, q are distinct primes), determination of all simple groups of order less than or equal to 60, non-simplicity of $A_n\,(n \geq 5)$, uniqueness of simple group of order 60.

Group B : Linear Algebra - II [Marks : 40] [32 classes]

- Finite dimensional inner product spaces and norms, Gram-Schmidt orthonormalisation process, orthogonal complements, Bessel's inequality, the adjoint of a linear operator and its basic properties.
- Bilinear and quadratic forms, Diagonalisation of symmetric matrices, Second derivative test for critical point of a function of several variables, Hessian matrix, Sylvester's law of inertia (statement only). Index, signature.
- Fundamental theorem of Linear Algebra (Part - I and Part - II), existence and uniqueness of solutions to $Ax = b$, a matrix transforms its row space to its column space.
- Duality and transposition, linear forms or linear functionals, dual space V^d, bi-dual space V^{dd}, dual basis, natural isomorphism between V and V^{dd}, Annihilators W^0 of a nonempty subset W of a vector space V. $\dim W^0 = \dim V - \dim W$ where W is a subspace of V, transpose T^t of a linear transformation T, $T^{tt} = T$, $(T^t)^{-1} = (T^{-1})^t$ if T is an isomorphism, $(\mathrm{Im}\,T)^0 = \ker T^t$, $\dim(\mathrm{Im}\,T) = \dim(\mathrm{Im}\,T^t), (\ker T)^0 = \mathrm{Im}\,T^t$. Eigenspaces of a linear operator, diagonalizability, invariant subspaces and Cayley-Hamilton theorem, the minimal polynomial for a linear operator, canonical forms (Jordan & rational) [problems only].

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4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Complex Analysis - II & Measure Theory - I

Semester : VII	Paper Code : MTHM-DSCC 17-TH
Credit : 4	Full Marks : 100 (Theory : 75 & Tutorial : 25)
Minimum number of classes required : 60	

4-yr Credit Distribution | MDC Credit Distribution | Course Overview
Major | Minor | MDC | Question Pattern

Course Outcome

CO1 :

Group A : Complex Analysis - II [Marks : 40] [32 classes]

- Curves in the complex plane, complex line integrations and its properties, fundamental theorem of calculus, Cauchy-Goursat theorem (statement only), Cauchy's integral formula, Cauchy's integral formula for derivatives (statement only), Morera's theorem, Liouville's theorem, fundamental theorem of algebra.
- Maximum Modulus theorem (statement only) and its applications, Minimum Modulus Theorem (statement only).
- Taylor's theorem, Laurent's theorem (statement only), zeros of an analytic function, interior uniqueness theorem/Identity theorem.
- Various kinds of singularities of complex valued functions in the extended complex plane, removable singularity, pole, essential singularity, Casorati-Weierstrass theorem concerning the nature of a function having an essential singularity, singularities of entire functions at infinity.
- Residue calculus : Residue theorem and its applications, Residue theorem for the extended complex plane.

Group B : Measure Theory - I [Marks : 35] [28 classes]

- Extended real number system $\mathbb{R}^*$ $\Big(\equiv \mathbb{R} \cup \{\infty, -\infty\}\Big)$, arithmetic operations on $\mathbb{R}^*$, linear order on $\mathbb{R}^*$.
- Motivation for the Theory of Lebesgue integration : limitations of Riemann integration, necessity of extending the concept of length of an interval to an arbitrary set; Lebesgue outer measure (m^*), properties of m^* : monotonicity, $m^*(I)$ is the length of I for any interval I, translation invariance property of m^*, countable subadditivity of m^*, m^* is not additive even for two disjoint sets. σ-algebra, Borel σ-algebra, Borel sets, example of Borel sets, additivity of m^* if one of the sets is open, additivity of m^* if one of the sets is closed, approximation of Borel sets from below by closed sets, additivity of m^* if one of the sets is a Borel set, existence of a subset of $\mathbb{R}$ that is not a Borel set, m^* is countably additive on Borel sets. Definition of Lebesgue measurable set : A set $A \subseteq \mathbb{R}$ is called *Lebesgue measurable* if there exists a Borel set $B \subseteq A$ such that $m^*(A \setminus B) = 0$, m^* is countably additive on Lebesgue measurable sets, the set of all Lebesgue measurable sets form a σ-algebra, any set $A \subset \mathbb{R}$ with $m^*(A) = 0$ is Lebesgue measurable; characterisation of Lebesgue measurable sets by open sets, closed sets, F_σ-sets, G_δ-sets; a set $A \subseteq \mathbb{R}$ is Lebesgue measurable if and only if for any set $E \subseteq \mathbb{R}$ we have $m^*(E) = m^*(E \cap A) + m^*(E \setminus A)$ [Carathéodory's criterion], non-measurable sets, Cantor set and its properties.

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4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Generalised functions, Integral transforms & Integral Equations

Semester : VII	Paper Code : MTHM-DSCC 18-TH
Credit : 4	Full Marks : 100 (Theory : 75 & Tutorial : 25)
Minimum number of classes required : 60	

4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Course Outcome

CO1 :

Group A : Generalised Functions [Marks : 15] [12 classes]

- Introduction and notations, Test functions, Linear functional, Space of Generalised functions, Completeness of Generalised functions, Support of a Generalised Function, Regular Generalised functions, Singular Generalised Function, The Dirac Delta function, Support of a Delta function, and Delta sequences. Change of variables in Generalised function, Multiplication of Generalised Function, Sochozki formula, Derivative of a Generalised function, Anti-derivative of a Generalised Function and examples.

Group B : Integral Transforms [Marks : 35] [28 classes]

- **Fourier Transform :** Definition and Algebraic properties of Fourier transform, Convolution, Translation, Modulation, Analytical properties of Fourier transforms, Transform of derivatives and derivatives of transform, Perseval formula, Inversion theorem, Application to solving ordinary differential equations.
- **Laplace Transforms :** Definition and Algebraic properties of Laplace transform, Transform of derivatives and derivatives of transform, Convolution, The inversion theorem and its application to find inverse of Laplace Transform, Application to solving ordinary differential equations.

Group C : Integral Equations [Marks : 25] [20 classes]

- Reduction of boundary value problem of an ordinary differential equation to an integral equation. Fredholm equation: Solution by the method of successive approximation. Neumann series. Existence and uniqueness of the solution of Fredholm equation. Equations with degenerate kernel. Eigen values and eigen solutions. Volterra equation: Solution by the method of iterated kernel, existence and uniqueness of solution. Solution of Abel equation. Solution of Volterra equation of convolution type by Laplace transform.

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4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Topology - I

Semester : VII	Paper Code : MTHM-DSCC 19-TH
Credit : 4	Full Marks : 100 (Theory : 75 & Tutorial : 25)
Minimum number of classes required : 60	

4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Course Outcome

CO1 :

- **Basi Concepts :** Definition and examples of topological spaces. Metric space as a topological space. Closed sets, closure, dense subsets. Neighbourhood, interior, exterior, boundary, accumulation point, derived set. Bases and subbases. Subspace topology. Finite product of topological spaces. Alternative methods for defining a topology in terms of Kuratowski closure operator and neighbourhood system.
- **Countability Axioms :** First and second countability, separability and Lindelöf property. Every metric space is first countable. Equivalence of second countability, separability and Lindelöf property in metric spaces.
- **Continuous functions :** Definition and examples. Simple properties and characterizations of continuous functions. Pasting lemma for continuous functions. Heine's continuity criterion for first countable topological spaces. Open map, closed map and homeomorphism, topological invariants.
- **Separation Axioms :** T_i-property $(i = 0, 1, 2, 3, 3\frac{1}{2}, 4, 5)$, regularity, complete regularity, normality and complete normality, basic properties of separation axioms, characterizations of T_1, T_2, regularity and normality, Urysohn's lemma (statement only), Tietze's extension theorem (statement only). T_5-property of a metric space.
- **Compactness :** Characterizations and basic properties, Alexander subbase theorem (statement only) and its application, compactness and finite intersection property, compactness and separation axioms. Every compact Hausdorff space without isolated point is uncountable. Compactness and continuous functions. Product of two compact spaces is compact. Countably compact, sequentially compact, Frechet compact, pseudo compact and their equivalence in metric spaces.

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4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Functional Analysis - I

Semester : VII Credit : 4	Paper Code : MTHM-DSCC 20-TH Full Marks : 100 (Theory : 75 & Tutorial : 25)
Minimum number of classes required : 60	

4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Course Outcome

CO1 :

- **Cardinal Number :** Concept of Cardinal number of an infinite set, Cardinality of $\mathbb{N}\ (=\aleph_0), \mathbb{Z}, \mathbb{Q}, \mathbb{R}\ (=c), \mathbb{C}$, order relation of Cardinal numbers, Schröder-Bernstein theorem.
- Concept of infinite basis of a linear space (or vector space), every linear space has a basis (statement only), cardinality of any two bases of a linear space are same (statement only), *dimension* defined as the cardinal number of a basis of a linear space.
- Normed linear space (n.l.sp.), every n.l.sp. is a metric space and hence a topological space, norm function is continuous, examples of n.l.sp. : finite dimensional spaces $\mathbb{R}^n, \mathbb{C}^n$ etc., $P[a,b]$, ℓ^∞, c, c_0, c_{00}, $\ell^p\ (p \geq 1)$, the space $C[a,b]$ of all continuous functions on $[a,b]$ with supremum norm, the space $R[a,b]$ of all Riemann integrable functions on $[a,b]$ with Riemann integral norm, Banach space, quotient space, convexity of open and closed balls, a n.l.sp. is complete if and only if every absolutely convergent series is convergent.
- Bounded linear transformation between two n.l.spaces, its equivalence with continuity, norm of a bounded linear transformation, various formulae for calculating norm of a bounded linear transformation, space of bounded linear transformations, equivalence of two norms in a linear space, isometric isomorphism and topological isomorphism (i.e. isomorphism and homeomorphism) between two n.l.spaces. Every finite dimensional n.l.sp. is a Banach space, equivalence of any two norms in a finite dimensional linear space, every n-dimensional n.l.sp. is topologically isomorphic with the n-dimensional Euclidean space, every linear transformation is bounded on a finite dimensional n.l.sp. Riesz lemma, a closed bounded set A in a n.l.sp. X is compact if and only if X is finite dimensional.
- Bounded linear functional and its example, a functional f on a n.l.sp. X is bounded if and only if $\ker f$ is closed in X, formula for calculating $\|f\|$ of a bounded linear functional f on a normed linear space, construction of unbounded linear functional on every infinite dimensional linear space, Hahn-Banach theorem (extension form only) and its consequences, dual and 2nd dual of a n.l.sp., dual space of any n.l.sp. is a Banach space, every n.l.sp. can be embedded isometrically and isomorphically into its 2nd dual space, definition of reflexivity of a n.l.sp. Dual spaces of $\mathbb{R}^n, \ell^p\ (p \geq 1), c, c_0, c_{00}$.

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4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Ordinary Differential Equation - II & Partial Differential Equation - II

Semester : VIII	Paper Code : MTHM-DSCC 21-TH
Credit : 4	Full Marks : 100 (Theory : 75 & Tutorial : 25)
Minimum number of classes required : 60	

4-yr Credit Distribution | MDC Credit Distribution | Course Overview
Major | Minor | MDC | Question Pattern

Course Outcome

CO1 :

Group A : Ordinary Differential Equation - II [Marks: 45] [40 classes]

- **Qualitative Analysis of One-dimensional Continuous Systems :** Autonomous first order differential equations –Equilibrium points (or steady states or fixed points or stationary points), Stability and asymptotic stability of a steady state, linearization and stability analysis.
- **One-dimensional Bifurcations :** Saddle-node, Transcritical and Pitchfork bifurcations in one-dimensional case. Simple examples.
- **Systems of Differential Equations :** Types of linear systems, Differential Operators and an Operator Method, Basic Theory of Linear Systems in Normal Form: Two Equations in Two Unknown Functions, Homogeneous Linear Systems with Constant Coefficients: The Matrix Method for Homogeneous Linear Systems with Constant Coefficients: Two Equations in Two Unknown Functions, Planar linear autonomous systems: Equilibrium points, Interpretation of the phase plane and phase portraits. Planar Nonlinear systems: Equilibrium points and their stability by linearization. Simple examples.
- **Series Solution and Special Functions :** Ordinary point and singular point. Types of singularity. Series solution of a second order differential equation, Frobeneous method, Legendre equation and Legendre function, Bessel equation and Bessel functions, orthogonality conditions.
- **Sturm–Liouville Problems and Eigenfunction Expansions :** Introduction to Sturm-Liouville theory; The Sturm–Liouville problem; Inner product spaces and orthonormal systems; The basic properties of Sturm–Liouville eigenfunctions and eigenvalues; Green's function, Nonhomogeneous equations; Nonhomogeneous boundary conditions; Simple problems.

Group B : Partial Differential Equation - II [Marks : 30] [20 classes]

- Classification of second order quasi linear partial differential equations, Reduction to Canonical form and general solution, Characteristic curves of second order equation.
- **Hyperbolic Equations: The One-dimensional Wave Equation**
  Wave equation and its formulation. The Cauchy problem and d'Alembert's solution; Physical interpretation of the solution. Solution of wave equation by the method of Separation of variables in cartesian coordinates. Solution by the method of Integral transform.
- **Parabolic equations: The Heat equation**
  Heat equation and its formulation: homogeneous and nonhomogeneous boundary conditions; Solution of heat equation by the method of Separation of variables in Cartesian coordinates; Solution of Heat equation using integral transform.

- **Elliptic equations: Laplace and Poisson equations**
  Laplace and Poisson equation, Dirichlet and Neumann boundary conditions, Interior and exterior boundary value problems. Separation of variables in Cartesian and cylindrical coordinates with simple examples, Poisson's formula. Green's functions and integral representations.

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4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Graph Theory

Semester : VIII	Paper Code : MTHM-DSCC 22-TH
Credit : 4	Full Marks : 100 (Theory : 75 & Tutorial : 25)
Minimum number of classes required : 60	

4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Course Outcome

CO1 :

- Historical background of Graph Theory. Seven bridges problem. Definition of an undirected graph, degree of a vertex, degree sequences, Havel-Hakimi Theorem.
- Walks, paths, trails and cycles, subgraphs, spanning subgraphs and induced subgraphs, connected graph, disconnected graph and components, distance in a graph, complete and complete bipartite graphs, self-complementary graphs.
- Eulerian graphs, Theorems on existence of Euler paths and circuits, Hamiltonian paths and cycles, Hamiltonian graphs. Sufficient conditions of Dirac and Ore for a graph to be Hamiltonian. Applications: Traveling Salesman Problem (TSP), Route planning (planning street sweeping routes, Garbage collection routes), DNA sequencing and computational biology.
- Definition and properties of trees, minimal spanning tree in a weighted graph, Kruskal algorithm and Prim's algorithm. Binary trees and their properties, Dijkstra's algorithm to find shortest path in a graph. Applications: Network design (telephone, electrical, computer networks), Data structures (binary search trees), Hierarchical systems (organizational charts, file systems), Decision trees in artificial intelligence.
- Definition of planar graphs, Kuratowski's two graphs, the Euler polyhedron formula (Euler identity for connected planar graphs $V - E + F = 2$, where $V=$ no. of vertices, $E =$ no. of edges, $F =$ no. of faces) detection of planarity, Kuratowski's theorem (proof not required). Homeomorphic graph, Isomorphic graph, Dual of a graph. Applications: Circuit board design (VLSI design), Geographic information systems, Network visualization.
- Directed graphs (digraphs), digraphs and binary relations, strongly connected digraphs, Euler digraphs, vertex colouring of graphs, Chromatic number of graphs and its elementary properties, perfect graph, perfect matching, matrix representation of graphs, adjacency matrices of graphs and digraphs and their properties, path matrix, incidence matrices of graphs and digraphs and their properties. Applications: Map coloring problems, Four color problem.

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4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Mechanics - III

Semester : VIII	Paper Code : MTHM-DSCC 23.1-TH
Credit : 4	Full Marks : 100 (Theory : 75 & Tutorial : 25)
Minimum number of classes required : 60	

4-yr Credit Distribution | MDC Credit Distribution | Course Overview
Major | Minor | MDC | Question Pattern

Course Outcome

CO1 :

Group A : Classical Mechanics [Marks : 60] [48 classes]

- Mechanics of a system of particles: Constraints, Degrees of freedom, reactions due to constraints. D'Alembert's principle; Lagrange's first kind equations; Generalized coordinates; Generalized forces; Lagrangian; Second kind Lagrange's equations of motion; velocity dependent potential; Principle of energy, Cyclic coordinates; Routhian formalism, Canonically conjugate coordinates and momenta.
- Action Integral; Hamilton's principle; Lagrange's equations by variational methods; Hamilton's principle for non-holonomic system; Integrals of motion, Symmetry properties and conservation laws; Statement of Noether's theorem with some illustrations; Hamiltonian and Hamiltonian equations.
- Euler-Lagrange Equation, Simple variational problems (Brachistochrone Problem, Shortest distance between two points), Hamilton's equations from variational principle; Principle of stationary action; Invariance of volume in phase space, Liouville's theorem (Statement).
- Canonical transformation; Generating function; Poisson Bracket; Equation of motion; Jacobi-Poisson equation.

Group B : Continuum Mechanics [Marks : 15] [12 classes]

- The Continuum hypothesis. Deformation and flow. Lagrangian and Eulerian descriptions. Material derivative. Deformation tensors. Finite strain tensor. Small deformation. Infinitesimal strain tensor. Principal strains. Strain invariants. Compatibility equations for linear strains. Body forces and surface forces. Stress vector. Stress components. Normal and Shear stresses. Stress deviator. Principal stresses. Invariants. Maximum shearing stress. Conservation of mass. The continuity equation. Momentum principles. Equation of motion. Energy balance. First Law of Thermodynamics. Ideal materials. Classical elasticity. Generalized Hooke's Law. Strain energy Function. Physical interpretation.

References

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4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Measure Theory - II

Semester : VIII Credit : 4	Paper Code : MTHM-DSCC 23.2-TH Full Marks : 100 (Theory : 75 & Tutorial : 25)
Minimum number of classes required : 60	

4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Course Outcome

CO1 :

- Lebesgue measurable functions and their example, characterisation of Lebesgue measurable functions, a function $f : \mathbb{R} \to \mathbb{R}$ is Lebesgue measurable if and only if $f^{-1}(U)$ is Lebesgue measurable for any open set U in the real line $\mathbb{R}$, a function $f : \mathbb{R} \to \mathbb{R}$ is Lebesgue measurable if and only if $f^{-1}(B)$ is Lebesgue measurable for any Borel set B in the real line $\mathbb{R}$, concept of almost everywhere, algebra of measurable functions, restriction of a measurable function to a measurable set is measurable, pasting lemma regarding measurable functions, Borel measurable functions and their example, if $f : \mathbb{R} \to \mathbb{R}$ is measurable and $g : \mathbb{R} \to \mathbb{R}$ is a Borel function then $g \circ f$ is measurable, limsup and liminf of a sequence of measurable functions are measurable, point-wise limit of a sequence of measurable functions is measurable, simple functions, measurable functions as point-wise limit of a sequence of simple measurable functions, approximation of Lebesgue measurable functions by continuous functions (statement only).
- **Lebesgue integral of non-negative measurable function :** Definition of the Lebesgue integral $\int_{\mathbb{R}} f(x)dx$ of a measurable function $f : \mathbb{R} \to [0, \infty]$, definition of the Lebesgue integral $\int_E f(x)dx$ as $\int_{\mathbb{R}} f\big|_E(x)dx$ for any measurable set $E \subset \mathbb{R}$, properties of Lebesgue integral of such functions : $\int_{\mathbb{R}} f(x)dx \geq 0$ for any measurable function $f : \mathbb{R} \to [0, \infty]$, if A, B be two measurable sets with $A \subseteq B$ then $\int_A f(x)dx \leq \int_B f(x)dx$ for any measurable function $f : \mathbb{R} \to [0, \infty]$, $\int_E f(x)dx = 0$ whenever E is a measurable set with $m(E) = 0$ (m being the Lebesgue measure), if $f = g$ almost everywhere on $\mathbb{R}$ then $\int_{\mathbb{R}} f(x)dx = \int_{\mathbb{R}} g(x)dx$, if $f : \mathbb{R} \to [0, \infty]$ is measurable and $\int_E f(x)dx = 0$ then $f = 0$ almost everywhere on E, Monotone Convergence Theorem (MCT), Fatou's lemma, $\int_{\mathbb{R}} (\alpha f + g)(x)dx = \alpha \int_{\mathbb{R}} f(x)dx + \int_{\mathbb{R}} g(x)dx$ for any measurable functions $f, g : \mathbb{R} \to [0, \infty]$ and $\alpha \geq 0$, some applications of MCT.
- **Lebesgue integral of a measurable function with value in $\mathbb{R}^*$:** Positive and negative parts of a measurable function $f : \mathbb{R} \to \mathbb{R}^*$, definition of $\int_{\mathbb{R}} f(x)dx$ of a measurable function $f : \mathbb{R} \to \mathbb{R}^*$, Lebesgue integrability of a measurable function $f : \mathbb{R} \to \mathbb{R}^*$, if $f : \mathbb{R} \to \mathbb{R}^*$ is Lebesgue integrable then f is real-valued almost everywhere, the set $L^1(\mathbb{R})$ of all Lebesgue integrable functions from $\mathbb{R}$ to $\mathbb{R}$ is a vector space over the field $\mathbb{R}$, linearity of Lebesgue integral for functions in $L^1(\mathbb{R})$, properties of Lebesgue integral of functions in $L^1(\mathbb{R})$: $\left|\int_{\mathbb{R}} f(x)dx\right| \leq \int_{\mathbb{R}} |f(x)|dx$, if $f \in L^1(\mathbb{R})$ and $\int_E f(x)dx = 0$ for every measurable set $E\,(\subseteq \mathbb{R})$ then $f = 0$ almost everywhere on $\mathbb{R}$, Dominated Convergence Theorem (DCT), $\int_{A \cup B} f(x)dx = \int_A f(x)dx + \int_B f(x)dx$ for any $f \in L^1(\mathbb{R})$ and any two disjoint measurable sets $A, B \subset \mathbb{R}$, relation between Lebesgue integral and Riemann integral.

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4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Operations Research & Stochastic Process

Semester : VIII	Paper Code : MTHM-DSCC 24.1-TH
Credit : 4	Full Marks : 100 (Theory : 75 & Tutorial : 25)
Minimum number of classes required : 60	

4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Course Outcome

CO1 :

Group A : Operations Research [Marks : 50] [40 classes]

- **Integer Programming:** Integer programming models; Branch-and-Bound method; Gomory's Cutting-plane method
- **Network Optimization:** Graph representations, Shortest path algorithms (Dijkstra, Bellman–Ford), Minimum spanning tree (Kruskal, Prim), Maximum flow (Ford–Fulkerson, Edmonds–Karp), Minimum cost flow problems, Network construction, Critical Path Method (CPM), Project Evaluation and Review Technique (PERT), Float time, Slack time.
- **Queuing Theory:** Poisson process and Exponential distribution, single channel exponential queuing models, steady state solutions for M/M/1/∞/FIFO model, Little's Law (Average number of items within a system equals the average arrival rate of items into and out of the system multiplied by the average amount of time an item spends in the system), Measure of effectiveness, Waiting time distributions, Finite system capacity queues Applications in communication and service systems.
- **Monte Carlo simulation:** Simulating deterministic behaviour (area under a curve, volume under a surface), generating random numbers: middle square method, linear congruence, queuing models: harbour system, morning rush hour.
- **Inventory Models:** Concept of EOQ(Economic Order Quantity) and EPQ (Economic Production Quantity), Problem of EOQ with finite rate of replenishment, Problem of EOQ with shortages, Quantity discounts, Safety stocks, Newsvendor model.

Group B : Stochastic process [Marks : 25] [20 classes]

- Stochastic Process: Basic Idea and Definition, Classification of Stochastic processes, Stationary Processes, Markov Chain-Introduction, Discrete Parameter Markov Chain, Transition Probabilities, Stochastic matrices, Examples: Random Walk with no Barrier, absorbing barrier, Reflecting Barrier, Markov chains: Definitions, Chapman-Kolmogorov equation, Equilibrium distributions, Classification of states, Long-time behaviour. Stochastic process in continuous time: Poisson process.

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4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Differential Geometry

Semester : VIII	Paper Code: MTHM-DSCC 24.2-TH
Credit : 4	Full Marks : 100 (Theory : 75 & Tutorial : 25)
Minimum number of classes required : 60	

4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Course Outcome

CO1 :

- **Tensor :** Different transformation laws, Properties of tensors, Metric tensor, Riemannian space, Covariant Differentiation, Einstein space.
- **Theory of curves :** Curves in plane and space, Arc-length, Reparametrization, Closed curves, Level curves versus parametrized curves , curvature, torsion , Serret-Frenet formulae, Isoperimetric Inequality, Four Vertex Theorem.
- **Theory of Surfaces :** Definition of smooth parametrized surfaces in $\mathbb{R}^3$, Examples: (regular) level surfaces, quadric surfaces, ruled surfaces, surfaces of revolution, smooth functions on a surface, the tangent plane and the differential maps between regular surfaces, the first fundamental form, length of curves, isometries of surfaces, conformal mappings of surfaces, normal fields and orientability.
- **Geometry of surfaces :** Geodesics - definition and example (in particular, geodesics on a surface of revolution), second fundamental form, Gauss and Weingarten maps and their properties, normal and geodesic curvatures, Gaussian and mean curvature, principal curvatures of a surface.

References

[1] Christian Bar, Elementary Differential Geometry, Cambridge University Press, 2011.

[2] Manfredo P. Do Carmo, Differential Geometry of Curves and Surfaces, Prentice-Hall, Inc., Upper Saddle River, New Jersey 07458, 1976.

[3] L. P. Eisenhart, An Introduction to Differential Geometry (with the use of tensor Calculus), Princeton University Press, 1940.

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4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Fluid Mechanics & Computational Mathematics

Semester : VIII	Paper Code : MTHM-DSCC 25.1-TH&P
Credit : 4	Full Marks : 100 (Theory : 75 & Practical : 25)
Minimum number of classes required : 60	

4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Course Outcome

CO1 :

Group A : Fluid Mechanics [Marks : 35] [28 classes]

- Introduction to material continuum; Lagrangian and Eulerian formulation; Fluid Kinematics : Path lines, stream lines; Velocity field, acceleration of a fluid particle; Material derivative; Equation of continuity (in Cartesian and cylindrical coordinates) in both forms and their equivalence
- Basic concepts of fluid at rest and fluid in motion. Viscous, non-viscous, Newtonian, perfect, compressible and incompressible fluids. Stress analysis. Stress in a fluid at rest and in motion. Transformation of stress, principal stresses, principal directions, strain analysis, rate of strain, rate of strain quadric. Constitutive equations for ideal / perfect fluid, idea of pressure at a point for perfect and viscous fluid, constitutive equation for a linearly viscous isotropic fluid.
- Conservation of momentum and derivation of equation of motion. Euler's equation for perfect fluids. Navier-Stokes equation. Equation of equilibrium for perfect fluids. Applications to hydrostatics. Bernoulli's equation. Conservative field of force. Impulsive motion. Application of Bernoulli's theorem. Equation of energy for perfect fluid.
- Irrotational motion, vorticity, flow, circulation, Kelvin's theorem. Motion of an incompressible fluid in two dimensions. Stream function, velocity potential, complex potential; Two-dimensional source, sink and doublet. Method of images. Image of a source and doublet with respect to a plane and circle. Circle theorem. Flow past a circular cylinder (with circulation). Blasius' theorem. Lift force.
- Some exact solutions of Navier-Stokes' equation. Laminar flow between parallel plates. Plane Couette flow. Plane Poiseuille flow. Flow between parallel plates. Flow in a circular pipe.

Group B : Computational Mathematics [Marks : 40] [32 classes]

- **Numerical Integration:** Gaussian quadrature, Romberg integration.
- **Numerical Solution of System of Linear Equations:** Direct methods- LU Factorisation - Crout's method. Ill-conditioned linear systems.
- **Numerical Solution of Ordinary Differential Equations (ODE):** First Order ODE (Initial value problems) – Multistep method – Adams-Moulton method, Convergence and stability of solutions. System of Equations and Higher-order Equations – Runge-Kutta method (4-th order). Fast Fourier Transform (FFT) and Spectral methods.
- **The Finite Difference Method :** Finite difference approximations - general principle, truncation errors, finite difference approximations to first order ordinary and partial derivatives, forward difference, backward difference, central difference approximations; approximations of the second order derivatives. Finite difference schemes - explicit schemes, implicit schemes, convergence and consistency of finite difference schemes, stability of finite difference schemes. The Courant-Friedrichs-Lewy (CFL) condition.

- **Numerical Solution of Boundary Value Problems for ODE:** Two-point Boundary Value Problems for ODE – Finite difference formulation for linear one-dimensional problems.
- **Numerical Solution of Partial Differential Equations (PDE):** Finite difference formultion and solutions of (i) Parabolic type equation in one dimension (Heat equation), (ii) Hyperbolic type equation in one dimension (Wave equation), (iii) Elliptic type equation (Laplace's equation in rectangles).

Practical [Marks : 25]

Use Python to solve the following problems.

(i) Finding eigenvalues and eigenvectors of a square matrix using NumPy.

(ii) Numerical integration using SciPy. Numerical integration using three point Gaussian quadrature.

(iii) Solution of equations using bisection method, Newton-Raphson method. Solution of equations using SciPy.

(iv) Numerical solution of a system of linear equations using Matrix inversion method and LU factorisation method (using NumPy and SciPy).

(v) Numerical solution of initial value problems using NumPy and SciPy. Pictorial representations of solutions.

(vi) Numerical solution of boundary value problems (for ODE) using NumPy and SciPy. Pictorial representations of solutions.

(vii) Numerical solution of Heat equation and Wave equation using NumPy and SciPy. Pictorial representations of solutions.

(viii) In irrotational, inviscid flow, the velocity potential ϕ satisfies $\nabla^2\phi = 0$. Solve $\frac{\partial^2\phi}{\partial x^2} + \frac{\partial^2\phi}{\partial y^2} = 0$ on a 2D grid with a "step" or "hump" at the bottom using the Gauss-Seidel iterative method.

(ix) Consider the interference of two waves of the same amplitude of $A_0 = 1m$. The resultant wave can be described by $A(x,t) = A_0\left\{\sin\left(2\pi\left(\frac{x}{\lambda_1} - \frac{t}{T_1}\right)\right) + \sin\left(2\pi\left(\frac{x}{\lambda_2} - \frac{t}{T_2}\right)\right)\right\}$.

(x) Using Python, produce animations for different interference scenarios with varying periods T_1, T_2 and wavelengths λ_1, λ_2.

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4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Functional Analysis - II & Topology - II

Semester : VIII	Paper Code : MTHM-DSCC 25.2-TH
Credit : 4	Full Marks : 100 (Theory : 75 & Tutorial : 25)
Minimum number of classes required : 60	

4-yr Credit Distribution | MDC Credit Distribution | Course Overview
Major | Minor | MDC | Question Pattern

Course Outcome

CO1 :

Group A : Functional Analysis - II [Marks : 40] [32 classes]

- Open mapping theorem, closed graph theorem and uniform boundedness principle, some applications of these theorems.
- Inner product space, Hilbert space, example of Hilbert space : $\mathbb{R}^n$, $\mathbb{C}^n$, ℓ^2 etc., orthonormality, orthogonal complement, orthonormal basis, separable Hilbert space, a Hilbert space is separable if and only if it has a countable orthonormal basis, Bessel's inequality for separable Hilbert space, Parseval's equation for separable Hilbert space, Gram-Schmidt orthonomalisation process, Riesz representation theorem, reflexivity of Hilbert space (statement only).

Group B : Topology - II [Marks : 35] [28 classes]

- **Connectedness :** Connected sets and their characterizations, components, Union of connected sets, Closure of a connected set is connected. Continuous image of a connected set is connected, generalized intermediate value theorem for topological spaces, Finite product of connected spaces is connected, for any countable subset S of $\mathbb{R}^2$, $\mathbb{R}^2 \setminus S$ is connected. Locally connected spaces and its properties.

  Path connectedness, an open subset of $\mathbb{R}^n$ is connected iff it is path connected, path component.
- **Quotient spaces :** Definition and examples of Quotient topology, quotient map. Definition of a quotient space of a topological space X determined by an equivalence relation on X and associated theorems. Formation of quotient spaces, such as, circle, cylinder, Möbius strip, torus, etc.
- **Nets and Filters**: Definitions and examples, subnets, ultrafilters; Convergence and cluster points of nets and filters; Hausdorffness, continuity, limit point of sets and compactness in terms of nets and filters; canonical way of converting nets to filters and vice-versa.

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4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Research Methodology I

Semester : VIII	Paper Code : MTHM-RM1-TH
Credit : 4	Full Marks : 100 (Theory : 75 & Viva-Voce : 25)
Minimum number of classes required : 60	

4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Course Outcome

CO1 :

Group A : Foundations of Research [Marks : 15] [10 classes]

- **Introduction to Research :** Meaning and objectives of research; Types and significance of research; Research process and scientific methods.
- **Research in Mathematics :** How to identify a research topic; Literature survey.
- **Research Problem :** Definition and necessity; Techniques of defining a research problem; Formulation and objectives of research problem.
- **Principles of mathematical writing :** Clarity and elimination of ambiguity; Logical structure and coherence; Proper definitions and assumptions; Rigor in proofs; Consistency of notation; Integration of symbols and words; Citation and acknowledgment; Reproducibility; Avoiding errors.

Group B : Web Resources & Research Ethics [Marks : 15] [10 classes]

- **Professional Organizations and Web Resources :** American Mathematical Society (AMS), Mathematical Association of America (MAA), Society for Industrial and Applied Mathematics (SIAM), arXiv, ResearchGate.
- **Journal Metrics :** Impact Factor (JCR), MCQ, SNIP, SJR, h-index, CiteScore, Google Scholar Metrics, Limitations and challenges of journal metrics.
- **Databases and Indexing Services :** MathSciNet, zbMath, Web of Science, Scopus.
- **Research Ethics :** Ethics in scientific research, Plagiarism and academic integrity, Use of plagiarism detection software (URKUND / Ouriginal / Turnitin).

Group C : Mathematical Modelling Tool [Marks : 45] [40 classes]

- **Partial Differential Equation (PDE) :** Classification of second order quasi-linear PDE, Reduction to Canonical form and general solution, Characteristic curves of second order equation.
- **Hyperbolic Equation:** One-dimensional Wave Equation and itormulation. The Cauchy problem and d'Alembert's solution; Physical interpretation of the solution. Solution of wave equation - method of Separation of variables in Cartesian coordinates using Integral transform.
- **Parabolic equations:** Heat equation and its formulation, homogeneous and nonhomogeneous boundary conditions, Solution of heat equation - method of Separation of variables in Cartesian coordinates, using integral transform.

- **Elliptic equations:** Laplace and Poisson equations, Dirichlet and Neumann boundary conditions, Interior and exterior boundary value problems, Separation of variables in Cartesian coordinates with simple examples, Poisson's formula. Green's function and integral representations.
- **Numerical Solution of PDE :** Explicit and implicit types of finite difference methods. Numerical solutions of Heat equation, Wave equation, Laplace's equation in rectangles.

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[1] Donald Bindner & Martin Erickson, A Student's Guide to the Study, Practice, and Tools of Modern Mathematics, CRC Press, Taylor & Francis Group, 2011.

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4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Research Methodology II

Semester : VIII	Paper Code : MTHM-RM2-TH
Credit : 4	Full Marks : 100 (Theory : 75 & Viva-Voce : 25)
Minimum number of classes required : 60	

4-yr Credit Distribution | MDC Credit Distribution | Course Overview
Major | Minor | MDC | Question Pattern

Course Outcome

CO1 :

Group A : Scientific Communication & Publishing : [Marks : 10] [8 classes]

- **Structure of a research paper :** Title and running title, Authorship (single and multiple), Writing abstract and introduction, Problem formulation and analytical proofs, Results and discussion, Figures, tables, graphs (design principles), Acknowledgements, Conflict of interest, References and citation styles, Selection of keywords, AMS subject classification.
- **Communication and Publishing :** Manuscript submission and communication with editor; Handling referees' comments and galley proofs, transferring copyright, open access publishing.
- Basic idea of how to write review articles.

Group B : Thesis writing & Presentation Tools [Marks : 15] [10 classes]

- **Fundamentals of Thesis and Project Report Writing :** Format of the Thesis/ Project report, Review of Literature, Writing methods and results, Preparation of tables and figures, Discussion and Conclusion, Summary and Synopsis, Bibliography and citation, Avoiding Plagiarism and self-plagiarism.
- **Latex for Typesetting and Slide preparation :** Knowledge on preamble, Input file structure and commands. Documentclasses and formatting - article, amsart, report, book, beamer. Mathematical equations and symbols, commutative diagrams, arrays, tables and figures, Bibliography and indexing. Slide preparation using beamer class. Output formats, DVI, PS, PDF.

Group C : [Marks : 50] [42 classes]

(Either Unit - I or Unit - II will be offered)

Unit - I : Machine Learning in Mathematical Research

- **Introduction to Graph Theory:** What is a graph? Simple graphs, Vertices (nodes), Edges (lines), Degrees of vertices, Connected graphs, Konigsberg bridges problem, Adjacency matrix, Incidence matrix, Complete graphs, Regular graphs, Bipartite graphs, Walk, Path, Cut Sets, Cut vertices, Eulerian graphs and Euler's theorem,- Hamiltonian graphs, Weighted graph, Digraphs, The travelling salesman problem, Tree, Spanning tree, Counting labeled trees, Cayley's theorem (statement only).
- **Graph algorithms:** Breadth-first search and Depth-first search algorithms, Kruskal's and Prim's algorithms, Dijkstra's algorithm.

- **Introduction to Machine learning (ML):** Definition and scope of Machine Learning, Types of Machine learning - Supervised Learning, Unsupervised Learning, Reinforcement Learning; Applications of ML in Science, Business and Technology.
- **Supervised Learning :** Linear Regression (model idea and cost function); Logistic Regression (basic idea); K-nearest neighbour (KNN) algorithm; The Bootstrap; Model selection, Model evaluation -accuracy, confusion matrix; Overfitting and Underfitting.
- **Unsupervised Learning :** Clustering concept, K-Means Algorithm (basic steps & objective function), Principal Component Analysis (PCA) – geometric interpretation.
- **Tree-based Methods :** Decision Trees (concept & splitting criteria), Overfitting in trees; Ensemble methods (basic idea)- Random Forest, Boosting (introductory idea).
- **Support Vector Machines :** The Maximal Margin Classifier, Construction of the Maximal Margin Classifier, Support Vector Classifiers, The Support Vector Machine (SVM); Relationship to Logistic Regression.

Laboratory Practice Assignments

- **Machine Learning with Python :** Introduction to Python, Use of libraries NumPy, SciPy, Scikit, Simple linear regression, Logistic Regression, K-Nearest Neighbors, The Bootstrap, Random Forests, Boosting, Support Vector Machine, Principal Components Analysis, K-Means Clustering.

Unit - II : Graph Theory in Mathematical Research

- Historical background of Graph Theory. Seven bridges problem. Definition of an undirected graph, degree of a vertex, degree sequences, Havel-Hakimi Theorem.
- Walks, paths, trails and cycles, subgraphs, spanning subgraphs and induced subgraphs, connected graph, disconnected graph and components, distance in a graph, complete and complete bipartite graphs, self-complementary graphs.
- Eulerian graphs, Theorems on existence of Euler paths and circuits, Hamiltonian paths and cycles, Hamiltonian graphs. Sufficient conditions of Dirac and Ore for a graph to be Hamiltonian.
- Definition and properties of trees, minimal spanning tree in a weighted graph, Kruskal algorithm and Prim's algorithm. Binary trees and their properties, Dijkstra's algorithm to find shortest path in a graph.
- Definition of planar graphs, Kuratowski's two graphs, the Euler polyhedron formula (Euler identity for connected planar graphs $V - E + F = 2$, where V= no. of vertices, E = no. of edges, F = no. of faces) detection of planarity, Kuratowski's theorem (proof not required). Homeomorphic graph, Isomorphic graph, Dual of a graph.
- Directed graphs (digraphs), digraphs and binary relations, strongly connected digraphs, Euler digraphs, vertex colouring of graphs, Chromatic number of graphs and its elementary properties, perfect graph, perfect matching, matrix representation of graphs, adjacency matrices of graphs and digraphs and their properties, path matrix, incidence matrices of graphs and digraphs and their properties.

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4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

C Language with Mathematical Applications

Semester : I	Paper Code : MTHM-SEC 1-TH MMTH-SEC-TH
Semester : II or III	Paper Code : MMTH-SEC-TH
Credit : 4	Full Marks : 100 (Theory : 75 & Tutorial : 25)
Minimum number of classes required : 60	

4-yr Credit Distribution | MDC Credit Distribution | Course Overview
Major | Minor | MDC | Question Pattern

Course Outcome

CO1 : To learn C language in detail.

CO2 : To learn how to use different types of control statements and arrays.

CO3 : To learn how to write different types of computer programs using C language.

- **Overview** of architecture of a computer, compiler, interpreter, assembler, machine language, high level language, procedural vs object oriented language.
- **Constants, Variables and Data types :** Character set, constants and variables, data types, C statements, declaration.
- **Operations and Expressions:** Arithmetic operators, relational operators, logical operators, assignment operator, expressions.
- **Decision Making and Branching:** decision making with if, if-else, Nested if, switch-case, break and continue statements.
- **Control Statements:** while, do-while and for statements.
- **Arrays and Strings:** One-dimensional, two-dimensional and multidimensional arrays, declaration of arrays, initialization of arrays, strings.
- **User-defined Functions:** Definition of functions, Scope of variables, return values and their types, function declaration, function call by value, Nesting of functions, passing of arrays to functions, Recursive function.
- **Introduction to Library functions:** stdio.h, math.h, string.h, stdlib.h, time.h etc.

Sample problems:

1. Display first 15 natural numbers.
2. Compute the sum of first 10 natural numbers.
3. Read 10 numbers from keyboard and find their average.
4. Find the sum of first 15 even natural numbers.
5. Write a program to find factorial of a number using recursion.
6. Write a program to make a pyramid pattern with numbers increased by 1.

7. From the terminal read three values, namely, length, width, height. Print a message whether the box is a cube or rectangle or semi-rectangle.
8. Find the AM, GM, HM of a given set of numbers.
9. Write a program to print multiplication table.
10. Find the maximum and minimum element of a given array.
11. Sort the elements of an array in ascending order.
12. Write a program to read in an array of names and to sort them in alphabetical order.
13. Write a program for addition of two matrices.
14. Find the transpose of a given matrix.
15. Find the product of two matrices.
16. Write a program to check whether two given strings are an anagram.
17. Write a program to check Armstrong and Perfect numbers.
18. Write a program to check whether a number is a prime number or not.
19. Prepare a code for summing a Series.
20. Compute approximate value of pi .
21. Compute the area under a given curve.
22. Solve a quadratic equation.
23. Write a program to solve a system of two linear equations in two unknowns.
24. Write a program to find the shortest distance between two straight lines (parallel or intersecting or skew) in space.
25. Prepare an investment report by calculating compound interest.

Note: A practical notebook must be maintained for internal assignments and submitted for the partial fulfillment of the course.

References

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4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Python Programming & Introduction to Latex

Semester : II	Paper Code : MTHM-SEC 2.1-TH
Credit : 4	Full Marks : 100 (Theory : 75 & Tutorial : 25)
Minimum number of classes required : 60	

4-yr Credit Distribution | MDC Credit Distribution | Course Overview
Major | Minor | MDC | Question Pattern

Course Outcome

CO1 : To learn Python programming language in detail.

CO2 : To write programs using Python language and also plot functions.

CO3 : To learn Latex for typing and formatting scientific documents.

Group A : Python Programming [Marks : 50] [40 classes]

- Python Programming Language, features, Installing Python. Running Code in the Interactive Shell, IDLE. Input, Processing and Output, Editing, Saving and Running a Script, Debugging: Syntax Errors, Runtime Errors, Semantic Errors.
- **Data types and expressions :** Variables and the Assignment Statement, Program Comments and Doc strings. Data Types-Numeric integers and Floating-point numbers. Boolean string. Mathematical operators, PEMDAS. Arithmetic expressions, Mixed-Mode Arithmetic and type Conversion, type( ). Input( ), print( ), program comments. id( ), int( ), str( ), float( ).
- **Loops and selection statements :** Definite Iteration: for Loop, Executing statements a given number of times, Specifying steps using range( ), Loops that count down, Boolean and Comparison operators and Expressions, Conditional and alternative statements - Chained and Nested Conditionals: if, if-else, if-elseif-else, nested if, nested if-else. Compound Boolean Expressions.
- **Conditional Iteration :** while Loop – with True condition, break Statement. Random Numbers. Loop Logic, errors and testing.
- **Strings, Lists, Tuple, Dictionary :** Accessing characters, indexing, slicing, replacing. Concatenation (+), Repetition (*). Searching a substring with the 'in' Operator, Traversing string using while and for. String methods- find, join, split, lower, upper, len( ).
- **Lists :** Accessing and slicing, Basic Operations (Comparison, +), List membership and for loop. Replacing element (list is mutable). List methods- append, extend, insert, pop, sort, max( ), min( ). Tuples. Dictionaries - Creating a Dictionary, Adding keys and replacing Values, dictionary - key( ), value( ), get(), pop( ), Traversing a Dictionary. Math module: sin(), cos(), exp(), sqrt(), constants - pi, e.
- **Design with functions :** Defining Simple Functions- Parameters and Arguments, the return Statement, tuple as return value. Boolean Functions. Defining a main function. Defining and tracing recursive functions. Working with Numbers: Calculating the Factors of an Integer, Generating Multiplication Tables, converting units of measurement, Finding the roots of a quadratic equation.
- **Algebra and Symbolic Math with SymPy :** symbolic math using the SymPy library. Defining Symbols and Symbolic Operations, factorizing and expanding expressions, Substituting in Values, Converting strings to mathematical expressions. Solving equations, Solving quadratic equations, Solving for one variable in terms of others, Solving a system of linear equations.
- Plotting using SymPy, Plotting expressions input by the user, Plotting multiple functions.

Sample problems :

1. Convert number from decimal to binary system.
2. Convert number from decimal to octal system.
3. Convert from Hexadecimal to binary system.
4. Write a program to read one subject mark and print pass or fail. Use single return values function with argument.
5. Find the median of a given set of numbers.
6. Write a Python function that takes two lists and returns True if they have at least one common member.
7. Write a program for Enhanced Multiplication Table Generator.
8. Write down Unit converter code.
9. Write down Fraction Calculator code.
10. Write down Factor Finder code.
11. Write down Graphical Equation Solver code.
12. Write down a code for solving Single-Variable Inequalities.
13. Prepare an investment report by calculating compound interest.
14. Write a python program to open and write the content to file and read it.
15. Write a python program to check whether a given year is leap year or not and also print all the months of the given year.

Group B : Introduction to Latex [Marks : 25] [20 classes]

- Introduction to LATEX: Preparing a basic LATEX file. Compiling LATEX file.
- Document classes: Different types of document classes, e.g., article, report, book, beamer etc.
- Page Layout: Titles, Abstract, Chapters, Sections, subsections, paragraph, verbatim, References, Equation references, citation.
- List structures: Itemize, enumerate, description etc.
- Representation of mathematical equations: Inline math, Equations, Fractions, Matrices, trigonometric, logarithmic, exponential functions, line, surface, volume integrals with and without limits, closed line integral, surface integrals, Scaling of Parentheses, brackets etc.
- Customization of fonts: Bold fonts, emphasise, mathbf, mathcal etc. Changing sizes Large, Larger, Huge, tiny etc.
- Writing tables: Creating tables with different alignments, placement of horizontal, vertical lines.
- Figures: Changing and placing the figures, alignments.
- Packages: amsmath, amssymb, amsfont, amsthm, graphics, graphicx, Geometry, algorithms, color, Hyperref etc. Use of Different LATEX commands and environments, Changing the type style, symbols from other languages, special characters.

Sample Projects :

1. Write down a research article.

2. Write down a given mathematical derivation.
3. Write a book chapter.
4. Write a report on a practical done in laboratory with results, tables and graphs.
5. Present graphical analysis taking graphs plotted in gnuplot.

Note: A practical notebook must be maintained for internal assignments and submitted for the partial fulfillment of the course.

References

[1] E. Balgurusamy, Problem solving and Python programming, Tata McGraw Hill, 2017.

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4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Linear Programming and Rectangular Games

Semester : III	Paper Code : MTHM-SEC 3-TH
Credit : 4	Full Marks : 100 (Theory : 75 & Tutorial : 25)
Minimum number of classes required : 60	

4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Course Outcome

CO1 : To learn how to formulate real-life problems into mathematical models.

CO2 : To learn simplex method to solve linear programming problems.

CO3 : To understand duality theory and post optimal analysis.

CO4 : To learn how to solve transportation problems and assignment problems.

CO5 : To learn different techniques to solve rectangular games.

- Definition of Linear Programming Problem (L.P.P.). Formation of L.P.P. from daily life involving inequations. Graphical solution of L.P.P. Basic solutions and Basic Feasible Solution (B.F.S) with reference to L.P.P. Matrix formulation of L.P.P. Degenerate and Non-degenerate B.F.S.
- Hyperplane, Convex set, Cone, extreme points, convex hull and convex polyhedron. Supporting and Separating hyperplane. The collection of a feasible solutions of an L.P.P. constitutes a convex set. The extreme points of the convex set of feasible solutions correspond to its B.F.S. and conversely. The objective function has its optimal value at an extreme point of the convex polyhedron generated by the set of feasible solutions (the convex polyhedron may also be unbounded). In the absence of degeneracy, if the L.P.P. admits of an optimal solution then at least one B.F.S. must be optimal. Reduction of a F.S. to a B.F.S.
- Slack and surplus variables. Standard form of L.P.P. Theory of simplex method. Feasibility and optimality conditions. Algorithm. Two phase method, Degeneracy in L.P.P. and its resolution.
- Duality theory: The dual of dual is the primal. Relation between the objective values of dual and the primal problems. Relation between their optimal values. Post-optimal Analysis: Discrete changes in the cost vector, Discrete changes in the requirement vector, Discrete changes in the coefficient matrix, Addition of a variable, Addition of a constraint.
- Transportation and Assignment problems. Mathematical justification for optimality criterion. Hungarian method. Traveling Salesman problem.
- Concept of game problem. Rectangular games. Pure strategy and Mixed strategy. Saddle point and its existence. Optimal strategy and value of the game. Necessary and sufficient condition for a given strategy to be optimal in a game. Concept of Dominance. Fundamental Theorem of rectangular games. Algebraic method. Graphical method and Dominance method to solve, Rectangular games. Inter-relation between theory of games and L.P.P.

Note : A practical notebook must be maintained for internal assignments and submitted for the partial fulfillment of the course.

References

[1] Mokhtar S. Bazaraa, John J. Jarvis and Hanif D. Sherali, Linear Programming and Network Flows, 2nd Ed., John Wiley and Sons, India, 2004.

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4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Question Pattern for
4-year B.A./B.Sc. Honours & Honours with Research, with Mathematics Major

MTHM-DSCC 1-TH	**Calculus, Geometry & Vector Analysis**
Group A : Calculus (Marks : 20)	(a) Short answer type questions: 2 questions are to be attempted out of 3 questions each carrying 2 marks. (b) Long answer type questions: 4 questions are to be attempted out of 6 questions each carrying 4 marks.
Group B : Geometry (Marks : 35)	(a) Short answer type questions: 2 questions are to be attempted out of 3 questions each carrying 2.5 marks. (b) Long answer type questions: 5 questions are to be attempted out of 8 questions each carrying 6 marks.
Group C : **Vector Analysis** (Marks : 20)	(a) Short answer type questions: 2 questions are to be attempted out of 3 questions each carrying 2 marks. (b) Long answer type questions: 4 questions are to be attempted out of 6 questions each carrying 4 marks.
MTHM-SEC 1-TH	**C Language with Mathematical Applications**
(Marks : 75)	(a) Short answer type questions: 5 questions are to be attempted out of 7 questions each carrying 3 marks (b) Long answer type questions: 5 questions are to be attempted out of 7 questions each carrying 8 marks (a) Longer answer type questions: 2 questions are to be attempted out of 3 questions each carrying 10 marks.
MTHM-DSCC 2-TH	**Basic Algebra**
Group A, B, C : (Each group carries 25 marks)	(a) Short answer type questions: 2 questions are to be attempted out of 3 questions each carrying 2.5 marks. (b) Long answer type questions: 4 questions are to be attempted out of 6 questions each carrying 5 marks.
MTHM-SEC 2.1-TH	**Python Programming & Introduction to Latex**
Group A : **Python programming** (Marks : 50)	(a) Short answer type questions: 5 questions are to be attempted out of 7 questions each carrying 3 marks. (b) Long answer type questions: 7 questions are to be attempted out of 10 questions each carrying 5 marks
Group B : **Introduction to Latex** (Marks : 25)	(a) Short answer type questions: 5 questions are to be attempted out of 7 questions each carrying 2 marks (b) Long answer type questions: 3 questions are to be attempted out of 5 questions each carrying 5 marks.

MTHM-DSCC 3-TH	**Real Analysis**
Group A : (Marks : 30)	(a) Short answer type questions: 3 questions are to be attempted out of 5 questions each carrying 3 marks. (b) Long answer type questions: 3 questions are to be attempted out of 5 questions each carrying 7 marks.
Group B : (Marks : 35)	(a) Short answer type questions: 4 questions are to be attempted out of 6 questions each carrying 2 marks. (b) Long answer type questions: 3 questions are to be attempted out of 5 questions each carrying 5 marks.
Group C : (Marks : 10)	2 questions are to be attempted out of 4 questions each carrying 5 marks.
MTHM-DSCC 4-TH	**Ordinary Differential Equations-I and Group Theory-I**
Group A : Ordinary Differential Equations (Marks : 45)	9 questions are to be attempted out of 14 questions each carrying 5 marks.
Group B : Group Theory (Marks : 30)	6 questions are to be attempted out of 9 questions each carrying 5 marks.
MTHM-SEC 3-TH	**Linear Programming & Rectangular Games**
(Marks : 75)	(a) Short answer type questions: 5 questions are to be attempted out of 8 questions each carrying 3 marks. (b) Long answer type questions: (i) 5 questions are to be attempted out of 8 questions each carrying 6 marks. (questions are to be set from first three groups, starting from LPP formulation to Two-phase method)] (ii) 5 questions are to be attempted out of 8 questions each carrying 6 marks. (questions are to be set from last three groups, starting from Duality theory to Game problems)
MTHM-DSCC 5-TH	**Theory of Real Functions**
Group A : Limit & Continuity of functions (Marks : 45)	(a) Short answer type questions: 5 questions are to be attempted out of 8 questions each carrying 3 marks. (b) Long answer type questions: 6 questions are to be attempted out of 9 questions each carrying 5 marks.
Group B : Differentiability of functions (Marks : 30)	(a) Short answer type questions: 4 questions are to be attempted out of 6 questions each carrying 3 marks. (b) Long answer type questions: 3 questions are to be attempted out of 5 questions each carrying 6 marks.

MTHM-DSCC 6-TH	**Mechanics-I**
(Marks : 75)	(a) Short answer type questions: 6 questions are to be attempted out of 9 questions each carrying 2 marks. (b) Long answer type questions: (i) 7 questions are to be attempted out of 10 questions each carrying 6 marks. (2 questions from Statics, 4 questions from Law of gravitation portion, 2 questions from Work, Power, Energy portion and 2 questions from Impulse of a force portion are to be set.) (ii) 3 questions are to be attempted out of 5 questions each carrying 7 marks. (questions are to be set from Motion of a particle in a plane)
MTHM-DSCC 7-TH	**Multivariate Calculus-I and Partial Differential Equations-I**
Group A : Multivariate Calculus - I (Marks : 60)	(a) Short answer type questions: 5 questions are to be attempted out of 8 questions each carrying 2 marks. (b) Long answer type questions: 5 questions are to be attempted out of 8 questions each carrying 10 marks.
Group B : Partial Differential Equations - I (Marks : 15)	3 questions are to be attempted out of 5 questions each carrying 5 marks.
MTHM-DSCC 8-TH	**Group Theory-II and Ring Theory-I**
Group A : Group Theory - II (Marks : 40)	8 questions are to be attempted out of 11 questions each carrying 5 marks.
Group B : Ring Theory - I (Marks : 35)	7 questions are to be attempted out of 10 questions each carrying 5 marks.
MTHM-DSCC 9-TH	**Probability and Statistics**
Group A : Probability (Marks : 45)	(a) Short answer type questions: 5 questions are to be attempted out of 8 questions each carrying 3 marks. Each question may have further parts. (b) Long answer type questions: 5 questions are to be attempted out of 8 questions each carrying 6 marks. Each question may have further parts.
Group B : Statistics (Marks : 30)	(a) Short answer type questions: 3 questions are to be attempted out of 5 questions each carrying 3 marks. Each question may have further parts. (b) Long answer type questions: 3 questions are to be attempted out of 5 questions each carrying 7 marks. Each question may have further parts.

MTHM-DSCC 10-TH	**Ring Theory-II & Linear Algebra-I**
Group A : **Ring Theory - II** (Marks : 40)	(a) Short answer type questions: 5 questions are to be attempted out of 8 questions each carrying 3 marks. Each question may have further parts. (b) Long answer type questions: 5 questions are to be attempted out of 8 questions each carrying 5 marks. Each question may have further parts.
Group B : **Linear Algebra - I** (Marks : 35)	(a) Short answer type questions: 5 questions are to be attempted out of 8 questions each carrying 3 marks. Each question may have further parts. (b) Long answer type questions: 4 questions are to be attempted out of 7 questions each carrying 5 marks. Each question may have further parts.
MTHM-DSCC 11-TH	**Riemann Integration & Series of functions**
Group A : **Riemann Integration** (Marks : 50)	(a) Short answer type questions: 5 questions are to be attempted out of 8 questions each carrying 3 marks. Each question may have further parts. (b) Long answer type questions: 7 questions are to be attempted out of 11 questions each carrying 5 marks. Each question may have further parts.
Group B : Series of functions (Marks : 25)	5 questions are to be attempted out of 8 questions each carrying 5 marks. Each question may have further parts.
MTHM-DSCC 12-TH	**Mechanics-II**
Group A : **Analytical Statics** (Marks : 28)	4 questions are to be attempted out of 7 questions each carrying 7 marks. Each question may have further parts.
Group B : Dynamics of particles (Marks : 15)	1 question of Particle Dynamics is to be attempted from 3 questions carrying 8 marks and 1 question of Dynamics of a system of particles is to be attempted from 3 questions carrying 7 marks. Each question may have further parts.
Group C : Dynamics of rigid body (Marks : 32)	4 questions are to be attempted out of 7 questions each carrying 8 marks. Each question may have further parts with decomposition (2+6), (3+5), (4+4) etc.

MTHM-DSCC 13-TH	**Metric Space & Complex Analysis-I**
Group A : **Metric Space** (Marks : 45)	(a) Short answer type questions: 5 questions are to be attempted out of 7 questions each carrying 3 marks. Each question may have further parts. (b) Long answer type questions: 6 questions are to be attempted out of 8 questions each carrying 5 marks. Each question may have further parts.
Group B : **Complex Analysis - I** (Marks : 30)	6 questions are to be attempted out of 9 questions each carrying 5 marks. Each question may have further parts.
MTHM-DSCC 14-TH	**Multivariate Calculus & Application of Calculus**
Group A : **Multivariate Calculus** (Marks : 50)	(a) Short answer type questions: 5 questions are to be attempted out of 8 questions each carrying 3 marks. Each question may have further parts. (b) Long answer type questions: 5 questions are to be attempted out of 8 questions each carrying 7 marks. Each question may have further parts.
Group B : **Application of Calculus** (Marks : 25)	5 questions are to be attempted out of 8 questions each carrying 5 marks. Each question may have further parts.
MTHM-DSCC 15-TH	**Numerical Analysis**
(Marks : 75)	(a) Short answer type questions: 5 questions are to be attempted out of 8 questions each carrying 3 marks. Each question may have further parts. (b) Long answer type questions: (i) 6 questions are to be attempted out of 9 questions each carrying 5 marks. These questions will be set from the topics Representation of numbers and errors in Numerical Analysis, Approximation, Interpolation, Numerical Differentiation and Numerical Integration. Each question may have further parts. (ii) 6 questions are to be attempted out of 9 questions each carrying 5 marks. These questions will be set from the topics Numerical solution of linear and nonlinear equations, matrix inversion, algebraic Eigen value problem and Numerical solution of initial value problems for ordinary differential equations. Each question may have further parts.

MTHM-DSCC 16-TH	Group Theory III & Linear Algebra - II
Group A : **Group Theory III** (Marks : 35)	(a) Short answer type questions: 5 questions are to be attempted out of 8 questions each carrying 2 marks. (b) Long answer type questions: 5 questions are to be attempted out of 8 questions each carrying 5 marks Each question may have multiple parts.
Group B : **Linear Algebra II** (Marks : 40)	(a) Short answer type questions: 5 questions are to be attempted out of 8 questions each carrying 2 marks. (b) Long answer type questions: 6 questions are to be attempted out of 10 questions each carrying 5 marks. Each question may have multiple parts.
MTHM-DSCC 17-TH	**Complex Analysis II and Measure Theory I**
Group A : **Complex Analysis II** (Marks : 40)	(a) Short answer type questions: 5 questions are to be attempted out of 8 questions each carrying 2 marks. (b) Long answer type questions: 6 questions are to be attempted out of 10 questions each carrying 5 marks Each question may have multiple parts.
Group B : **Measure Theory I** (Marks : 35)	(a) Short answer type questions: 5 questions are to be attempted out of 8 questions each carrying 2 marks. (b) Long answer type questions: 5 questions are to be attempted out of 8 questions each carrying 5 marks Each question may have multiple parts.
MTHM-DSCC 18-TH	**Generalized Functions, Integral Transforms & Integral Equation**
Group A : **Integral Transforms** (Marks : 35)	7 questions are to be attempted out of 11 questions each carrying 5 marks. Each question may have further parts. From each of the integral transforms at least five questions should be set.
Group B : **Integral Equations** (Marks : 25)	5 questions are to be attempted out of 8 questions each carrying 5 marks. Each question may have further parts.
Group C : **Generalized Functions** (Marks : 15)	3 questions are to be attempted out of 6 questions each carrying 5 marks. Each question may have further parts.
MTHM-DSCC 19-TH	**Topology I**
(Marks : 75)	(a) 7 questions are to be attempted out of 10 questions each carrying 5 marks. Each question may have multiple parts. (b) 5 questions are to be attempted out of 8 questions each carrying 8 marks Each question may have multiple parts.

MTHM-DSCC 20-TH	**Functional Analysis I**
(Marks : 75)	(a) 7 questions are to be attempted out of 10 questions each carrying 5 marks. Each question may have multiple parts. (b) 5 questions are to be attempted out of 8 questions each carrying 8 marks Each question may have multiple parts.
MTHM-DSCC 21-TH	**Ordinary Differential Equations-II & Partial Differential Equations-II**
Group A: Ordinary Differential Equations (Marks: 45)	(a) 5 questions are to be attempted out of 8 questions each carrying 5 marks. These questions will be set from the topics Qualitative Analysis of One-dimensional Continuous Systems, One-dimensional Bifurcations and Systems of Differential Equations. Each question may have multiple parts. (b) 2 questions are to be attempted out of 4 questions each carrying 10 marks These questions will be set from the topics Series Solution and Special Functions and Sturm–Liouville Problems and Eigen function Expansions. Each question may have further parts.
Group-B : Partial Differential Equations (Marks : 30)	5 questions are to be attempted out of 8 questions each carrying 6 marks. Each question may have further parts.
MTHM-DSCC 22-TH	**Graph Theory**
(Marks : 75)	(a) 7 questions are to be attempted out of 10 questions each carrying 5 marks. Each question may have multiple parts. (b) 5 questions are to be attempted out of 8 questions each carrying 8 marks. Each question may have multiple parts.
MTHM-DSCC 23.1-TH	**Mechanics-III**
Group A: Classical Mechanics (Marks : 60)	(a) 5 questions are to be attempted out of 8 questions each carrying 6 marks. These will be set from the topics mentioned in the syllabus starting from 'Mechanics of a system of particles...' to '...Statement of Noether's theorem with some illustrations' (b) 5 questions are to be attempted out of 8 questions each carrying 6 marks. These will be set from the topics mentioned in the syllabus istarting from 'Hamiltonian and Hamiltonian equations...' to '...Generating function; Poisson Bracket; Equations of motion'. Each question may have further parts.
Group B: Continuum Mechanics (Marks : 15)	3 questions are to be attempted out of 6 questions each carrying 5 marks. Each question may have further parts.
MTHM-DSCC 23.2-TH	**Measure Theory-II**
(Marks : 75)	(a) 7 questions are to be attempted out of 10 questions each carrying 5 marks . Each question may have multiple parts. (b) 5 questions are to be attempted out of 8 questions each carrying 8 marks. Each question may have multiple parts.

MTHM-DSCC 24.1-TH	**Operations Research & Stochastic process**
Group A: **Operations Research** (Marks : 50)	(a) 5 questions are to be attempted out of 8 questions each carrying 7 marks. These will be set from the topics Integer Programming, Network Optimization and Queuing Theory. Each question may have further parts. (b) 3 questions are to be attempted out of 5 questions each carrying 5 marks. These will be set from the topics Monte Carlo simulation and Inventory Models. Each question may have further parts.
Group B : **Stochastic process** (Marks : 25)	5 questions are to be attempted out of 8 questions each carrying 5 marks. Each question may have further parts.
MTHM-DSCC 24.2-TH	**Differential Geometry**
(Marks : 75)	(a) Short answer type questions: 5 questions are to be attempted out of 8 questions each carrying 2 marks. (b) Long answer type questions: 11 questions are to be attempted out of 8 questions each carrying 5 marks. Each question may have multiple parts.
MTHM-DSCC 25.1-TH	**Fluid Mechanics & Computational Mathematics**
Group A: **Fluid Mechanics** (Marks : 35)	5 questions are to be attempted out of 8 questions each carrying 7 marks. Each question may have further parts.
Group B : Computational Mathematics (Marks : 40)	8 questions are to be attempted out of 12 questions each carrying 5 marks. Each question may have further parts.
MTHM-DSCC 25.2-TH	**Functional Analysis - II and Topology - II**
Group A : **Functional Analysis-II** (Marks : 40)	5 questions are to be attempted out of 8 questions each carrying 8 marks. Each question may have multiple parts.
Group B : Topology-II (Marks : 35)	5 questions are to be attempted out of 8 questions each carrying 7 marks. Each question may have multiple parts.

4-yr Credit Distribution | MDC Credit Distribution | Course Overview
Major | Minor | MDC | Question Pattern

Guidelines for Summer Internship in Mathematics

1. Two or three neighbouring Colleges may interchange their students for an internship program and the students may b e offered a course related to their curriculum by the mentor in the neighbouring College. The content of the program will depend on the respective mentor. It may be a theoretical course on Mathematical Analysis / Numerical Analysis / Applied Mathematics / Financial Mathematics / Mathematical Logic / Industrial Mathematics or it may be any hands on training with the help of programming technique. After completion of the course the respective mentor / supervisor should give a completion certificate to the candidate.

2. A student can select a mentor/supervisor in some Industry for doing summer internship. At the end o f the course candidate should collect a completion certificate from the mentor / supervisor.

3. A student can do internship under the supervision of a teacher in his / her College in allied subjects (i.e., a student with Mathematics major can do internship on Chemistry, Statistics, Physics, Economics, Computer Science) and at the end of the course the mentor / supervisor should give a completion certificate to the candidate.

4. Interns may be engaged in Practice Teaching, in their previous schools or schools to be identified and arranged by the respective College, in topics to be decided by the concerned school authority. After completion of the Practice Teaching interns should collect the completion certificate from the respective School Authority.

5. Interns may be engaged in advanced learning in topics beyond their course curriculum under the guidance of the respective mentor.

6. Interns may be required to write codes for problems assigned to them in C / Python / any other programming language and run those in the computer laboratory under the guidance of respective mentor.

7. Interns may be asked to prepare study materials in MS-Power Point / LaTeX o n topics to be assigned to them by the respective mentor.

8. Interns may arranged to learn to work as a quantitative researcher in a financial establishment like bank / insurance company / financial consulting firm. After completion of internship students should collect completion certificate from the concerned authority.

9. Interns may visit Research Institute / Research Laboratory / University / College and may do some research related work with a researcher / scientist. After completion of internship students should collect completion certificate from the concerned authority.

Note : For the modalities of the summer internship one may refer to CSR/132/2024, dt. 14.11.2024.

4-yr Credit Distribution | MDC Credit Distribution | Course Overview

Major | Minor | MDC | Question Pattern

Guidelines for Research Internship in Mathematics for Semester VIII (Honours with Research)

1. Every Undergraduate student enrolled in Four year B.Sc. in Mathematics Honours with Research (under CCF) must complete one Research Internship carrying 4 credits in Semester VIII. This internship is a mandatory academic requirement for the completion of the programme.

2. The duration of the internship shall be 6–8 weeks. The internship must be completed before the End-Semester Examination, at least 30 days prior to the commencement of the semester-end examination.

3. The internship should involve academic or research-oriented work in Mathematics. The following types of activities may be considered appropriate:

   - A mini research project in mathematics.
   - Mathematical modelling or computational work.
   - A study project under the supervision of a college faculty member.
   - Internship at research institutes or recognized academic organizations.

4. The internship may include activities such as:

   - Reading and understanding mathematical research papers or books.
   - Learning and using mathematical or computational software.
   - Solving mathematical problems or preparing a survey/study report.
   - Maintaining and submitting a project notebook documenting the work.

5. At the completion of the internship, each student must submit a Project Notebook / Internship Report and appear for a Viva-Voce Examination. The total marks (100) has the following distribution :

   - Project Notebook / Internship Report - 60
   - Viva-Voce Examination - 40

   Students must obtain a minimum of 40% of the total marks (i.e., 40 out of 100) to successfully complete the internship.

6. The evaluation of the Research Internship will be conducted by the Mathematics Department of the College (the student's mother institution). The evaluation committee will consist of the Head of the Department of the concerned college, the Supervisor(s), and an External Expert. The name of the External Expert will be proposed by the college and approved by the University.
   The committee will assess the Project Notebook / Internship Report submitted by the student as well as the knowledge and understanding acquired during the internship, through the viva-voce examination.

7. The Internship Report should be prepared following the structure/design provided below.

4-yr Credit Distribution | MDC Credit Distribution | Course Overview
Major | Minor | MDC | Question Pattern

Guidelines for Dissertation/Project in Mathematics for Semester VIII (Honours with Research)

1. The Project Dissertation is intended to introduce students to independent learning, mathematical investigation, and academic writing. It provides an opportunity for students to explore in depth a specific topic in mathematics under the guidance of a supervisor.

2. The Head of the department of Mathematics of the student's own college will assign a supervisor from the faculty members of his/her department. The supervisor will help the student in selecting a topic, identifying appropriate references, understanding mathematical concepts and structuring the dissertation. This process may be initiated at the beginning of Semester VII, so that students have sufficient time for topic selection and preliminary study before formally undertaking the Project Dissertation in semester VIII.

3. The Dissertation will be evaluated by a Committee consisting of at least the Supervisor and an External Expert. The name of the External Expert will be proposed by the college and approved by the University. The evaluation will include assessment of the written dissertation, oral presentation of his/her work and a viva-voce examination to judge the student's understanding of the work.

4. The total marks (200) will be distributed as follows:

   - Dissertation - 100
   - Oral Presentation - 50
   - Viva-Voce Examination - 50.

   Students must obtain a minimum of 40% of the total marks (i.e., 80 out of 200) for successful completion of this 8 credit course.

5. Dissertation should be prepared following the structure provided below.

4-yr Credit Distribution | MDC Credit Distribution | Course Overview
Major | Minor | MDC | Question Pattern

Structure of Project Notebook /Internship Report and Dissertation in Mathematics

1. The title Page should include the following items:
   - Title of the Project
   - Name of the student
   - University Roll number and Registration number
   - Course : 4 Year B. Sc. Honours with Research with Mathematics Major
   - Semester VIII
   - College Name, University name
   - Name of Supervisor(s)
   - Year of submission
2. Certificate from the supervisor confirming that the work is done under his/her guidance and that the work is free from plagiarism.
3. Acknowledgement
4. Abstract (i.e., A summary of the work in 150-250 words.)
5. A brief introduction which will include the objective and the background of the topic under consideration.
6. Literature Review.
7. Main part : Definitions, Results/Theorems/Computations, examples, etc.
8. Outcome of the entire work and Conclusion.
9. References (List should not exceed 2 pages)