RAMAIAH UNIVERSITY OF APPLIED SCIENCES

M S Ramaiah University of Applied Sciences

Programme Structure and Course Details of M. Sc. in Mathematics

BATCH 2022 Onwards

Programme Code: 076

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Bangalore - 560 054

M S Ramaiah University of Applied Sciences

Faculty of Mathematical and Physical Science

Dean (Academics)
M.S. Ramaiah University of Applied Sciences
Bangalore-560054

Approved by the Academic Council at its 26th meeting held on 14th July 2022

University's Vision, Mission and Objectives

The M. S. Ramaiah University of Applied Sciences (MSRUAS) will focus on student-centric professional education and motivates its staff and students to contribute significantly to the growth of technology, science, economy and society through their imaginative, creative and innovative pursuits. Hence, the University has articulated the following vision and objectives.

Vision

MSRUAS aspires to be the premier university of choice in Asia for student centric professional education and services with a strong focus on applied research whilst maintaining the highest academic and ethical standards in a creative and innovative environment

Mission

Our purpose is the creation and dissemination of knowledge. We are committed to creativity, innovation and excellence in our teaching and research. We value integrity, quality and teamwork in all our endeavors. We inspire critical thinking, personal development and a passion for lifelong learning. We serve the technical, scientific and economic needs of our Society.

Objectives

1. To disseminate knowledge and skills through instructions, teaching, training, seminars, workshops and symposia in Engineering and Technology, Art and Design, Management and Commerce, Health and Allied Sciences, Physical and Life Sciences, Arts, Humanities and Social Sciences to equip students and scholars to meet the needs of industries, business and society
2. To generate knowledge through research in Engineering and Technology, Art and Design, Management and Commerce, Health and Allied Sciences, Physical and Life Sciences, Arts, Humanities and Social Sciences to meet the challenges that arise in industry, business and society
3. To promote health, human well-being and provide holistic healthcare
4. To provide technical and scientific solutions to real life problems posed by industry, business and society in Engineering and Technology, Art and Design, Management and Commerce, Health and Allied Sciences, Physical and Life Sciences, Arts, Humanities and Social Sciences
5. To instill the spirit of entrepreneurship in our youth to help create more career opportunities in the society by incubating and nurturing technology product ideas and supporting technology backed business
6. To identify and nurture leadership skills in students and help in the development of our future leaders to enrich the society we live in
7. To develop partnership with universities, industries, businesses, research establishments, NGOs, international organizations, governmental organizations in India and abroad to enrich the experiences of faculties and students through research and developmental programmes

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Programme Specifications: M. Sc. Mathematics

Faculty	Mathematical & Physical Sciences
Department	Mathematics and Statistics
Programme Code	076
Programme Name	M.Sc. Mathematics
Dean of the Faculty	Dr. Dilip Kumar Mahanty
Head of the Department	Dr. S. Chandankumar

1. **Title of the Award:** M.Sc. Mathematics
2. **Mode of Study:** Full-Time
3. **Awarding Institution /Body:** M. S. Ramaiah University of Applied Sciences, Bengaluru
4. **Joint Award:** Not Applicable
5. **Teaching Institution:** Faculty of Mathematical & Physical Sciences, M. S. Ramaiah University of Applied Sciences, Bengaluru
6. **Date of Programme Specifications: 14 July 2022**
7. **Date of Programme Approval by the Academic Council of MSRUAS: 14 July 2022**
8. **Next Review Date:** June-2024
9. **Programme Approving Regulating Body and Date of Approval:**
10. **Programme Accredited Body and Date of Accreditation:**
11. **Grade Awarded by the Accreditation Body:**
12. **Programme Accreditation Validity:**
13. **Programme Benchmark:**

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14. **Rationale for the Programme**

In the present day, the application of mathematical methods to solve real life problems in a wide variety of disciplines such as physics, chemistry, information science, business management, finance, economics and various branches of engineering has become a necessity. Apart from being an indispensable problem-solving and decision-making tool, mathematics is at the heart of advances in science, engineering and technology. The large scale use of computers in education and industry has given an impetus to the wide use of numerical methods and simulation. There is a need for qualified and competent mathematicians with a sound knowledge in applied mathematics. In our country, teaching/research in Mathematics is being carried out in a number of Universities. However, a vast majority of post graduate degree courses in Mathematics offer more conventional, content-based academic curriculum which inherently lacks application oriented approach, which is essential to make the degree programme more fulfilling and professional from the career perspective.

The Faculty of Mathematical and Physical Sciences of MSRUAS offers the M.Sc. (Mathematics) course

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with an outcome based curriculum emphasizing the Critical, Analytical and Problem Solving skills to equip the students to pursue their scientific and research career with better preparedness and matured professional outlook. The presence of other allied Faculties of the University provides additional exposure to students the multi-disciplinary approach which is emerging as a key differentiator in the success of modern scientific and engineering endeavors. An expanding job market is open for applied mathematicians since employers value the intellectual rigour and reasoning skills that mathematicians have. Mathematician's familiarity with numerical and symbolic thinking and the analytic approach to problem-solving is highly valued in industry.

15. Programme Mission

The purpose of the programme is to create innovative problem solvers in multi-disciplinary settings, entrepreneurs and leaders that apply their knowledge, understanding, cognitive abilities, practical skills and transferable skills gained through systematic, flexible and rigorous learning in the chosen academic domain.

16. Gradate Attributes (GAs)

GA-1. Ability to apply fundamental knowledge of Mathematical and Physical Sciences to solve real life problems in their chosen domain

GA-2. Ability to teach in schools, colleges and universities with relevant training and perform administrative duties in government, semi-government, private and public sector organizations

GA-3. Ability to understand and solve scientific problems by conducting experimental investigations

GA-4. Ability to apply appropriate tools, techniques and understand utilization of resources appropriately in various laboratories

GA-5. Ability to conduct scientific research and disseminate the knowledge in the chosen domain

GA-6. Ability to understand the effect of scientific solutions on legal, cultural, social, public health and safety aspects, and apply ethical principles to scientific practices and professional responsibilities

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GA-7. Ability to develop sustainable solutions and understand their effect on society and environment

GA-8. Ability to Ability to work as a member of a team, to plan and to integrate knowledge of various disciplines and to lead teams in multidisciplinary settings

GA-9. Ability to make effective oral presentations and communicate technical ideas to a broad audience using written and oral means

GA-10. Ability to adapt to the changes and advancements in science and engage in independent and life-long learning

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17. Programme Outcomes (POs)

M.Sc. graduates will be able to:

PO-1. **Scientific Knowledge:** Apply fundamental knowledge of Mathematics to solve real life problems in their chosen domain

PO-2. **Dissemination of Knowledge:** Disseminate knowledge in educational institutions with relevant training and prepare students to qualify in various competitive examinations

PO-3. **Problem Solving:** Understand and solve scientific problems by using analytical techniques

PO-4. **Modern Tool Usage:** Apply appropriate tools, techniques and understand utilization of resources appropriately in various laboratories

PO-5. **Research:** Conduct scientific research and disseminate the knowledge in the chosen domain

PO-6. **Individual and teamwork:** Work as a member of a team, to plan and to integrate knowledge of various disciplines as individual and to lead teams in multidisciplinary settings

PO-7. **Communication:** Make effective oral presentations and communicate technical ideas to a broad audience using written and oral means

PO-8. **Life-long learning:** Adapt to the changes and advancements in mathematics and engage in independent and life-long learning

18. Programme Goal

The programme goal is to train students with advanced knowledge and understanding of Applied Mathematics with higher order critical, analytical, problem solving and research skills; ability to think rigorously and independently to meet higher level expectations of academia and research with sufficient transferrable skills.

19. Program Educational Objectives (PEOs)

The objectives of the M.Sc. (Mathematics) Programme are to:

PEO-1. To provide students knowledge in mathematics to enable them to deliver efficient solutions for complex Scientific problems using analytical and cognitive skills in their chosen domain

PEO-2. To enable students to apply appropriate tools, techniques and understand utilization of resources in laboratories and computational skills in conducting research in their chosen domains and work as an individual as well as lead team in multidisciplinary settings

PEO-3. To inculcate communication, soft, and managerial skills for a successful career and to engage in lifelong learning

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20. Programme Specific Outcomes (PSOs)

At the end of the M.Sc. (Mathematics) programme, the graduate will be able to:

PSO-1. Apply the basic principles of mathematics to solve scientific problems, model, simulate and interpret the results.

PSO-2. Develop abstract mathematical thinking, assimilate complex mathematical ideas and arguments and conduct research in applied mathematics.

PSO-3. Demonstrate communication skills and involvement in lifelong learning for the betterment of organization.

21. Programme Structure:

Semester 1

Sl. No.	Course Code	Course Title	Theory (h/W/S)	Tutorials (h/W/S)	Practical (h/W/S)	Max. Marks	Total Credits
1	MTC511A	Linear Algebra	3	1	0	100	4
2	MTC512A	Theory of Ordinary Differential Equations	3	1	0	100	4
3	MTC513A	Real Analysis	3	1	0	100	4
4	MTC514A	Numerical Analysis – 1	2	1	0	100	3
5	MTC515A	Abstract Algebra	3	1	0	100	4
6	MTL511A	Numerical Analysis Laboratory – 1	0	0	2	50	1
Total			**14**	**5**	**2**	**550**	**20**

Semester 2

Sl. No.	Course Code	Course Title	Theory (h/W/S)	Tutorials (h/W/S)	Practical (h/W/S)	Max. Marks	Total Credits
1	MTC521A	Complex Analysis	3	1	0	100	4
2	MTC522A	Theory of Partial Differential Equations	3	1	0	100	4
3	MTC523A	Topology	3	1	0	100	4
4	MTC524A	Introduction to Statistics and Probability	3	1	0	100	4
5	MTC525A	Fundamentals of Fluid Dynamics	3	1	0	100	4
Total			**15**	**5**	**0**	**500**	**20**

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Semester 3

Sl. No.	Course Code	Course Title	Theory (h/W/S)	Tutorials (h/W/S)	Practical (h/W/S)	Max. Marks	Total Credits
1	MTC531A	Measure Theory and Integration	3	1	0	100	4
2	MTC532A	Differential Geometry	3	1	0	100	4
3	MTC533A	Numerical Analysis – 2	2	1	0	100	3
4	MTE5XXX	Elective – 1	3	1	0	100	4
5	MTL532A	Numerical Analysis Laboratory – 2	0	0	2	50	1
6	MTS531A	Seminar – 1	0	0	4	50	2
7	MPF615A	Research Methodology	2	0	0	50	2
Total			**13**	**4**	**6**	**550**	**20**

Semester 4

Sl. No.	Course Code	Course Title	Theory (h/W/S)	Tutorials (h/W/S)	Practical (h/W/S)	Max. Marks	Total Credits
1	MTC541A	Functional Analysis	3	1	**0**	100	4
2	MTE5XXX	Elective – 2	3	1	0	100	4
3	MTE5XXX	Elective – 3	3	1	0	100	4
4	MTH600A	Dissertation			16	200	8
Total			**9**	**3**	**16**	**500**	**20**

* Internship can be done during the vacation period for a maximum period of 8 weeks

Electives			
Group 1		**Group 2**	
Course Code	**Course Title**	**Course Code**	**Course Title**
MTE531A	Mechanics	MTE631A	Machine Learning – 1
MTE541A	Fluid Mechanics	MTE641A	Machine Learning – 2
MTE542A	Magnetohydrodynamics	MTE642A	Probability and Stochastic Process

22. Course Delivery: As per the Timetable

23. Teaching and Learning Methods

1. Face to Face Lectures using Audio-Visuals
2. Workshops, Group Discussions, Debates, Presentations
3. Demonstrations

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4. Guest Lectures
5. Laboratory work/Field work/Workshop
6. Industry Visit
7. Seminars
8. Group Exercises
9. Project Work
10. Project
11. Exhibitions
12. Technical Festivals

24. Assessment and Grading

24.1. Components of Grading

There shall be **two components** of grading in the assessment of each course:

Component 1, Continuous Evaluation (CE): This component involves multiple subcomponents (SC1, SC2, etc.) of learning assessment. The assessment of the subcomponents of CE is conducted during the semester at regular intervals. This subcomponent represents the formative assessment of students' learning.

Component 2, Semester-end Examination (SEE): This component represents the summative assessment carried out in the form an examination conducted at the end of the semester.

Marks obtained CE and SEE components have equal weightage (CE: 50% and SEE: 50%) in determining the final marks obtained by a student in a Course.

The complete details of Grading are given in the Academic Regulations.

24.2. Continuous Evaluation Policies

Continuous evaluation and Semester-End Examination depends on the type of the course as discussed below:

24.2.1 Theory Courses

Theory Course			
CE (Weightage : 50%)			**SEEE (Weightage : 50%)**
TSC1 Midterm Exam/Term Test	TSC2 Assignment	TSC3 Innovative	SEE Written Exam
50 Marks	25 Marks	25 Marks	100 Marks

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There shall be three subcomponents, first one is midterm exam carrying 50 marks and others carrying 25 marks each.
The innovative TSC3 can be of any of the following types:

a) Online Test
b) Assignments/Problem Solving
c) Field Assignment
d) Open Book Test
e) Portfolio
f) Reports
g) Case Study
h) Group Task
i) Any other

After the three subcomponents are evaluated, the CE component marks are determined as:
CE Component Marks = (Total of the marks obtained in all the three subcomponents) ÷ 2

24.2.2 Laboratory Course

For a laboratory course, the scheme for determining the CE marks is as under:

Laboratory Course		
CE (Weightage: 50 %)		SEE (Weightage: 50 %)
LSC1	LSC2	Lab - SEE
25 Marks	25 Marks	50 Marks

The subcomponents can be of any of the following types:

a) Laboratory / Clinical Work Record
b) Experiments
c) Computer Simulations
d) Creative Submission
e) Virtual Labs
f) Viva / Oral Exam
g) Lab Manual Report
h) Any other (e.g. combinations)

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After the subcomponents of CE are evaluated, the CE component Marks are determined as:

CE Component Marks = (Total of the best two subcomponent marks out of the three) ÷ 2

24.2.3 Course Having a Combination of Theory and Laboratory

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For a course that contains the combination of theory and laboratory sessions, the scheme for determining the CE marks is as under:

Course with the combination of Theory and Laboratory					
CE (Weightage: 50 %)				SEE (Weightage: 50 %)	
TSC1: (20 %) Midterm exam / Term Test	TSC2: (10 %) Assignment	TSC3: (10 %) Innovative	LSC4: (10 %) CE	SEE (35 %) Theory	SEE (15 %) Laboratory
50 marks	25 Marks	25 Marks	25 Marks	100 Marks	25 Marks

There shall be four subcomponents, each carrying 25 marks. Out of these, there shall be two term-tests and an assignment to evaluate the students' performance in theory. The fourth subcomponent shall be set to evaluate the students' performance in the laboratory.

The theory assignment can be of any of the following types:

a) Online Test
b) Problem Solving
c) Field Assignment
d) Open Book Test
e) Portfolio
f) Reports
g) Case Study
h) Group Task
i) Any other

The laboratory subcomponent can be of any of the following types:

a) Laboratory / Clinical Work Record
b) Experiments
c) Computer Simulations
d) Creative Submission
e) Virtual Labs
f) Viva / Oral Exam
g) Lab Manual Report
h) Any other (e.g. combinations)

After the four subcomponents are evaluated, the CE component marks are determined as:
CE Component Marks = (Total of the marks obtained in all the four subcomponents) ÷ 2

25. Minor Programme

The details of the following aspects of the minor programmes are presented in the **Academic Regulations** for the B. Tech. Degree Programme:

1. Programme Structure
2. Eligibility to Minor Programme
3. Registration to Minor Programme
4. Certification for Minor Programme

26. Student Support for Learning

1. Course Notes
2. Reference Books in the Library
3. Magazines and Journals
4. Internet Facility
5. Computing Facility
6. Laboratory Facility
7. Workshop Facility
8. Staff Support
9. Lounges for Discussions
10. Any other support that enhances their learning

27. Quality Control Measures

1. Review of Course Notes
2. Review of Question Papers and Assignment Questions
3. Student Feedback
4. Moderation of Assessed Work
5. Opportunities for students to see their assessed work
6. Review by external examiners and external examiners reports
7. Staff Student Consultative Committee meetings
8. Student exit feedback
9. Subject Assessment Board (SAB)
10. Programme Assessment Board (PAB)

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28. Programme Map (Course-PO-PSO Map)

Sem.	Course Title	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PSO-1	PSO-2	PSO-3
1	Linear Algebra	3	3	2	2	2		1		3	2	1
1	Theory of Ordinary Differential Equations	3	2	2	1	1	1			3	2	1
1	Real Analysis	2	2	3		2	2		1	3		1
1	Numerical Analysis – 1	3	2	3	3	2	1	1	1	3	2	1
1	Abstract Algebra	2	3	1		2	1	1	1	2	3	1
1	Numerical Analysis Laboratory – 1	3	1	1	1	1				3	3	
2	Complex Analysis	3	2	3		3	1	1	1	3	3	1
2	Theory of Partial Differential Equations	3	2	2		1	1			3	2	1
2	Topology	3	2			1	1	1	1	2	3	1
2	Fundamentals of Fluid Dynamics	3	2	2				1	1	3	1	
2	Introduction to Statistics and Probability	3	2	2			1	1		3	2	
3	Measure Theory and Integration	3	2			1	1	1	1	2	3	1
3	Differential Geometry	3	1	3	2	2	1	1		3	2	1
3	Numerical Analysis – 2	3	2	3	3	2	1	1	1	3	3	1
3	Mechanics	3	2	3	1	1			1	3	3	

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3	Machine Learning – 1	3	2	3	3	1	1	1	1	3	1	1
3	Numerical Analysis Laboratory – 2	3	1	1	1	1				3	3	
3	Research Methodology		2			3	2	3	2	2	2	3
3	Seminar – 1	3	2	2	3	3	2	2	2	3	3	2
4	Functional Analysis	3	2			1	1	1	1	2	3	1
4	Fluid Mechanics	3	2	2	1	1			1	3	2	1
4	Magnetohydrodynamics	3	1	3		3	1	1	3	3	3	1
4	Machine Learning – 2	3	2	3	3	1	1	1	1	3	1	1
4	Probability and Stochastic Process	3	3	3	3	3				3	3	1
4	Dissertation	3		3	3	3	3	3	2	3	3	3

29. Co-curricular Activities

Students are encouraged to take part in co-curricular activities like seminars, conferences, symposia, paper writing, attending industry exhibitions, project competitions and related activities for enhancing their knowledge and networking.

30. Cultural and Literary Activities

Annual cultural festivals are held to showcase the creative talents in students. They are involved in planning and organizing the activities.

31. Sports and Athletics

Students are encouraged to take part in sports and athletic events regularly. Annual sports meet will be held to demonstrate sportsmanship and competitive spirit.

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Course Specifications: Linear Algebra

Course Title	Linear Algebra
Course Code	MTC511A
Course Type	Core Theory
Department	Mathematics and Statistics
Faculty	Mathematical and Physical Sciences

1. Course Summary

The aim of the course is to introduce the concepts of linear algebra and its applications.

In this core course the students are taught basic operations of matrices, solutions of linear system of equations, vector spaces, subspaces, linear dependence and independence, span of vectors. Matrix representation of linear transformations, eigenvalue problems and canonical forms are studied in detail. Inner product spaces and operators and their applications are discussed.

2. Course Size and Credits:

Number of Credits	04
Credit Structure (Lecture: Tutorial: Practical)	3:1:0
Total Hours of Interaction	60
Number of Weeks in a Semester	15
Department Responsible	Mathematics and Statistics
Total Course Marks	100
Pass Criterion	As per the Academic Regulations
Attendance Requirement	As per the Academic Regulations

3. Course Outcomes (COs)

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

- **CO-1.** Illustrate the concepts of linear system of equations, vector spaces, linear transformation, diagonalization and inner product spaces
- **CO-2.** State and prove important theorems in linear algebra
- **CO-3.** Solve simple mathematical problems in linear system of equations, matrix theory, vector spaces, linear transformations, diagonalization and inner product spaces
- **CO-4.** Solve complex mathematical problems in linear system of equations, matrix theory, vector spaces, linear transformations, diagonalization and inner product spaces
- **CO-5.** Apply the concepts of linear algebra to model, solve, and analyze real-world situations

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4. Course Contents

Unit 1: System of Linear Equations **5 Hrs**

Systems of linear equations, Matrices, Elementary row operations, Row-reduced echelon matrices.

Unit 2 (Vector Spaces): **5 Hrs**

Vector spaces, Subspaces, Linear dependence and independence, Bases and dimension, Ordered bases and coordinates.

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Unit 3 (Linear Transformations): **10 Hrs**

Linear transformations, Rank-nullity theorem, Algebra of linear transformations, Isomorphism, Matrix representation, Linear functional, Annihilator, Double dual, Transpose of a linear transformation.

Unit 4 (Eigenvalues and Eigenvectors): **15 Hrs**

Characteristic values and characteristic vectors of linear transformations, Diagonalizability, Minimal polynomial of a linear transformation, Cayley-Hamilton theorem, Invariant subspaces, Direct-sum decompositions, Invariant direct sums, The primary decomposition theorem, Cyclic subspaces and annihilators, Cyclic decomposition, Rational and Jordan forms, Singular Value Decomposition.

Unit 5 (Inner Product Spaces): **10 Hrs**

Inner product spaces, Orthonormal bases, Gram-Schmidt process, QR decomposition, Best approximation – Least square solutions, Orthogonal projections, Adjoint operator, Unary operators, Self-Adjoint operators, Normal operators – Spectral theorem.

5. Course Map (CO-PO-PSO Map)

	Programme Outcomes (POs)								Programme Specific Outcomes (PSOs)		
	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PSO-1	PSO-2	PSO-3
CO-1	3	2	2						3	2	
CO-2	2	3	2						3	2	
CO-3	3	3	1	1			1		3	2	
CO-4	3	3	2	2	2		1		3	2	1
CO-5	3	3	2	2	2		1		3	2	1

6. Course Teaching and Learning Methods

Teaching and Learning Methods	Duration in hours	Total Duration in Hours
Face to Face Lectures		45
Demonstrations		00
1. Demonstration using Videos	00	
2. Demonstration using Physical Models / Systems	00	
3. Demonstration on a Computer	00	
Numeracy		15
1. Solving Numerical Problems	15	
Practical Work		00
1. Course Laboratory	00	
2. Computer Laboratory	00	
3. Engineering Workshop / Course/Workshop / Kitchen	00	
4. Clinical Laboratory	00	
5. Hospital	00	
6. Model Studio	00	
Others		00
1. Case Study Presentation	00	
2. Guest Lecture	00	
3. Industry / Field Visit	00	

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4. Brain Storming Sessions	00	
5. Group Discussions	00	
6. Discussing Possible Innovations	00	
Term Tests, Laboratory Examination/Written Examination, Presentations		10
Total Duration in Hours		**70**

7. Course Assessment and Reassessment

The details of the components and subcomponents of course assessment are presented in the Programme Specifications document pertaining to the M. Sc. Mathematics Programme. The procedure to determine the final course marks is also presented in the Programme Specifications document.

The evaluation questions are set to measure the attainment of the COs. In either component (CE or SEE) or subcomponent of CE (TSC1, TSC2, or TSC3), COs are assessed as illustrated in the following Table.

Focus of COs on each Component or Subcomponent of Evaluation				
	Component 1: CE (50% Weightage)			**Component 2: SEE (50% Weightage)**
Subcomponent ▶	**TSC1**	**TSC2**	**SC3**	
Subcomponent Type ▶	**Mid term /Term Test**	**Assignment**	**Innovative**	**100 Marks**
Maximum Marks ▶	**50**	**25**	**25**	
CO-1	×	×		×
CO-2	×	×		×
CO-3	×	×	×	×
CO-4			×	×
CO-5			×	×

The Course Leader assigned to the course, in consultation with the Head of the Department, shall provide the focus of COs in each component of assessment in the above template at the beginning of the semester. Course reassessment policies are presented in the Academic Regulations document.

8. Achieving COs

The following skills are directly or indirectly imparted to the students in the following teaching and learning methods:

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S. No	Curriculum and Capabilities Skills	How imparted during the course
1.	Knowledge	Classroom lectures, tutorials, Assignments
2.	Understanding	Classroom lectures, tutorials, Assignments
3.	Critical Skills	Classroom lectures, Assignment
4.	Analytical Skills	Assignment
5.	Problem Solving Skills	Assignment, Examination
6.	Practical Skills	--
7.	Group Work	Assignment
8.	Self-Learning	Self-study, Assignment
9.	Written Communication Skills	Assignment, Examination

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10.	Verbal Communication Skills	--
11.	Presentation Skills	--
12.	Behavioral Skills	Course work
13.	Information Management	Assignment, Examination
14.	Personal Management	Course work
15.	Leadership Skills	--

9. Course Resources

a. Essential Reading

1. Course notes
2. Hoffman, K. and Kunze R., 2015, Linear Algebra, 2nd Ed., Pearson Education India
3. Friedberg, S. H., Insel, A. J., and Spence, L. E., 2022, Linear Algebra, 5th Ed., Pearson Education India

b. Recommended Reading

1. Axler, S. 2016, Linear Algebra Done Right, 3rd Ed., Springer UTM
2. Halmos, P. R., 2011, Finite-Dimensional Vector Spaces, Springer UTM
3. Kumaresan, S., 2004, Linear Algebra: A Geometric Approach, Prentice-Hall of India
4. Ramachandra Rao A. and Bhimasankaram P., 2000, Linear Algebra, Hindustan Book Agency
5. Lang, S. 2010, Linear Algebra, 3rd Ed., Springer UTM
6. Strang, G., 2016, Introduction to Linear Algebra, 5th Ed., Wellesley-Cambridge Press
7. Leon, S. J., 2015, Linear Algebra with Applications, 9th Ed., Pearson
8. Artin, M, 2015, Algebra, 2nd Ed., Pearson India

c. Magazines and Journals

1. The Electronic Journal of Linear Algebra (ELA) http://repository.uwyo.edu/ela/

d. Websites

1. https://swayam.gov.in
2. https://coursera.org
3. http://ocw.mit.edu/courses/mathematics/18-06-linear-algebra-spring-2010/

e. Other Electronic Resources

1. https://www.khanacademy.org/math/linear-algebra

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10. Course Organization

Course Code	MTC511A	
Course Title	Linear Algebra	
Course Leader's Name	As per Timetable	
Course Leader's Contact Details	**Phone:**	+91-804-906-5555
	E-mail:	hod.mt.mp@msruas.ac.in
Course Specifications Approval Date	July 2022	
Next Course Specifications Review Date	June 2024	

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Course Specifications: Theory of Ordinary Differential Equations

Course Title	Theory of Ordinary Differential Equations
Course Code	MTC512A
Course Type	Core Theory
Department	Mathematics and Statistics
Faculty	Mathematical and Physical Sciences

1. Course Summary

Theory of Ordinary differential Equations (ODEs) deals with solving ODEs analytically and numerically. Here the students learn the abstract theorems on existence and uniqueness of solution to linear differential equations. This core course introduces the concept of Wronskian and its relevance to linear independence. The course introduces ideas of regular and irregular points and the power series solutions. Students also learn the methods to solve linear system of differential equations and matrix exponential. Course Size and Credits:

Number of Credits	04
Credit Structure (Lecture: Tutorial: Practical)	3:1:0
Total Hours of Interaction	60
Number of Weeks in a Semester	15
Department Responsible	Mathematics and Statistics
Total Course Marks	100
Pass Criterion	As per the Academic Regulations
Attendance Requirement	As per the Academic Regulations

2. Course Outcomes (COs)

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

- **CO-1.** Illustrate the principles of linear and non-linear differential equations, initial and boundary value problems, Sturm-Liouville problems and system of linear differential equations, autonomous systems
- **CO-2.** State and prove theorems on existence and uniqueness of solution, series solutions, of ordinary differential equations and system of differential equations.
- **CO-3.** Solve Sturm-Liouville problems, construct special functions as series solutions of some particular ordinary differential equations
- **CO-4.** Model real world problems using ordinary differential equations and verify the results of the model
- **CO-5.** Solve complex mathematical problems involving linear and non-linear differential equations, initial and boundary value problems, system of linear differential equations, and autonomous systems

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3. Course Contents

Unit 1 (Adjoint & Self-Adjoint Differential Equation): **10 Hrs**

Introduction and origin of ODEs, linear differential equations, initial and boundary value problems. Wronskian, self-adjoint linear operator, Adjoint equations, Variation of parameters, Sturm's comparison and separation theorems

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Unit 2 (Strum-Liouville Problems): **8 Hrs**

Existence and uniqueness theorem, eigenvalue problems, Sturm-Liouville problems, orthogonality of eigen functions, eigen function expansion and series of orthonormal functions, Green's function.

Unit 3 (Power Series Solution): **12 Hrs**

Classification into regular and irregular singular points, power series solution, Frobenius method, Bessel, Hermite, Laguerre, Chebyshev and Gauss Hypergeometric equations and their general solutions, concept of point at infinity.

Unit 4 (Linear System of Order Linear Differential Equations): **15 Hrs**

Linear system of equations and matrix exponential. Linear systems with periodic coefficients - Floquet theory, Linear and Non-linear autonomous system of equations, phase-plane analysis, critical points, stability of critical points and Lyapunov methods, limit cycle and periodic solutions, bifurcation of plane autonomous systems.

4. Course Map (CO-PO-PSO Map)

	Programme Outcomes (POs)								Programme Specific Outcomes (PSOs)		
	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PSO-1	PSO-2	PSO-3
CO-1	3	2							3	2	
CO-2	3	2							3	2	
CO-3	3	2	1			1			3	2	
CO-4	3		2	1	1	1			3	2	1
CO-5	3		2	1	1	1			3	2	1

5. Course Teaching and Learning Methods

Teaching and Learning Methods	Duration in hours	Total Duration in Hours
Face to Face Lectures		45
Demonstrations		00
1. Demonstration using Videos	00	
2. Demonstration using Physical Models / Systems	00	
3. Demonstration on a Computer	00	
Numeracy		15
1. Solving Numerical Problems	15	
Practical Work		00
1. Course Laboratory	00	
2. Computer Laboratory	00	
3. Engineering Workshop / Course/Workshop / Kitchen	00	
4. Clinical Laboratory	00	
5. Hospital	00	
6. Model Studio	00	
Others		00
1. Case Study Presentation	00	

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2. Guest Lecture	00	
3. Industry / Field Visit	00	
4. Brain Storming Sessions	00	
5. Group Discussions	00	
6. Discussing Possible Innovations	00	
Term Tests, Laboratory Examination/Written Examination, Presentations		10
Total Duration in Hours		**70**

6. Course Assessment and Reassessment

The details of the components and subcomponents of course assessment are presented in the Programme Specifications document pertaining to the M. Sc. Mathematics Programme. The procedure to determine the final course marks is also presented in the Programme Specifications document.

The evaluation questions are set to measure the attainment of the COs. In either component (CE or SEE) or subcomponent of CE (TSC1, TSC2 or TSC3), COs are assessed as illustrated in the following Table.

Focus of COs on each Component or Subcomponent of Evaluation				
	Component 1: CE (50% Weightage)			Component 2: SEE (50% Weightage)
Subcomponent ▶	TSC1	TSC2	SC3	
Subcomponent Type ▶	Mid term /Term Test	Assignment	Innovative	100 Marks
Maximum Marks ▶	50	25	25	
CO-1	×	×		×
CO-2	×	×		×
CO-3	×	×	×	×
CO-4			×	×
CO-5			×	×

The Course Leader assigned to the course, in consultation with the Head of the Department, shall provide the focus of COs in each component of assessment in the above template at the beginning of the semester.

Course reassessment policies are presented in the Academic Regulations document.

7. Achieving COs

The following skills are directly or indirectly imparted to the students in the following teaching and learning methods:

S. No	Curriculum and Capabilities Skills	How imparted during the course
1.	Knowledge	Classroom lectures, tutorials, Assignments
2.	Understanding	Classroom lectures, tutorials, Assignments
3.	Critical Skills	Classroom lectures, Assignment
4.	Analytical Skills	Assignment
5.	Problem Solving Skills	Assignment, Examination
6.	Practical Skills	--

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7.	Group Work	Assignment
8.	Self-Learning	Self-study, Assignment
9.	Written Communication Skills	Assignment, Examination
10.	Verbal Communication Skills	--
11.	Presentation Skills	--
12.	Behavioral Skills	Course work
13.	Information Management	Assignment, Examination
14.	Personal Management	Course work
15.	Leadership Skills	--

8. Course Resources

a. Essential Reading

1. Course notes
2. Walter, W. (1998) Ordinary Differential Equations, Springer.
3. Coddington, E. A. and Levinson, N. (1955) Theory of Ordinary Differential Equations, McGraw-Hill.
4. Simmons, G. F. (1974) Differential Equations with Applications and Historical Notes, 2nd edition, McGraw Hill.
5. Ross, S. L. (1984) Differential Equations, Wiley.
6. Eastham, M. S. P. (1970) Theory of Ordinary Differential Equations, Van Nostrand.

b. Recommended Reading

1. Boyce, W. E. and DiPrima, R. C. (2001) Elementary Differential Equations, 10th Edition, John Wiley and sons.
2. King, A. C., Billingham, J. and Otto, S.R. (2003) Differential Equations, Cambridge University Press.
3. Tenenbaum, M. and Pollard, H. (1985) Ordinary Differential Equations, Dover Publications.

c. Magazines and Journals

1. Dynamical Systems & Differential Equations http://www.springer.com/mathematics/dynamical+systems/journal/10625
2. Journal of Differential Equations http://www.sciencedirect.com/science/journal/00220396
3. Journal of Differential Equations http://www.journals.elsevier.com/journal-of-differential-equations

d. Websites

1. http://ocw.mit.edu/courses/mathematics/18-03-differential-equations-spring-2010/
2. http://tutorial.math.lamar.edu/Classes/DE/DE.aspx

e. Other Electronic Resources

1. https://www.khanacademy.org/
2. http://courseware.ku.edu.tr/ahmetkoc/public_html/W.%20E.%20Boyce%20R.C.%20DiPrima%20-%20Elementary%20Differential%20Equations%20and%20Boundary%20Value%20Problems.pdf

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9. Course Organization

Course Code	MTC512A	
Course Title	Theory of Ordinary Differential Equations	
Course Leader's Name	As per Timetable	
Course Leader's Contact Details	**Phone:**	+91-804-906-5555
	E-mail:	hod.mt.mp@msruas.ac.in
Course Specifications Approval Date	July 2022	
Next Course Specifications Review Date	June 2024	

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Course Specifications: Real Analysis

Course Title	Real Analysis
Course Code	MTC513A
Course Type	Core Theory
Department	Mathematics and Statistics
Faculty	Mathematical and Physical Sciences

1. Course Summary

The aim of the course is to introduce students the concepts of real analysis. The students will learn to write proofs for abstract theorems in real analysis. This core course serves as an introduction to abstract definitions of limits, continuity, integration and differentiation, uniform convergence of real valued functions. In this course the concepts on sequence and series of functions and related topics are covered. Riemann integrals and functions of bounded variations are also dealt in great detail.

2. Course Size and Credits:

Number of Credits	04
Credit Structure (Lecture: Tutorial: Practical)	3:1:0
Total Hours of Interaction	45
Number of Weeks in a Semester	15
Department Responsible	Mathematics and Statistics
Total Course Marks	100
Pass Criterion	As per the Academic Regulations
Attendance Requirement	As per the Academic Regulations

3. Course Outcomes (COs)

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

- **CO-1.** Understand and explain the underlying concepts of metric spaces, continuity, differentiability, integrability, uniform convergence
- **CO-2.** Prove statements in the context of real analysis using definitions
- **CO-3.** State and produce rigorous proofs of important theorems that arise in real analysis
- **CO-4.** Solve problems on metric spaces, sequence and series, continuity, differentiability, uniform convergence, integrability and functions of several variables
- **CO-5.** Analyse and apply definitions and theorems of real analysis to problems

4. Course Contents

Unit 1 (Basic Topology):

Field and order structure in $\mathbb{R}$. Finite, countable and uncountable sets. Elementary theory of metric spaces, open, closed, compact, perfect and connected sets. k-cell and its compactness, Hein - Borel theorem. Bolzano-Weierstrass theorem.

Unit 2 (Continuity and Differentiability):

Introduction, continuity and compactness, continuity and connectedness, uniform continuity and discontinuities. Derivative of real functions, mean value theorems and Taylor's theorem.

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Unit 3 (Integration):
Riemann integrals, Riemann - Stieltjes integrals, definition and existence, properties. Integration and differentiation, Fundamental theorems of integral calculus. Rectifiable curves.

Unit 4 (Sequence and Series of Functions):
Point wise convergence, uniform convergence and Weierstrass M-test. Uniform convergence and continuity. Uniform convergence and Riemann - Stieltjes integration. Uniform convergence and differentiation. Uniform convergence and boundedness. The Stone-Weierstrass theorem.

Unit 5 (Functions of Several Variables):
Differentiation, partial differentiation, chain rule, directional derivative, Hessian matrix. The inverse function and implicit function theorems, illustration and examples.

5. Course Map (CO-PO-PSO Map)

	Programme Outcomes (POs)								Programme Specific Outcomes (PSOs)		
	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PSO-1	PSO-2	PSO-3
CO-1	2	2						1	3		1
CO-2	2	1	3		2			1	3		1
CO-3	2	1	3		2	2		1	3		1
CO-4	2	1	3		2			1	3		1
CO-5	2	1	3			2		1	3		1

6. Course Teaching and Learning Methods

Teaching and Learning Methods	Duration in hours	Total Duration in Hours
Face to Face Lectures		45
Demonstrations		00
1. Demonstration using Videos	00	
2. Demonstration using Physical Models / Systems	00	
3. Demonstration on a Computer	00	
Numeracy		15
1. Solving Numerical Problems	15	
Practical Work		00
1. Course Laboratory	00	
2. Computer Laboratory	00	
3. Engineering Workshop / Course/Workshop / Kitchen	00	
4. Clinical Laboratory	00	
5. Hospital	00	
6. Model Studio	00	
Others		00
1. Case Study Presentation	00	
2. Guest Lecture	00	
3. Industry / Field Visit	00	
4. Brain Storming Sessions	00	
5. Group Discussions	00	

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6. Discussing Possible Innovations	00	
Term Tests, Laboratory Examination/Written Examination, Presentations		10
Total Duration in Hours		**70**

7. Course Assessment and Reassessment

The details of the components and subcomponents of course assessment are presented in the Programme Specifications document pertaining to the M. Sc. Mathematics Programme. The procedure to determine the final course marks is also presented in the Programme Specifications document.

The evaluation questions are set to measure the attainment of the COs. In either component (CE or SEE) or subcomponent of CE (TSC1, TSC2, or TSC3), COs are assessed as illustrated in the following Table.

Focus of COs on each Component or Subcomponent of Evaluation				
	Component 1: CE (50% Weightage)			Component 2: SEE (50% Weightage)
Subcomponent ▶	TSC1	TSC2	SC3	
Subcomponent Type ▶	Mid term /Term Test	Assignment	Innovative	100 Marks
Maximum Marks ▶	50	25	25	
CO-1	×	×		×
CO-2	×	×		×
CO-3	×	×	×	×
CO-4			×	×
CO-5			×	×

The Course Leader assigned to the course, in consultation with the Head of the Department, shall provide the focus of COs in each component of assessment in the above template at the beginning of the semester.
Course reassessment policies are presented in the Academic Regulations document.

8. Achieving COs

The following skills are directly or indirectly imparted to the students in the following teaching and learning methods:

S. No	Curriculum and Capabilities Skills	How imparted during the course
1.	Knowledge	Classroom lectures, tutorials, Assignments
2.	Understanding	Classroom lectures, tutorials, Assignments
3.	Critical Skills	Classroom lectures, Assignment
4.	Analytical Skills	Assignment
5.	Problem Solving Skills	Assignment, Examination
6.	Practical Skills	--
7.	Group Work	Assignment
8.	Self-Learning	Self-study, Assignment
9.	Written Communication Skills	Assignment, Examination
10.	Verbal Communication Skills	--
11.	Presentation Skills	--
12.	Behavioral Skills	Course work

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13.	Information Management	Assignment, Examination
14.	Personal Management	Course work
15.	Leadership Skills	--

9. Course Resources

a. Essential Reading

2. Course notes
3. Rudin, W., 1976, Principles of Mathematical Analysis, 3rd Ed., McGraw Hill.
4. Apostal, T.M., 1988, Mathematical Analysis, 2nd Ed., Narosa publishing house.

b. Recommended Reading

1. Bartle, R.G., 1976, The Elements of Real analysis, 2nd Ed., John Wiley and Son Inc.
2. Pugh, C.C., 2002, Real Mathematical Analysis, Springer.
3. Malik, S.C., 2011, Principle of Real Analysis, 2nd Ed., New Academic Sciences Ltd.
4. Howie, J.M., 2006 Real Analysis, Springer.

c. Websites

5. https://www.coursera.org/
6. http://nptel.ac.in/
7. https://ocw.mit.edu/index.htm

d.Other Electronic Resources

8. https://www.khanacademy.org/

10. Course Organization

Course Code	MTC513A	
Course Title	Real Analysis	
Course Leader's Name	As per Timetable	
Course Leader's Contact Details	**Phone:**	+91-804-906-5555
	E-mail:	hod.mt.mp@msruas.ac.in
Course Specifications Approval Date	July 2022	
Next Course Specifications Review Date	June 2024	

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Course Specifications: Numerical Analysis – 1

Course Title	Numerical Analysis – 1
Course Code	MTC514A
Course Type	Core Theory
Department	Mathematics and Statistics
Faculty	Mathematical and Physical Sciences

1. Course Summary

The course aims at training students in handling various aspects numerical computations. In this course, the students learn the basics of numerical methods to solve linear and non-linear equations. The course describes the different numerical techniques of numerical linear algebra, interpolation, numerical integration and differentiation.

2. Course Size and Credits:

Number of Credits	03
Credit Structure (Lecture: Tutorial: Practical)	2:1:0
Total Hours of Interaction	30
Number of Weeks in a Semester	15
Department Responsible	Mathematics and Statistics
Total Course Marks	100
Pass Criterion	As per the Academic Regulations
Attendance Requirement	As per the Academic Regulations

3. Course Outcomes (COs)

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

- **CO-1.** Illustrate various methods of numerical solution to polynomial and transcendental equations, numerical solution to non-linear system, interpolation and numerical integration
- **CO-2.** State and prove theorems on convergence and stability of numerical algorithms
- **CO-3.** Solve simple problems of linear and non-linear root finding methods, system of linear equations, eigenvalues, interpolation methods and quadrature rules
- **CO-4.** Solve complex problems of linear and non-linear root finding methods, system of linear equations, eigenvalues, interpolation methods and quadrature rules
- **CO-5.** Solve complex real world problems associated with nonlinear equations, system of equations, interpolation and numerical integration

4. Course Contents

Unit 1 (Solution of linear and Nonlinear Equations): **5 Hrs**

Mathematical preliminary and error analysis. Numerical solutions of nonlinear algebraic equations: Bisection, Secant and Newton's method, fixed-point iteration.
Iterative methods for nonlinear system of equations: Newton-Raphson method.

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Unit 2 (Numerical Linear Algebra): **10 Hrs**

Direct methods for linear system of equations: LU decomposition and Cholesky methods. Iterative methods for linear system of equations: Matrix norms, Jacobi and Gauss-Siedel methods, relaxation methods.

Computation of eigenvalues and eigenvectors: Power method, Householder's method, QR algorithm.

Unit 3 (Interpolation): **7 Hrs**

Lagrange, Hermite and Cubic-spline interpolations with uniqueness and error term. Numerical differentiation using interpolation and method of undetermined coefficients

Unit 4 (Numerical Integration): **8 Hrs**

Methods based on interpolation. Gaussian quadrature, Gauss-Legendre, Gauss-Chebeshev, Gauss-Leguree, Gauss-Hermite integration rules. Integration over rectangular and general quadrilateral areas and multiple integration with variable limits.

5. Course Map (CO-PO-PSO Map)

	Programme Outcomes (POs)								Programme Specific Outcome (PSOs)		
	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PSO-1	PSO-2	PSO-3
CO-1	3	3							3		1
CO-2	3	2							3	3	1
CO-3	1	2	3	3		1	1	1	3		1
CO-4	2	2	2	3		1	1	1	3		1
CO-5	1	2	3	3	2	1	1	1	3	2	1

6. Course Teaching and Learning Methods

Teaching and Learning Methods	Duration in hours	Total Duration in Hours
Face to Face Lectures		30
Demonstrations		00
1. Demonstration using Videos	00	
2. Demonstration using Physical Models / Systems	00	
3. Demonstration on a Computer	00	
Numeracy		15
1. Solving Numerical Problems	15	
Practical Work		00
1. Course Laboratory	00	
2. Computer Laboratory	00	
3. Engineering Workshop / Course/Workshop / Kitchen	00	
4. Clinical Laboratory	00	
5. Hospital	00	
6. Model Studio	00	
Others		00
1. Case Study Presentation	00	
2. Guest Lecture	00	

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3. Industry / Field Visit	00	
4. Brain Storming Sessions	00	
5. Group Discussions	00	
6. Discussing Possible Innovations	00	
Term Tests, Laboratory Examination/Written Examination, Presentations		10
Total Duration in Hours		**55**

7. Course Assessment and Reassessment

The details of the components and subcomponents of course assessment are presented in the Programme Specifications document pertaining to the M. Sc. (Mathematics) Programme. The procedure to determine the final course marks is also presented in the Programme Specifications document.

The evaluation questions are set to measure the attainment of the COs. In either component (CE or SEE) or subcomponent of CE (TSC1, TSC2 or TSC3), COs are assessed as illustrated in the following Table.

Focus of COs on each Component or Subcomponent of Evaluation				
	Component 1: CE (50% Weightage)			**Component 2: SEE (50% Weightage)**
Subcomponent ▶	**TSC1**	**TSC2**	**SC3**	
Subcomponent Type ▶	**Mid term /Term Test**	**Assignment**	**Innovative**	**100 Marks**
Maximum Marks ▶	**50**	**25**	**25**	
CO-1	×	×		×
CO-2	×	×		×
CO-3	×	×	×	×
CO-4			×	×
CO-5			×	×

The Course Leader assigned to the course, in consultation with the Head of the Department, shall provide the focus of COs in each component of assessment in the above template at the beginning of the semester. Course reassessment policies are presented in the Academic Regulations document.

8. Achieving COs

The following skills are directly or indirectly imparted to the students in the following teaching and learning methods:

S. No	Curriculum and Capabilities Skills	How imparted during the course
1.	Knowledge	Classroom lectures, tutorials, Assignments
2.	Understanding	Classroom lectures, tutorials, Assignments
3.	Critical Skills	Classroom lectures, Assignment
4.	Analytical Skills	Assignment
5.	Problem Solving Skills	Assignment, Examination
6.	Practical Skills	--
7.	Group Work	Assignment

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8.	Self-Learning	Self-study, Assignment
9.	Written Communication Skills	Assignment, Examination
10.	Verbal Communication Skills	--
11.	Presentation Skills	--
12.	Behavioral Skills	Course work
13.	Information Management	Assignment, Examination
14.	Personal Management	Course work
15.	Leadership Skills	--

9. Course Resources

a. Essential Reading

1. Class Notes
2. Sastry, S.S., 1998, Introductory Methods of Numerical Analysis, Prentice-Hall of India.
3. Jain, M.K., Iyengar, S.R.K. and Jain, R.K., 1993, Numerical Methods for Scientific and Engineering Computation, Wiley Eastern.
4. Demmel, J. W., 1997, Applied Numerical Linear Algebra, 1st Ed., SIAM.

b. Recommended Reading

1. Chapra, S.C. and Raymond, P.C., 2000, Numerical Methods for Engineers, Tata McGraw Hill.
2. Burden, R.L. and Faires, J.D., 1989, Numerical Analysis, 4th Ed., P.W.S. Kent Publishing Company
3. Golub, G. H. and Van Loan, C. F., 1996, Matrix Computations, 3rd Ed. Johns Hopkins University Press

c. Websites

1. https://swayam.gov.in
2. https://coursera.org
3. http://ocw.mit.edu

d. Other Electronic Resources

10. Course Organization

Course Code	MTC514A	
Course Title	Numerical Analysis – 1	
Course Leader's Name	As per Timetable	
Course Leader's Contact Details	**Phone:**	+91-804-906-5555
	E-mail:	hod.mt.mp@msruas.ac.in
Course Specifications Approval Date	July 2022	
Next Course Specifications Review Date	July 2024	

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Faculty of Mathematical and Physical Sciences

Course Specifications: Abstract Algebra

Course Title	Abstract Algebra
Course Code	MTC515A
Course Type	Core Theory
Department	Mathematics and Statistics
Faculty	Mathematical and Physical Sciences

1. Course Summary

The aim of the Course is to introduce the fundamentals of abstract algebra. The students are introduced with major building blocks of abstract algebra, namely, group theory and ring theory. This Course trains students to prove abstract theorems in a meaningful way.

2. Course Size and Credits:

Number of Credits	04
Credit Structure (Lecture: Tutorial: Practical)	3:1:0
Total Hours of Interaction	45
Number of Weeks in a Semester	15
Department Responsible	Mathematics and Statistics
Total Course Marks	100
Pass Criterion	As per the Academic Regulations
Attendance Requirement	As per the Academic Regulations

3. Course Outcomes (COs)

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

CO-1. Understand basic concepts of group theory, ring theory with suitable examples
CO-2. State and prove important theorems in group theory, ring theory
CO-3. Solve algebraic problems using appropriate techniques
CO-4. Demonstrate and understand special groups and rings and their properties
CO-5. Examine the properties implied by the definitions and theorems of groups, rings

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4. Course Contents

Unit 1 (Group Theory): **5 hrs**
Introduction to groups: Basic axioms and examples, dihedral groups, symmetric groups, matrix groups, homomorphisms and isomorphisms.

Unit 2 (Subgroups): **7 hrs**
Definition and examples, centralizers and normalizers, stabilizers and kernels, cyclic groups and cyclic subgroups, subgroups generated by subsets of a group

Unit 3 (Quotient Groups and Homomorphisms): **18 hrs**
Definitions and examples, cosets and Lagrange's theorem, the isomorphism theorems, automorphisms, Permutation groups, Cayley's theorem, the class equation, the Sylow's theorems, the simplicity of A_n, direct products, the fundamental theorem of finitely generated abelian groups.

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Unit 4 (Ring Theory:): **15 hrs**

Fundamentals of rings, integral domains, division rings, fields. Homomorphisms, kernel and image of homomorphisms of rings, isomorphism of rings. Ideals and quotient rings, fundamental theorem of homomorphism of rings. Euclidean domains, principal ideal domains, unique factorization domains. Polynomial rings, polynomial rings over fields, polynomial rings that are unique factorization domains, irreducibility criteria.

5. Course Map (CO-PO-PSO Map)

	Programme Outcomes (POs)								Programme Specific Outcomes (PSOs)		
	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PSO-1	PSO-2	PSO-3
CO-1	2	3			2				2	2	
CO-2	2	3	1		2				2	3	
CO-3	2	3	1		2	1	1	1	2	2	1
CO-4	2	3				1	1	1	2	3	1
CO-5	2	3	1		2	1	1	1	2	3	1

6. Course Teaching and Learning Methods

Teaching and Learning Methods	Duration in hours	Total Duration in Hours
Face to Face Lectures		45
Demonstrations		00
1. Demonstration using Videos	00	
2. Demonstration using Physical Models / Systems	00	
3. Demonstration on a Computer	00	
Numeracy		15
1. Solving Numerical Problems	15	
Practical Work		00
1. Course Laboratory	00	
2. Computer Laboratory	00	
3. Engineering Workshop / Course/Workshop / Kitchen	00	
4. Clinical Laboratory	00	
5. Hospital	00	
6. Model Studio	00	
Others		00
1. Case Study Presentation	00	
2. Guest Lecture	00	
3. Industry / Field Visit	00	
4. Brain Storming Sessions	00	
5. Group Discussions	00	
6. Discussing Possible Innovations	00	
Term Tests, Laboratory Examination/Written Examination, Presentations		10
Total Duration in Hours		**70**

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7. Course Assessment and Reassessment

The details of the components and subcomponents of course assessment are presented in the Programme Specifications document pertaining to the M. Sc. (Mathematics) Programme. The procedure to determine the final course marks is also presented in the Programme Specifications document.

The evaluation questions are set to measure the attainment of the COs. In either component (CE or SEE) or subcomponent of CE (TSC1, TSC2, or TSC3), COs are assessed as illustrated in the following Table.

Focus of COs on each Component or Subcomponent of Evaluation				
	Component 1: CE (50% Weightage)			Component 2: SEE (50% Weightage)
Subcomponent ▶	TSC1	TSC2	SC3	
Subcomponent Type ▶	Mid term /Term Test	Assignment	Innovative	100 Marks
Maximum Marks ▶	50	25	25	
CO-1	×	×		×
CO-2	×	×		×
CO-3	×	×	×	×
CO-4			×	×
CO-5			×	×

The Course Leader assigned to the course, in consultation with the Head of the Department, shall provide the focus of COs in each component of assessment in the above template at the beginning of the semester. Course reassessment policies are presented in the Academic Regulations document.

8. Achieving COs

The following skills are directly or indirectly imparted to the students in the following teaching and learning methods:

S. No	Curriculum and Capabilities Skills	How imparted during the course
1.	Knowledge	Classroom lectures, tutorials, Assignments
2.	Understanding	Classroom lectures, tutorials, Assignments
3.	Critical Skills	Classroom lectures, Assignment
4.	Analytical Skills	Assignment
5.	Problem Solving Skills	Assignment, Examination
6.	Practical Skills	--
7.	Group Work	Assignment
8.	Self-Learning	Self-study, Assignment
9.	Written Communication Skills	Assignment, Examination
10.	Verbal Communication Skills	--
11.	Presentation Skills	--

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12.	Behavioral Skills	Course work
13.	Information Management	Assignment, Examination
14.	Personal Management	Course work
15.	Leadership Skills	--

9. Course Resources

a. Essential Reading

1. Class notes.
2. Dummit, D.M. and Foote, R.M., 2011, Abstract Algebra, 3rd Ed., Wiley.
3. Herstein, I.N., 2006, Topics in Algebra, 2nd Ed., Wiley.

b. Recommended Reading

1. Artin, M., 2015, Algebra, 2nd Ed., Pearson Education India.
2. Fraleigh, J.B., 2013, A first course in abstract algebra, 7th Ed., Pearson Education India.
3. Gallian, J.A., 2013, Contemporary Abstract Algebra, 8th edition, Cengage.
4. Jacobson, N., 2009, Basic Algebra – I, 2nd Ed., Dover Publications.
5. Lang, S., 2002, Algebra, 3rd Ed., Springer.
6. Singh, S. and Zameeruddin, Q., 2006, Modern Algebra, 8th Ed., Vikas Publishing House.

c. Magazines and Journals

d. Websites

1. https://swayam.gov.in
2. https://ocw.mit.edu/index.htm

e. Other Electronic Resources

10. Course Organization

Course Code	MTC515A	
Course Title	Abstract Algebra	
Course Leader's Name	As per Timetable	
Course Leader's Contact Details	**Phone:**	+91-804-906-5555
	E-mail:	hod.mt.mp@msruas.ac.in
Course Specifications Approval Date	July 2022	
Next Course Specifications Review Date	June 2024	

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Course Specifications: Numerical Analysis Laboratory – 1

Course Title	Numerical Analysis Laboratory - 1
Course Code	MTL511A
Department	Mathematics and Statistics
Faculty	Mathematical and Physical Sciences

1. Course Summary

The aim of this course is to introduce students to the basic programing concepts and implement algorithms in MATLAB. Students are taught the concepts of solving linear and nonlinear system equations, computing eigenvalues in MATLAB. Interpolation, curve fitting and numerical integration are discussed using MATLAB.

2. Course Size and Credits:

Number of Credits	01
Credit Structure (Lecture: Tutorial: Practical)	0:0:1
Total Hours of Interaction	30
Number of Weeks in a Semester	15
Department Responsible	Mathematics and Statistics
Total Course Marks	50
Pass Criterion	As per the Academic Regulations
Attendance Requirement	As per the Academic Regulations

3. Course Outcomes (COs)

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

CO-1. Illustrate fundamentals of programming in MATLAB
CO-2. Implement algorithms and execute simple programs using MATLAB.
CO-3. Solve mathematical problems associated with linear algebra and compare the results with that of solutions obtained using MATLAB
CO-4. Apply numerical methods to solve nonlinear equations in one variable, system of linear equations, computing eigenvalues, curve fitting, interpolation, integration, and implement the same using MATLAB
CO-5. Solve real world problems associated with system of equations, curve fitting, interpolation and integration using MATLAB.

4. Course Contents

1. Introduction to MATLAB: Basic arithmetic operations in MATLAB
2. Matrix operations in MATLAB
3. Control structures and looping structures in MATLAB
4. 2D and 3D plots
5. Newton-Raphson method

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6. Linear systems. Solution of triangular systems. Gaussian elimination with pivoting. LU decomposition. Gauss-Seidel method
7. Singular value decomposition and iterative algorithms for computing eigenvalues.
8. Curve fitting : The method of Least Squares
9. Interpolation: Polynomial interpolation by Lagrange polynomials. Newton divided differences and Cubic-Spline interpolation.
10. Numerical integration: Trapezoidal and Simpson's rules. Romberg integration.

5. Course Map (CO-PO-PSO Map)

	Programme Outcomes (POs)										Programme Specific Outcomes (PSOs)		
	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PSO-1	PSO-2	PSO-3
CO-1	3	1	1	1	1						3	3	
CO-2	3	1	1	1	2						2	2	
CO-3	2	2	1	1	2						2	3	
CO-4	3	1	2	2	2						3	2	
CO-5	3	1	3	2	2						2	2	

6. Course Teaching and Learning Methods

Teaching and Learning Methods	Duration in hours	Total Duration in Hours
Face to Face Lectures		30
Demonstrations		00
1. Demonstration using Videos	00	
2. Demonstration using Physical Models / Systems	00	
3. Demonstration on a Computer	00	
Numeracy		00
1. Solving Numerical Problems	00	
Practical Work		00
1. Course Laboratory	00	
2. Computer Laboratory	00	
3. Engineering Workshop / Course/Workshop / Kitchen	00	
4. Clinical Laboratory	00	
5. Hospital	00	
6. Model Studio	00	
Others		00
1. Case Study Presentation	00	
2. Guest Lecture	00	
3. Industry / Field Visit	00	
4. Brain Storming Sessions	00	
5. Group Discussions	00	
6. Discussing Possible Innovations	00	
Term Tests, Laboratory Examination/Written Examination, Presentations		05
Total Duration in Hours		**35**

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7. Course Assessment and Reassessment

The details of the components and subcomponents of course assessment are presented in the Programme Specifications document pertaining to the M. Sc. (Mathematics) Programme. The procedure to determine the final course marks is also presented in the Programme Specifications document.

The evaluation questions are set to measure the attainment of the COs. In either component (CE or SEE) or subcomponent of CE (SC1, SC2), COs are assessed as illustrated in the following Table.

Focus of COs on each Component or Subcomponent of Evaluation			
	Component 1: CE (50% Weightage)		Component 2: SEE (50% Weightage)
Subcomponent▶	SC1	SC2	
Subcomponent Type ▶	Laboratory Manual Report	Laboratory Test	50 Marks
Maximum Marks▶	25	25	
CO-1	×	×	×
CO-2	×	×	×
CO-3	×	×	×
CO-4	×	×	×
CO-5	×	×	×
The details of SC1 and SC2 are presented in the Program Specifications Document.			

The Course Leader assigned to the course, in consultation with the Head of the Department, shall provide the focus of COs in each component of assessment in the above template at the beginning of the semester.

Course reassessment policies are presented in the Academic Regulations document.

8. Achieving COs

The following skills are directly or indirectly imparted to the students in the following teaching and learning methods:

S. No	Curriculum and Capabilities Skills	How imparted during the course
1.	Knowledge	Classroom lectures, tutorials, Assignments
2.	Understanding	Classroom lectures, tutorials, Assignments
3.	Critical Skills	Classroom lectures, Assignment
4.	Analytical Skills	Assignment
5.	Problem Solving Skills	Assignment, Examination
6.	Practical Skills	--
7.	Group Work	Assignment
8.	Self-Learning	Self-study, Assignment
9.	Written Communication Skills	Assignment, Examination
10.	Verbal Communication Skills	--
11.	Presentation Skills	--
12.	Behavioral Skills	Course work
13.	Information Management	Assignment, Examination
14.	Personal Management	Course work
15.	Leadership Skills	--

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9. Course Resources

a. Essential Reading

1. Laboratory manual.
2. Rudra Pratap. 2013. Getting started with MATLAB. United Kingdom: Oxford University press.
3. Won Y. Yang, Wenwu Cao, Tae S. Chung, John Morris. Applied numerical methods using MATLAB, John Wiley & Sons, Inc.

b. Recommended Reading

1. Demmel, J. W., 1997, Applied Numerical Linear Algebra, 1st Ed., SIAM.
2. Dukkipati, R.V. 2011. Applied Numerical Methods using MATLAB. 1st Ed. New Delhi: New Age publication.
3. Shastry, S.S. 2010. Introductory methods of Numerical Analysis. 4th Ed. New Delhi: PHI learning Pvt. Limited.
4. Jain, M. K., Iyengar, S.R.K. and Jain, R.K. 2008. Numerical Methods. New Delhi: New Age.

c. Magazines and Journals

1. *SIAM Journal on Numerical Analysis* (SINUM) , https://www.siam.org/publications/journals/siam-journal-on-numerical-analysis-sinum
2. *Numerical Analysis and Applications,* https://www.springer.com/journal/12258
3. *International Journal of Numerical Analysis & Modeling, https://www.math.ualberta.ca/ijnam/*

d. Websites

1. https://www.coursera.org/
2. http://swayam.gov.in/

e. Other Electronic Resources

1. https://www.khanacademy.org/

10. Course Organization

Course Code	MTL511A		
Course Title	Numerical Analysis Laboratory - 1		
Course Leader's Name		As per Timetable	
Course Leader's Contact Details		**Phone:**	+91-804-906-5555
		E-mail:	hod.mt.mp@msruas.ac.in
Course Specifications Approval Date		July 2022	
Next Course Specifications Review Date		July 2024	

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Course Specifications: Complex Analysis

Course Title	Complex Analysis
Course Code	MTC521A
Course Type	Core Theory
Department	Mathematics and Statistics
Faculty	Mathematical and Physical Sciences

1. Course Summary

The aim of the module is to lay foundation on concepts such as complex analytic, meromorphic functions, complex integration and residue calculus.

The course provides a detailed analysis of analytic functions and its applications in mathematics and other disciplines. The module also emphasizes on the expansion of analytic and meromorphic functions in the form of power series, and conformality of analytic functions. The module illustrates the application of conformal mappings to fluid mechanics and residue integration method to mathematical transforms.

2. Course Size and Credits:

Number of Credits	04
Credit Structure (Lecture: Tutorial: Practical)	3:1:0
Total Hours of Interaction	70
Number of Weeks in a Semester	15
Department Responsible	Mathematics and Statistics
Total Course Marks	100
Pass Criterion	As per the Academic Regulations
Attendance Requirement	As per the Academic Regulations

3. Course Outcomes (COs)

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

- **CO-1.** Illustrate the underlying concepts of analyticity, complex integration, power series, residue calculus
- **CO-2.** State and prove important theorems such as Cauchy's theorem, Taylor's and Laurent's theorems, Rouche's theorem, maximum modulus theorem, Phragmen-Lindelof theorem and so on
- **CO-3.** Solve simple problems involving functions of a complex variable, analyticity, complex integration, power series, residue calculus, maximum modulus theorem
- **CO-4.** Apply properties of analytic functions to evaluate improper integrals and definite integrals on the real line using contour integration and key theorems in complex analysis
- **CO-5.** Solve complex mathematical problems arising from complex analysis

4. Course Contents

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Unit 1 (Introduction): **10 hrs**

Complex numbers and functions, limits, complex differentiability and Cauchy-Riemann equations, Analytic functions, Harmonic conjugates. Analysis of elementary functions, Bilinear transformations, Conformal mappings.

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Unit 2 (Complex integration): **7 hrs**

Cauchy's theorem for rectangle and triangle, Cauchy's theorem and Cauchy's integral formula, Morera's theorem. Liouville's Theorem, Fundaments theorem of algebra, Open mapping theorem.

Unit 3 (Series): **7 hrs**

Power series, Radius of convergences, Power series representation of analytic functions, Taylor series, Laurent Series.

Unit 4 (Residue Calculus): **7 hrs**

Singularities, types of singularities. Residue calculus, Cauchy's residue theorem, Evaluation of improper integrals and definite integrals on real line, zeros of analytic functions, number of zeros and poles, Argument principle, Rouche's theorem.

Unit 5: **7 hrs**

Maximum modulus theorem and their applications - Schwartz lemma. Convex functions, Hadmard's three circle theorem. Phragmen-Lindelof theorem.

Unit 6: **7 hrs**

Statements only: The Riemann mapping theorem, Weistrass factorization theorem, Mean Value theorem, Poisson's formula, Poisson's Integral formula, Jensen's formula.

5. Course Map (CO-PO-PSO Map)

	Programme Outcomes (POs)								Programme Specific Outcomes (PSOs)		
	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PSO-1	PSO-2	PSO-3
CO-1	3	2	2		2	1		1	3	2	1
CO-2	3	2	2		3	1		1	3	3	1
CO-3	3	2	3		2	2		1	3	2	1
CO-4	3	2	3		2	2		1	3	2	1
CO-5	3	2	3		2	2		1	3	3	1
3: Very Strong Contribution, 2: Strong Contribution, 1: Moderate Contribution											

6. Course Teaching and Learning Methods

Teaching and Learning Methods	Duration in hours	Total Duration in Hours
Face to Face Lectures		45
Demonstrations		00
1. Demonstration using Videos	00	
2. Demonstration using Physical Models / Systems	00	
3. Demonstration on a Computer	00	
Numeracy		15
1. Solving Numerical Problems	30	
Practical Work		00
1. Course Laboratory	00	

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2. Computer Laboratory	00	
3. Engineering Workshop / Course/Workshop / Kitchen	00	
4. Clinical Laboratory	00	
5. Hospital	00	
6. Model Studio	00	
Others		
1. Case Study Presentation	00	00
2. Guest Lecture	00	
3. Industry / Field Visit	00	
4. Brain Storming Sessions	00	
5. Group Discussions	00	
6. Discussing Possible Innovations	00	
Term Tests, Laboratory Examination/Written Examination, Presentations		10
Total Duration in Hours		**70**

7. Course Assessment and Reassessment

The details of the components and subcomponents of course assessment are presented in the Programme Specifications document pertaining to the M.Sc. (Mathematics) Programme. The procedure to determine the final course marks is also presented in the Programme Specifications document.

The evaluation questions are set to measure the attainment of the COs. In either component (CE or SEE) or subcomponent of CE (TSC1, TSC2 or TSC3), COs are assessed as illustrated in the following Table.

Focus of COs on each Component or Subcomponent of Evaluation				
	Component 1: CE (50% Weightage)			Component 2: SEE (50% Weightage)
Subcomponent ▶	TSC1	TSC2	SC3	
Subcomponent Type ▶	Mid term /Term Test	Assignment	Innovative	100 Marks
Maximum Marks ▶	50	25	25	
CO-1	×	×		×
CO-2	×	×		×
CO-3	×	×	×	×
CO-4			×	×
CO-5			×	×

The Course Leader assigned to the course, in consultation with the Head of the Department, shall provide the focus of COs in each component of assessment in the above template at the beginning of the semester. Course reassessment policies are presented in the Academic Regulations document.

8. Achieving COs

The following skills are directly or indirectly imparted to the students in the following teaching and learning methods:

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S. No	Curriculum and Capabilities Skills	How imparted during the course
1.	Knowledge	Classroom lectures, tutorials, Assignments
2.	Understanding	Classroom lectures, tutorials, Assignments
3.	Critical Skills	Classroom lectures, Assignment
4.	Analytical Skills	Assignment
5.	Problem Solving Skills	Assignment, Examination
6.	Practical Skills	--
7.	Group Work	Assignment
8.	Self-Learning	Self-study, Assignment
9.	Written Communication Skills	Assignment, Examination
10.	Verbal Communication Skills	--
11.	Presentation Skills	--
12.	Behavioral Skills	Course work
13.	Information Management	Assignment, Examination
14.	Personal Management	Course work
15.	Leadership Skills	--

9. Course Resources

a. Essential Reading

1. Class notes
2. Conway, J. B. (1995) *Functions of one complex variable*, 2nd edition, Springer.

b. Recommended Reading

1. Ahlfors, L.V. (1979) *Complex Analysis*, 3rd edition, McGraw Hill.
2. Ponnusamy, S. (2005) *Foundations of Complex Analysis*, 2nd edition, Narosa Publishing House
3. Lang, S. (1999) *Complex Analysis*, 4th edition, Springer.
4. Brown, J.W. and Churchill, R.V. (2013) *Complex Variables and Applications*, 9th edition, Mc Graw-Hill.
5. Palka, B. C., (2012), *An Introduction to Complex Function Theory*, Springer

c. Magazines and Journals

1. The College Mathematics Journal, Mathematical Association of America. https://www.maa.org/press/periodicals/college-mathematics-journal/the-collegemathematics-journal

d. Websites

1. https://www.coursera.org/
2. http://nptel.ac.in/

e. Other Electronic Resources

1. https://complex-analysis.com/

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10. Course Organization

Course Code	MTC521A
Course Title	Complex Analysis
Course Leader's Name	As per Timetable

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Course Leader's Contact Details	**Phone:**	+91-804-906-5555
	E-mail:	hod.mt.mp@msruas.ac.in
Course Specifications Approval Date	July 2022	
Next Course Specifications Review Date	July 2024	

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Course Specifications: Theory of Partial Differential Equations

Course Title	Theory of Partial Differential Equations
Course Code	MTC522A
Course Type	Core Theory Course
Department	Mathematics and Statistics
Faculty	Mathematical and Physical Sciences

1. Course Summary

The aim of the course is to provide an understanding the concepts of techniques and applications of partial differential equations. This course introduces linear partial differential equations and techniques for solving a first order linear and quasi-linear PDEs. Second order PDEs and their classifications are discussed. Solutions of Parabolic, Hyperbolic and Elliptic PDEs are dealt in detail. Finally this course covers a general nth order PDE and Cauchy-Kowalevski theorem wave equation as an example of hyperbolic

2. Course Size and Credits:

Number of Credits	04
Credit Structure (Lecture: Tutorial: Practical)	3:1:0
Total Hours of Interaction	60
Number of Weeks in a Semester	15
Department Responsible	Mathematics and Statistics
Total Course Marks	100
Pass Criterion	As per the Academic Regulations
Attendance Requirement	As per the Academic Regulations

3. Course Outcomes (COs)

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

- **CO-1.** Explain basic concepts in vector calculus, state and prove important theorems related to vector integration
- **CO-2.** Solve first order, second order linear partial differential equation (PDE).
- **CO-3.** Apply analytical methods to solve the heat equation as an example of Parabolic PDE,
- **CO-4.** Apply analytical methods to solve the wave equation as an example of Hyperbolic PDE,
- **CO-5.** Apply analytical methods to solve the Laplace as an example of elliptic PDE.

4. Course Contents

Unit 1(Real Valued Functions of Multivariable): **3 hrs**

Real valued functions of multivariable: - limit, continuity, partial derivatives and integrals. The inverse function theorem and the implicit function theorem. Vector geometry, calculus of vector valued functions. Green's theorem, Gauss-Divergence theorem and Stokes' theorem.

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Unit 2 (First Order Partial Differential Equations): **7 hrs**

First Order Partial Differential Equations: - Basic definitions, Origin of PDEs, Classification, Geometrical interpretation and physical models. The Cauchy problem, solutions of first order PDEs by method of characteristics, complete integrals. The general first order equation of two variables and solutions generated as envelopes. Compatible system of first order partial differential equations. The Hamilton–Jacobi Equation and Its Applications.

Unit 3 (Second Order Partial Differential Equations): **7 hrs**

Second Order Partial Differential Equations:- Definitions of Linear and Non-Linear Equations, Linear Superposition principle, Classification of second-order linear partial differential equations into hyperbolic, parabolic and elliptic PDEs, Reduction to canonical forms, solution of linear Homogeneous and non-homogeneous with constant coefficients, Variable coefficients, Mange's method.

Unit 4 (Heat Equation): **7 hrs**

Parabolic equation, heat equation as an example of parabolic PDE. The initial value problem, the initial-boundary value problem, and the Cauchy problem for the heat equation. Separation of variables. The maximum principle for the heat equation. The uniqueness and regularity of the solution to the heat equation.

Unit 5 (Wave Equation): **7 hrs**

Hyperbolic equation, wave equation as an example of hyperbolic PDE. The Cauchy problem and the initial-boundary value problems for the wave equation. Separation of variables. Propagation of singularities. Reduction of second-order PDEs into a linear system of first-order PDEs.

Unit 6 (Elliptic Equation): **7 hrs**

Elliptic equation, Laplace equation as an example of elliptic PDE. Green's identity, Fundamental solutions and Poisson's equation. Basic property of harmonic functions. Boundary value problem for the Laplace equation. Separation of variables in polar and spherical coordinates. Time harmonic wave propagation, the Helmholtz equation and Somerfield radiation condition.

Unit 7 (Solution of Boundary value Problems): **7 hrs**

Solution of boundary value problems: - Green's function method for PDEs. The general partial differential equation, Cauchy problem for an nth order PDE. The real analytic functions and the Cauchy-Kowalski theorem. The Lagrange-Green identity and the uniqueness theorem of Holmgren. Distributions as solutions of PDEs.

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5. Course Map (CO-PO-PSO Map)

	Programme Outcomes (POs)								Programme Specific Outcomes (PSOs)		
	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PSO-1	PSO-2	PSO-3
CO-1	3	2	2						3		
CO-2	3	2	2		1				3	2	
CO-3	2		2		1				3	2	
CO-4	3		2		1	1			3	2	1
CO-5	2		2		1	1			3	2	1

6. Course Teaching and Learning Methods

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Teaching and Learning Methods	Duration in hours	Total Duration in Hours
Face to Face Lectures		45
Demonstrations		00
1. Demonstration using Videos	00	
2. Demonstration using Physical Models / Systems	00	
3. Demonstration on a Computer	00	
Numeracy		15
1. Solving Numerical Problems	15	
Practical Work		00
1. Course Laboratory	00	
2. Computer Laboratory	00	
3. Engineering Workshop / Course/Workshop / Kitchen	00	
4. Clinical Laboratory	00	
5. Hospital	00	
6. Model Studio	00	
Others		00
1. Case Study Presentation	00	
2. Guest Lecture	00	
3. Industry / Field Visit	00	
4. Brain Storming Sessions	00	
5. Group Discussions	00	
6. Discussing Possible Innovations	00	
Term Tests, Laboratory Examination/Written Examination, Presentations		10
Total Duration in Hours		**70**

7. Course Assessment and Reassessment

The details of the components and subcomponents of course assessment are presented in the Programme Specifications document pertaining to the M. Sc. (Applied Mathematics) Programme. The procedure to determine the final course marks is also presented in the Programme Specifications document.

The evaluation questions are set to measure the attainment of the COs. In either component (CE or SEE) or subcomponent of CE (TSC1, TSC2, TSC3), COs are assessed as illustrated in the following Table.

Focus of COs on each Component or Subcomponent of Evaluation				
	Component 1: CE (50% Weightage)			Component 2: SEE (50% Weightage)
Subcomponent ▶	TSC1	TSC2	TSC3	100 Marks
Subcomponent Type ▶	Mid Term Test	Assignment	Innovative	
Maximum Marks ▶	50	25	25	
CO-1	×	×	×	×
CO-2	×		×	×
CO-3	×	×	×	×
CO-4			×	×
CO-5		×	×	×
The details of TSC1, TSC2, TSC3 are presented in the Programme Specifications Document.				

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The Course Leader assigned to the course, in consultation with the Head of the Department, shall provide the focus of COs in each component of assessment in the above template at the beginning of the semester.
Course reassessment policies are presented in the Academic Regulations document.

8. Achieving COs

The following skills are directly or indirectly imparted to the students in the following teaching and learning methods:

S. No	Curriculum and Capabilities Skills	How imparted during the course
1.	Knowledge	Classroom lectures, tutorials, Assignments
2.	Understanding	Classroom lectures, tutorials, Assignments
3.	Critical Skills	Classroom lectures, Assignment
4.	Analytical Skills	Assignment
5.	Problem Solving Skills	Assignment, Examination
6.	Practical Skills	--
7.	Group Work	Assignment
8.	Self-Learning	Self-study, Assignment
9.	Written Communication Skills	Assignment, Examination
10.	Verbal Communication Skills	--
11.	Presentation Skills	--
12.	Behavioral Skills	Course work
13.	Information Management	Assignment, Examination
14.	Personal Management	Course work
15.	Leadership Skills	--

9. Course Resources

a. Essential Reading

1. Course notes
2. McOwen, R., 2002, Partial Differential Equations, Methods and Applications, Pearson.
3. Colton, D., 2004, Partial Differential Equation an Introduction, Dover Publications.

b. Recommended Reading

1. Polyanin, A. D., 2001, Handbook of Linear Partial Differential Equations for Engineers and Scientists, CHAPMAN and HALL/CRC.
2. Myint, U. T. and Debnath, L., 2007, Linear Partial Differential Equations for Scientists and Engineers, 4th edition, Birkhäuser.
3. Haberman, R., 2012, Applied Partial Differential Equations with Fourier series and Boundary Value Problems, 5th edition, Pearson.
4. John, F.,1991, Partial Differential Equations, 4th edition, Springer.

c. Magazines and Journals

Analysis and PDE

http://msp.org/apde/about/journal/about.html

d. Websites

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http://ocw.mit.edu/courses/mathematics/18-03-differential-equations-spring-2010/

e. **Other Electronic Resources**

1. http://www.math.tifr.res.in/~publ/ln/tifr70.pdf
2. https://www.khanacademy.org/math/diff...

10. **Course Organization**

Course Code	MTC522A	
Course Title	Theory of Partial Differential Equations	
Course Leader's Name	As per Timetable	
Course Leader's Contact Details	**Phone:**	+91-804-906-5555
	E-mail:	hod.mt.mp@msruas.ac.in
Course Specifications Approval Date	July 2022	
Next Course Specifications Review Date	June 2024	

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Course Specifications: Topology

Course Title	Topology
Course Code	MTC523A
Course Type	Core Theory
Department	Mathematics and Statistics
Faculty	Mathematical and Physical Sciences

1. Course Summary

The aim of the Course is to introduce the basics of Topological spaces. The students are introduced with topological spaces, subspaces and Metric spaces. This Course trains students to study topological spaces, compactness, connectedness and separation axioms by using different examples of topological spaces.

2. Course Size and Credits:

Number of Credits	04
Credit Structure (Lecture: Tutorial: Practical)	3:1:0
Total Hours of Interaction	75
Number of Weeks in a Semester	15
Department Responsible	Mathematics and Statistics
Total Course Marks	100
Pass Criterion	As per the Academic Regulations
Attendance Requirement	As per the Academic Regulations

3. Course Outcomes (COs)

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

- **CO-1.** Understand basic concepts of topological spaces, open, closed, connected, compact sets and homomorphism with suitable examples.
- **CO-2.** Explain different types of topological spaces with suitable examples.
- **CO-3.** Explain the construction of different quotient topological spaces such as cylinder, Mobius band.
- **CO-4.** Discuss the connected and compact spaces with suitable examples.
- **CO-5.** Explain the concepts of countabillity and separation axioms.

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4. Course Contents

Unit 1 (Topological spaces): **5 hrs**

Open sets, closed sets, neighbourhoods, bases, subbases, limit points, closures, interiors, continuous functions, homomorphisms.

Unit 2 (Examples of topological spaces): **10 hrs**

Subspace topology, product topology, metric topology, order topology, induced topology, topological groups.

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Unit 3 (Quotient topology): **10 hrs**

Examples of quotient topology, construction of cylinder, cone, suspension, Mobius band, torus, orbit spaces.

Unit 4 (Connectedness and compactness): **10 hrs**

Connected spaces, local connectedness, compact spaces, local compactness, Tychnoff theorem.

Unit 5 (Countability and separation axioms): **10 hrs**

Countability axioms, Separation axioms, normal spaces, Urysohn lemma, Urysohn metrization theorem, Tietze extension theorem, one-point compactification, paracompactness and partition of unity.

5. Course Map (CO-PO-PSO Map)

	Programme Outcomes (POs)										Programme Specific Outcomes (PSOs)		
	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PSO-1	PSO-2	PSO-3
CO-1	3	1	2		1						2	3	
CO-2	3	1	2		1						2	2	
CO-3	3	1	1		1						2	3	
CO-4	3	1	2		1						2	3	
CO-5	3	1	3		1						2	2	

6. Course Teaching and Learning Methods

Teaching and Learning Methods	Duration in hours	Total Duration in Hours
Face to Face Lectures		45
Demonstrations		05
1. Demonstration using Videos	01	
2. Demonstration using Physical Models / Systems	00	
3. Demonstration on a Computer	03	
Numeracy		15
1. Solving Numerical Problems	30	
Practical Work		00
1. Course Laboratory	00	
2. Computer Laboratory	00	
3. Engineering Workshop / Course/Workshop / Kitchen	00	
4. Clinical Laboratory	00	
5. Hospital	00	
6. Model Studio	00	
Others		00
1. Case Study Presentation	00	
2. Guest Lecture	00	
3. Industry / Field Visit	00	
4. Brain Storming Sessions	00	

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5. Group Discussions	00	
6. Discussing Possible Innovations	00	
Term Tests, Laboratory Examination/Written Examination, Presentations		10
Total Duration in Hours		**75**

7. Course Assessment and Reassessment

The details of the components and subcomponents of course assessment are presented in the Programme Specifications document pertaining to the M. Sc.(Mathematics) Programme. The procedure to determine the final course marks is also presented in the Programme Specifications document.

The evaluation questions are set to measure the attainment of the COs. In either component (CE or SEE) or subcomponent of CE (TSC1, TSC2, TSC3), COs are assessed as illustrated in the following Table.

Focus of COs on each Component or Subcomponent of Evaluation				
	Component 1: CE (50% Weightage)			**Component 2: SEE (50% Weightage)**
Subcomponent ▶	**TSC1**	**TSC2**	**TSC3**	**100 Marks**
Subcomponent Type ▶	**Mid Term Test**	**Assignment**	**Innovative**	
Maximum Marks ▶	**50**	**25**	**25**	
CO-1	×	×	×	×
CO-2	×		×	×
CO-3	×	×	×	×
CO-4			×	×
CO-5		×	×	×
The details of TSC1, TSC2, TSC3 are presented in the Programme Specifications Document.				

The Course Leader assigned to the course, in consultation with the Head of the Department, shall provide the focus of COs in each component of assessment in the above template at the beginning of the semester.

Course reassessment policies are presented in the Academic Regulations document.

8. Achieving COs

The following skills are directly or indirectly imparted to the students in the following teaching and learning methods:

S. No	Curriculum and Capabilities Skills	How imparted during the course
1.	Knowledge	Classroom lectures, tutorials, Assignments
2.	Understanding	Classroom lectures, tutorials, Assignments
3.	Critical Skills	Classroom lectures, Assignment
4.	Analytical Skills	Assignment
5.	Problem Solving Skills	Assignment, Examination
6.	Practical Skills	--
7.	Group Work	Assignment
8.	Self-Learning	Self-study, Assignment
9.	Written Communication Skills	Assignment, Examination

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10.	Verbal Communication Skills	--
11.	Presentation Skills	--
12.	Behavioral Skills	Course work
13.	Information Management	Assignment, Examination
14.	Personal Management	Course work
15.	Leadership Skills	--

9. Course Resources

a. Essential Reading

1. Class notes
2. J. R. Munkers, Topology, 2nd edition, Pearson education, 2000.
3. J. F. Simmons, Introduction to Topology and Moderen analysis, Tata Mcgraw-hill, 1963.

b. Recommended Reading

1. W. J. Pervin, Foundation of General Topology, Academic Press, 1964.
2. J. Dugundji, Topology, Printice Hall of India, 1975.
3. G. J. L. Kelley, General Topology, Van Nostrand, Princton, 1955.

c. Magazines and Journals

1. The College Mathematics Journal, Mathematical Association of America. https://www.maa.org/press/periodicals/college-mathematics-journal/the-collegemathematics-journal
2. SIAM Undergraduate Research Online, Society for Industrial and Applied Mathematics, http://www.siam.org/students/siuro/index.php
3. Involve – A Journal of mathematics, https://msp.org/involve/about/journal/about.html
4. Rose-Hulman Undergraduate Mathematics Journal, Rose-Hulman Institute of Technology. https://scholar.rose-hulman.edu/rhumj/

d. Websites

1. https://www.coursera.org/
2. http://nptel.ac.in/

e. Other Electronic Resources

10. Course Organization

Course Code	MTC523A	
Course Title	Topology	
Course Leader's Name	As per Timetable	
Course Leader's Contact Details	**Phone:**	+91-804-906-5555
	E-mail:	hod.mt.mp@msruas.ac.in
Course Specifications Approval Date	July 2022	
Next Course Specifications Review Date	June 2024	

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Course Specifications: Introduction to Statistics and Probability

Course Title	Introduction to Statistics and Probability
Course Code	MTC524A
Course Type	Core Theory
Department	Mathematics and Statistics
Faculty	Mathematical and Physical Sciences

1. Course Summary

This specialization module aims at developing basic concepts in probability and statistics. It brings about the idea of Centre and variability of quantitative data and provide graphical summaries of data. The concepts of correlation and linear regression are discussed. This course introduces probability, probability distribution and sampling distribution. Analysis of the probability density functions and cumulative density functions of standard distributions are covered. Finally this module describes the hypotheses tests to identify the confidence intervals.

2. Course Size and Credits:

Number of Credits	04
Credit Structure (Lecture: Tutorial: Practical)	3:1:0
Total Hours of Interaction	60
Number of Weeks in a Semester	15
Department Responsible	Mathematics and Statistics
Total Course Marks	100
Pass Criterion	As per the Academic Regulations
Attendance Requirement	As per the Academic Regulations

3. Course Outcomes (COs)

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

CO-1. Define statistics and explain the importance and significance of statistics.
CO-2. Explain the importance of probability in data analysis and in quantification of randomness.
CO-3. State and prove important theorems on probability such as Bayes' theorem and law of large numbers.
CO-4. Explain different types of probability distribution such as Binomial, Poisson and normal distribution
CO-5. Illustrate t-distribution, F-distribution and chi-square distribution with examples and explain sampling distribution
CO-6. Explain statistical inference, confidence interval and significance tests about hypothesis

4. Course Contents

Unit 1 (Introduction to Statistics): 7 hrs

Introduction to Statistics, Sample versus Population. Different types of data, measuring the center and variabilility of quantitative data and graphical summaries of data. Gathering data from experimental and observation studies. Good ways to sample and Experiment.

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Unit 2 (Correlation and Regression): **8 hrs**

Correlation and Regression, Association between two catagorical variables and contingency table. Association between two quantitative variables and correlations. Predicting the outcome of a variable using linear regression

Unit 3 (Introduction to Probability): **10 hrs**

Introduction to probability, definition of probability as quantification of randomness. Sample space, events and probabilities of events. Using a Venn diagram to find probabilities. Joint probability, conditional probability and Baye's Theorem. Expectations and decisions.

Unit 4 (Probability distributions): **10 hrs**

Probability distributions, uniform, normal distribution, binomial distributions. Student's t-distribution and Chi-squared distribution. Probability density function and cumilative density function. Mean and variance of distributions. Sampling distribution and Binomial distribution as a sampling distribution.

Unit 5 (Statistical inference): **10 hrs**

Statistical inference and confidence intervals, point and interval estimates for population parameters. Confidence interval to estimate a population parameter and population mean. Significance tests about hypotheses. Null and alternate hypotheses. The relation between hypotheses tests and confidence intervals

5. Course Map (CO-PO-PSO Map)

	Programme Outcomes (POs)								Programme Specific Outcomes (PSOs)		
	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PSO-1	PSO-2	PSO-3
CO-1	3	2	2						3	2	
CO-2	3	2	2						3	2	
CO-3	2	2	3			1	1		3	2	
CO-4	3	2	3		1	1	1	1	3	2	1
CO-5	2	2	3		1	1	1	1	3	2	1
CO6	3	2	3		1	1	1	1	3	2	1

6. Course Teaching and Learning Methods

Teaching and Learning Methods	Duration in hours	Total Duration in Hours
Face to Face Lectures		45
Demonstrations		00
1. Demonstration using Videos	00	
2. Demonstration using Physical Models / Systems	00	
3. Demonstration on a Computer	00	
Numeracy		15
1. Solving Numerical Problems	15	
Practical Work		00
1. Course Laboratory	00	

2. Computer Laboratory	00	
3. Engineering Workshop / Course/Workshop / Kitchen	* 00	
4. Clinical Laboratory	00	
5. Hospital	00	
6. Model Studio	00	
Others		
1. Case Study Presentation	00	00
2. Guest Lecture	00	
3. Industry / Field Visit	00	
4. Brain Storming Sessions	00	
5. Group Discussions	00	
6. Discussing Possible Innovations	00	
Term Tests, Laboratory Examination/Written Examination, Presentations		10
Total Duration in Hours		**70**

7. Course Assessment and Reassessment

The details of the components and subcomponents of course assessment are presented in the Programme Specifications document pertaining to the M. Sc. (Mathematics) Programme. The procedure to determine the final course marks is also presented in the Programme Specifications document.

The evaluation questions are set to measure the attainment of the COs. In either component (CE or SEE) or subcomponent of CE (TSC1, TSC2, TSC3), COs are assessed as illustrated in the following Table.

Focus of COs on each Component or Subcomponent of Evaluation				
	Component 1: CE (50% Weightage)			**Component 2: SEE (50% Weightage)**
Subcomponent▶	**TSC1**	**TSC2**	**TSC3**	**100 Marks**
Subcomponent Type ▶	**Term Test**	**Assignment**	**Innovative**	
Maximum Marks▶	**50**	**25**	**25**	
CO-1	X		X	X
CO-2	X		X	X
CO-3	X		X	X
CO-4		X	X	X
CO-5		X	X	X
The details of TSC1, TSC2, TSC3 are presented in the Programme Specifications Document.				

The Course Leader assigned to the course, in consultation with the Head of the Department, shall provide the focus of COs in each component of assessment in the above template at the beginning of the semester.

Course reassessment policies are presented in the Academic Regulations document.

8. Achieving COs

The following skills are directly or indirectly imparted to the students in the following teaching

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and learning methods:

S. No	Curriculum and Capabilities Skills	How imparted during the course
1.	Knowledge	Classroom lectures, tutorials, Assignments
2.	Understanding	Classroom lectures, tutorials, Assignments
3.	Critical Skills	Classroom lectures, Assignment
4.	Analytical Skills	Assignment
5.	Problem Solving Skills	Assignment, Examination
6.	Practical Skills	--
7.	Group Work	Assignment
8.	Self-Learning	Self-study, Assignment
9.	Written Communication Skills	Assignment, Examination
10.	Verbal Communication Skills	--
11.	Presentation Skills	--
12.	Behavioral Skills	Course work
13.	Information Management	Assignment, Examination
14.	Personal Management	Course work
15.	Leadership Skills	--

9. Course Resources

a. Essential Reading

1. Class Notes
2. Agresti, A. and Franklin, C. (2012) Statistics: The Art and Science of Learning from Data, 3rd edition, Prentice Hall.
3. Johnson, R. (2010) Miller and Fruend's Probability and Statics for Engineers, 8th edition, Pearson.

b. Recommended Reading

1. Yates, R. and Goodman, D. (2004) Probability and Stochastic Processes, 2nd edition, Wiley.
2. Kreyszig, E. (2011) Advanced Engineering Mathematics, 10th edition, Wiley

c. Magazines and Journals

1. Journal of Applied Probability and Statistics (JAPS) http://www.isoss.net/japs/
2. Journal of the American Statistical Association www.amstat.org/publications/journals.cfm

d. Websites

1. http://ocw.mit.edu/courses/mathematics/18-05-introduction-to-probability-and-statistics-spring-2005/

e. Other Electronic Resources

1. https://www.khanacademy.org/math/probability

10. Course Organization

Course Code	MTC524A

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Course Title	Introduction to Statistics and Probability	
Course Leader's Name	As per Timetable	
Course Leader's Contact Details	Phone:	+91-804-906-5555
	E-mail:	hod.mt.mp@msruas.ac.in
Course Specifications Approval Date	July 2022	
Next Course Specifications Review Date	June 2024	

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Course Specifications: Fundamentals of Fluid Dynamics

Course Title	Fundamentals of Fluid Dynamics
Course Code	MTC525A
Course Type	Core Theory
Department	Mathematics and Statistics
Faculty	Mathematical and Physical Sciences

1. Course Summary

The main aim of this course is to make student gain thorough knowledge of basics of fluid mechanics and apply the same to real world problems. This course begins with the introduction to fluid properties and continuum mechanics. The course builds a strong foundation of fluid dynamics starting with some basic theorems and conservation equations.

2. Course Size and Credits:

Number of Credits	04
Credit Structure (Lecture: Tutorial: Practical)	3:1:0
Total Hours of Interaction	60
Number of Weeks in a Semester	15
Department Responsible	Mathematics and Statistics
Total Course Marks	100
Pass Criterion	As per the Academic Regulations
Attendance Requirement	As per the Academic Regulations

3. Course Outcomes (COs)

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

- **CO-1.** Illustrate the basic properties of fluids, description of motion and fundamental laws
- **CO-2.** Explain the concept of continuum hypothesis and flow visualization
- **CO-3.** Illustrate the basic theorems and conservation laws of fluid dynamics
- **CO-4.** Analyze the behavior of the fluid based on the fluid properties and conservation laws
- **CO-5.** Apply the conservation laws to analyze the fluid behavior of the real world problem

4. Course Contents

Unit 1 (Introduction and Fundamental Concepts): **15 hrs**

Introduction, properties of fluids, concept of continuum, classification of fluids: Newtonian fluid, Non-Newtonian fluids, Ideal fluid, compressibility. Fluid flow, Classification of fluid flows.

Unit 2 (Kinematics of Fluid): **15 hrs**

Scalar and vector fields, flow field. Description of fluid motion: Lagrangian method, Eulerian method. Relation between Eulerian and Lagrangian methods. Material derivative and acceleration, temporal derivative, convective derivative. Fundamentals of flow visualization: Stream lines, path lines, streak lines. Deformation of fluid elements: Reynolds transportation

theorem.

Unit 3 (Conservation Equations): **15 hrs**

Control mass system, control volume system, isolated system. Conservation of mass - the continuity equation: Differential form and vector form, integral form. Conservation of momentum: momentum theorem. Conservation of energy. The Bernoulli equation.

5. Course Map (CO-PO-PSO Map)

	Programme Outcomes (POs)								Programme Specific Outcomes (PSOs)		
	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PSO-1	PSO-2	PSO-3
CO-1	3	2							3		
CO-2	3	2							3		
CO-3	3	2	2						3	1	
CO-4	3		2				1	1	3	1	
CO-5	3		2				1	1	3	1	

6. Course Teaching and Learning Methods

Teaching and Learning Methods	Duration in hours	Total Duration in Hours
Face to Face Lectures		45
Demonstrations		00
1. Demonstration using Videos	00	
2. Demonstration using Physical Models / Systems	00	
3. Demonstration on a Computer	00	
Numeracy		15
1. Solving Numerical Problems	15	
Practical Work		00
1. Course Laboratory	00	
2. Computer Laboratory	00	
3. Engineering Workshop / Course/Workshop / Kitchen	00	
4. Clinical Laboratory	00	
5. Hospital	00	
6. Model Studio	00	
Others		00
1. Case Study Presentation	00	
2. Guest Lecture	00	
3. Industry / Field Visit	00	
4. Brain Storming Sessions	00	
5. Group Discussions	00	
6. Discussing Possible Innovations	00	
Term Tests, Laboratory Examination/Written Examination, Presentations		10
Total Duration in Hours		**70**

7. Course Assessment and Reassessment

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The details of the components and subcomponents of course assessment are presented in the Programme Specifications document pertaining to the M. Sc. Mathematics Programme. The procedure to determine the final course marks is also presented in the Programme Specifications document.

The evaluation questions are set to measure the attainment of the COs. In either component (CE or SEE) or subcomponent of CE (TSC1, TSC2, TSC3), COs are assessed as illustrated in the following Table.

Focus of COs on each Component or Subcomponent of Evaluation				
	Component 1: CE (50% Weightage)			Component 2: SEE (50% Weightage)
Subcomponent▶	TSC1	TSC2	TSC3	100 Marks
Subcomponent Type ▶	Term Test	Assignment	Innovative	
Maximum Marks▶	50	25	25	
CO-1	X		X	X
CO-2	X		X	X
CO-3	X		X	X
CO-4		X	X	X
CO-5		X	X	X
The details of TSC1, TSC2, TSC3 are presented in the Programme Specifications Document.				

The Course Leader assigned to the course, in consultation with the Head of the Department, shall provide the focus of COs in each component of assessment in the above template at the beginning of the semester.
Course reassessment policies are presented in the Academic Regulations document.

8. Achieving COs

The following skills are directly or indirectly imparted to the students in the following teaching and learning methods:

S. No	Curriculum and Capabilities Skills	How imparted during the course
1.	Knowledge	Classroom lectures, tutorials, Assignments
2.	Understanding	Classroom lectures, tutorials, Assignments
3.	Critical Skills	Classroom lectures, Assignment
4.	Analytical Skills	Assignment
5.	Problem Solving Skills	Assignment, Examination
6.	Practical Skills	--
7.	Group Work	Assignment
8.	Self-Learning	Self-study, Assignment
9.	Written Communication Skills	Assignment, Examination
10.	Verbal Communication Skills	--
11.	Presentation Skills	--
12.	Behavioral Skills	Course work

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13.	Information Management	Assignment, Examination
14.	Personal Management	Course work
15.	Leadership Skills	--

9. Course Resources

a. Essential Reading

1. Course notes
2. Yunus A. Çengel and John M. Cimbala (2006) Fluid mechanics: fundamentals and applications, McGraw-Hill,
3. Philip J. Pritchard and John C. Leylegian (2011) Introduction to Fluid Mechanics (8th edition), JOHN WILEY AND SONS INC.
4. Frank M. White, (2011) Fluid Mechanics (7th edition), McGraw Hill.

b. Recommended Reading

1. Chandrasekharaiah, D. S. and Debnath, L. (1994) Continuum Mechanics, Academic Press.
2. Chorlton, F. (1967) Text book of Fluid Dynamics, Van Nostrand.
3. Yuan, S. W. (1976) Foundations of Fluid Mechanics, Prentice Hall.
4. Kundu, P. K. and Cohen, I. M. (2008) Fluid Mechanics, Academic Press

c. Magazines and Journals

1. https://nptel.ac.in/courses/112104118
2. Journal of Differential Equations
   https://www.sciencedirect.com/topics/earth-and-planetary-sciences/fluid-mechanics

d. Websites

https://theteche.com/basic-concepts-of-fluid-mechanics-and-flow-of-fluids/

e. Other Electronic Resources

https://www.khanacademy.org/science/physics/fluids#fluid-dynamics

10. Course Organization

Course Code	MTC525A	
Course Title	Fundamentals of Fluid Dynamics	
Course Leader's Name	As per Timetable	
Course Leader's Contact Details	**Phone:**	+91-804-906-5555
	E-mail:	hod.mt.mp@msruas.ac.in
Course Specifications Approval Date	July 2022	
Next Course Specifications Review Date	June 2024	

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Course Specifications: Measure Theory and Integration

Course Title	Measure Theory and Integration
Course Code	MTC531A
Course Type	Core Theory
Department	Mathematics and Statistics
Faculty	Mathematical and Physical Sciences

1. Course Summary

The aim of this course is to introduce students the concepts of abstract integration. The course introduces the concepts of Lebesgue measure and integration. This course also discusses Lp spaces as examples of Banach and Hilbert spaces.

2. Course Size and Credits:

Number of Credits	04
Credit Structure (Lecture: Tutorial: Practical)	3:1:0
Total Hours of Interaction	60
Number of Weeks in a Semester	15
Department Responsible	Mathematics and Statistics
Total Course Marks	100
Pass Criterion	As per the Academic Regulations
Attendance Requirement	As per the Academic Regulations

3. Course Outcomes (COs)

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

- **CO-1.** Explain the basic principles of measure theory, integration and Lp spaces
- **CO-2.** Solve simple problems associated with measure theory, integration and Lp spaces
- **CO-3.** State and prove simple theorems in measure theory, integration and Lp spaces
- **CO-4.** State and prove complex theorems in measure theory, integration and Lp spaces
- **CO-5.** Solve complex problems associated with measure theory, integration and Lp spaces

4. Course Contents

Unit 1 (Measure Theory): **20 hrs**

Measure Spaces and Sigma-algebras: Operations on Measurable Functions (Sums, Products, Composition), Borel Sets. Real-valued Measurable Functions: Limits of Measurable Functions, Simple Functions, Positive Measures, Definition of Lebesgue Integral. Riemann Integral, Comparison of Lebesgue and Riemann Integrals, Properties of Positive Measure.

Unit 2 (Lebesgue Integration): **20 hrs**

Elementary Properties of the Lebesgue Integral. Monotone Convergence Theorem, Fatou's Lemma and Dominated Convergence Theorem. Integration as a Linear Functional: Riesz Representation Theorem for Positive Linear Functionals. Lusin's Theorem (Measurable Functions are nearly continuous), Vitali-Caratheodory Theorem.

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Unit 3 (Lp Spaces): **5 hrs**

Convex Functions Jensen's Inequality, Hölder and Minkowski Inequalities. Normed Spaces, Banach Spaces, Riesz-Fischer Theorem (Lp is complete).

5. Course Map (CO-PO-PSO Map)

	Programme Outcomes (POs)								Programme Specific Outcomes (PSOs)		
	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PSO-1	PSO-2	PSO-3
CO-1	3	2							2	3	
CO-2	3	2						1	2	3	
CO-3	3	2				1	1	1		3	1
CO-4	3	2			1	1	1	1		3	1
CO-5	3	2			1	1	1	1		3	1

6. Course Teaching and Learning Methods

Teaching and Learning Methods	Duration in hours	Total Duration in Hours
Face to Face Lectures		45
Demonstrations		00
1. Demonstration using Videos	00	
2. Demonstration using Physical Models / Systems	00	
3. Demonstration on a Computer	00	
Numeracy		15
1. Solving Numerical Problems	15	
Practical Work		00
1. Course Laboratory	00	
2. Computer Laboratory	00	
3. Engineering Workshop / Course/Workshop / Kitchen	00	
4. Clinical Laboratory	00	
5. Hospital	00	
6. Model Studio	00	
Others		00
1. Case Study Presentation	00	
2. Guest Lecture	00	
3. Industry / Field Visit	00	
4. Brain Storming Sessions	00	
5. Group Discussions	00	
6. Discussing Possible Innovations	00	
Term Tests, Laboratory Examination/Written Examination, Presentations		10
Total Duration in Hours		**70**

7. Course Assessment and Reassessment

The details of the components and subcomponents of course assessment are presented in the Programme Specifications document pertaining to the M. Sc. (Mathematics) Programme. The procedure to determine the final course marks is also presented in the Programme Specifications document.

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The evaluation questions are set to measure the attainment of the COs. In either component (CE or SEE) or subcomponent of CE (TSC1, TSC2, TSC3), COs are assessed as illustrated in the following Table.

Focus of COs on each Component or Subcomponent of Evaluation				
	Component 1: CE (50% Weightage)			Component 2: SEE (50% Weightage)
Subcomponent▶	TSC1	TSC2	TSC3	100 Marks
Subcomponent Type ▶	Term Test	Assignment	Innovative	
Maximum Marks▶	50	25	25	
CO-1	X		X	X
CO-2	X		X	X
CO-3	X		X	X
CO-4		X	X	X
CO-5		X	X	X
The details of TSC1, TSC2, TSC3 are presented in the Programme Specifications Document.				

The Course Leader assigned to the course, in consultation with the Head of the Department, shall provide the focus of COs in each component of assessment in the above template at the beginning of the semester.
Course reassessment policies are presented in the Academic Regulations document.

8. Achieving COs

The following skills are directly or indirectly imparted to the students in the following teaching and learning methods:

S. No	Curriculum and Capabilities Skills	How imparted during the course
1.	Knowledge	Classroom lectures, tutorials, Assignments
2.	Understanding	Classroom lectures, tutorials, Assignments
3.	Critical Skills	Classroom lectures, Assignment
4.	Analytical Skills	Assignment
5.	Problem Solving Skills	Assignment, Examination
6.	Practical Skills	--
7.	Group Work	Assignment
8.	Self-Learning	Self-study, Assignment
9.	Written Communication Skills	Assignment, Examination
10.	Verbal Communication Skills	--
11.	Presentation Skills	--
12.	Behavioral Skills	Course work
13.	Information Management	Assignment, Examination
14.	Personal Management	Course work
15.	Leadership Skills	--

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9. Course Resources

a. Essential Reading

1. Course notes

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2. Rudin, W., 1991, Real Analysis, 2nd, Ed., McGraw-Hill,
3. Royden, H.L., 1987, Real Analysis, Macmillan Publishing Company.

b. Recommended Reading

1. Rudin, W., 1976, Principles of Mathematical Analysis, 3rd Ed., McGraw-Hill.
2. Bartle, R.G., 1976, The Elements of Real analysis, 2nd Ed., John Wiley and Son Inc.
3. Pugh, C.C., 2002, Real Mathematical Analysis, Springer.
4. Malik, S.C., 2011, Principle of Real Analysis, 2nd Ed., New Academic Sciences Ltd.
5. Howie, J.M., 2006, Real Analysis, Springer.

c. Magazines and Journals

d. Websites

1. http://ocw.mit.edu/

e. Other Electronic Resources

10. Course Organization

Course Code	MTC531A	
Course Title	Measure Theory and Integration	
Course Leader's Name	As per Timetable	
Course Leader's Contact Details	**Phone:**	+91-804-906-5555
	E-mail:	hod.mt.mp@msruas.ac.in
Course Specifications Approval Date	July 2022	
Next Course Specifications Review Date	June 2024	

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Course Specifications: Differential Geometry

Course Title	Differential Geometry
Course Code	MTC532A
Course Type	Core Theory
Department	Mathematics and Statistics
Faculty	Mathematical and Physical Sciences

1. Course Summary

The aim of the Course is to introduce the Geometry of curves and surfaces. The students are introduced with topological spaces, curves and surfaces. This Course trains students to study geometric properties of curves, surfaces and their higher dimensional analogues using the method of calculus.

2. Course Size and Credits:

Number of Credits	04
Credit Structure (Lecture: Tutorial: Practical)	3:1:0
Total Hours of Interaction	75
Number of Weeks in a Semester	15
Department Responsible	Mathematics and Statistics
Total Course Marks	100
Pass Criterion	As per the Academic Regulations
Attendance Requirement	As per the Academic Regulations

3. Course Outcomes (COs)

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

- **CO-1.** Understand basic concepts of covariant vectors, contravariant vectors, tensors and their algebra.
- **CO-2.** Explain the concepts of tangent vector, directional derivatives, and differential forms
- **CO-3.** Calculate the curvature, torsion, normal and bi-normal vectors by using Frenet formulas
- **CO-4.** Compute the Patches of surfaces in E^3.
- **CO-5.** Explain the Gaussian curvature, the mean curvature, and geodesic of a surface and its importance.

4. Course Contents

Unit 1 (Calculus on Euclidean Space): **7 hrs**

Euclidean space, tangent vectors, directional derivatives, curves in E^3, level curve, parametrized curve, arc length, velocity and speed of a curve, reparametrization of a curve. 1-forms, differential forms, mapping of Euclidean spaces, derivative map.

Unit 2 (Frame Fields and Isometries): **8 hrs**

Dot product, cross product, vector field, Curvature and torsion of a curve, Frenet formulas, plane curves and spherical curves. Arbitrary speed curves, cylindrical and spherical frame fields.

Connection forms. Isometries of E^3, translation, rotation, and orthogonal transformations. The derivative map of an isometry.

Unit 3 (Calculus on a Surface): **10 hrs**

Coordinate patch, proper patch, surface in E^3, special surfaces- sphere, cylinder, surface of revolution and torus. Differential functions and tangent vectors on a surface of E^3. Directional derivatives, differential forms and exterior derivative of forms on surface of E^3. Pull back functions.

Unit 4: (Shape Operators): **10 hrs**

Definition of shape operator, shape operators of different surfaces. Normal curvature, principle curvature and umbilic points of a surface in E^3. Gaussian curvature, mean curvature and computational techniques. Minimal surfaces, special curves in a surface of E^3 and surface of revolution.

Unit 5 (Tensors): **10 hrs**

n-dimensional space, Superscript and subscript , the Einstein's summation convention, dummy index, free index, Kronecker delta, transformation of coordinates , covariant and contravariant vectors, tensors and their algebra.

5. Course Map (CO-PO-PSO Map)

	Programme Outcomes (POs)										Programme Specific Outcomes (PSOs)		
	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PSO-1	PSO-2	PSO-3
CO-1	2	1	3			1					2	3	
CO-2	3	1	2		1	1					2	2	
CO-3	3	1	2		1		1				2	3	
CO-4	3	1	2		1						2	3	
CO-5	3	2	3		2	1	1	1			2	2	

6. Course Teaching and Learning Methods

Teaching and Learning Methods	Duration in hours	Total Duration in Hours
Face to Face Lectures		45
Demonstrations		05
1. Demonstration using Videos	01	
2. Demonstration using Physical Models / Systems	00	
3. Demonstration on a Computer	03	
Numeracy		15
1. Solving Numerical Problems	30	
Practical Work		00
1. Course Laboratory	00	
2. Computer Laboratory	00	
3. Engineering Workshop / Course/Workshop / Kitchen	00	
4. Clinical Laboratory	00	
5. Hospital	00	

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6. Model Studio	00	
Others		00
1. Case Study Presentation	00	
2. Guest Lecture	00	
3. Industry / Field Visit	00	
4. Brain Storming Sessions	00	
5. Group Discussions	00	
6. Discussing Possible Innovations	00	
Term Tests, Laboratory Examination/Written Examination, Presentations		10
Total Duration in Hours		**75**

7. Course Assessment and Reassessment

The details of the components and subcomponents of course assessment are presented in the Programme Specifications document pertaining to the M. Sc. (Mathematics) Programme. The procedure to determine the final course marks is also presented in the Programme Specifications document.

The evaluation questions are set to measure the attainment of the COs. In either component (CE or SEE) or subcomponent of CE (TSC1, TSC2, TSC3), COs are assessed as illustrated in the following Table.

Focus of COs on each Component or Subcomponent of Evaluation				
	Component 1: CE (50% Weightage)			**Component 2: SEE (50% Weightage)**
Subcomponent▶	**TSC1**	**TSC2**	**TSC3**	**100 Marks**
Subcomponent Type ▶	**Term Test**	**Assignment**	**Innovative**	
Maximum Marks▶	**50**	**25**	**25**	
CO-1	X		X	X
CO-2	X		X	X
CO-3	X		X	X
CO-4		X	X	X
CO-5		X	X	X
The details of TSC1, TSC2, TSC3 are presented in the Programme Specifications Document.				

The Course Leader assigned to the course, in consultation with the Head of the Department, shall provide the focus of COs in each component of assessment in the above template at the beginning of the semester.

Course reassessment policies are presented in the Academic Regulations document.

8. Achieving COs

The following skills are directly or indirectly imparted to the students in the following teaching and learning methods:

S. No	Curriculum and Capabilities Skills	How imparted during the course
1.	Knowledge	Classroom lectures, tutorials, Assignments

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2.	Understanding	Classroom lectures, tutorials, Assignments
3.	Critical Skills	Classroom lectures, Assignment
4.	Analytical Skills	Assignment
5.	Problem Solving Skills	Assignment, Examination
6.	Practical Skills	--
7.	Group Work	Assignment
8.	Self-Learning	Self-study, Assignment
9.	Written Communication Skills	Assignment, Examination
10.	Verbal Communication Skills	--
11.	Presentation Skills	--
12.	Behavioral Skills	Course work
13.	Information Management	Assignment, Examination
14.	Personal Management	Course work
15.	Leadership Skills	--

9. Course Resources

a. Essential Reading

1. Class notes
2. Barrett O' Neil (1966) Elementary Differential Geometry, Academic press, New York and London.
3. Andrew Pressley, (2004) Elementary Differential Geometry
4. Kreyszig Erwin, (2019), Introduction to Differential Geometry and Riemannian Geometry, University of Toronto press, Canada.
5. Dube.K.K , (2009), Differential Geometry and Tensors, I K International Publishing House PVT.LTD, India

b. Recommended Reading

1. Wilmore, T.J. (1959) An Introduction to differential geometry, Clarendon Press, Oxford. India.
2. Struik, D. J. (1961) Lectures on Classical Differential Geometry, Addison Wesley, Massachusetts.
3. Christian B. (2010), Elementary Differential Geometry, Cambridge University Press, UK.
4. Nazrul Islam. (2006). Tensors and Their Applications, New Age International Publishers, India

c. Magazines and Journals

1. The College Mathematics Journal, Mathematical Association of America. https://www.maa.org/press/periodicals/college-mathematics-journal/the-collegemathematics-journal
2. SIAM Undergraduate Research Online, Society for Industrial and Applied Mathematics, http://www.siam.org/students/siuro/index.php
3. Involve – A Journal of mathematics, https://msp.org/involve/about/journal/about.html
4. Rose-Hulman Undergraduate Mathematics Journal, Rose-Hulman Institute of Technology. https://scholar.rose-hulman.edu/rhumj/

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d. Websites

1. https://www.coursera.org/
2. http://nptel.ac.in/

e. Other Electronic Resources

1. https://www.khanacademy.org/
2. tutorial.math.lamar.edu/
3. http://www.sosmath.com/diffeq/diffeq.html
4. http://serc.carleton.edu/sencer/ode_real_world/index.html

10. Course Organization

Course Code	MTC532A	
Course Title	Differential Geometry	
Course Leader's Name	As per Timetable	
Course Leader's Contact Details	**Phone:**	+91-804-906-5555
	E-mail:	hod.mt.mp@msruas.ac.in
Course Specifications Approval Date	July 2022	
Next Course Specifications Review Date	July 2024	

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Course Specifications: Numerical Analysis - 2

Course Title	Numerical Analysis – 2
Course Code	MTC533A
Course Type	Core Theory
Department	Mathematics and Statistics
Faculty	Mathematical and Physical Sciences

1. Course Summary

This course aims at training students in handling various aspects numerical computations. In this specialization module, the students learn the basics of numerical methods to solve non-linear ordinary and partial differential equations. Numerical techniques like finite difference, finite element and finite volume methods to solve partial differential equations are discussed. The module aims at training students in handling various aspects numerical computations.

2. Course Size and Credits:

Number of Credits	04
Credit Structure (Lecture: Tutorial: Practical)	3:1:0
Total Hours of Interaction	60
Number of Weeks in a Semester	15
Department Responsible	Mathematics and Statistics
Total Course Marks	100
Pass Criterion	As per the Academic Regulations
Attendance Requirement	As per the Academic Regulations

3. Course Outcomes (COs)

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

- **CO-1.** Illustrate various methods of numerical solution to solve ordinary and partial differential equations
- **CO-2.** State and prove theorems on convergence and stability of numerical algorithms
- **CO-3.** Solve simple problems using methods such as single step, multi-step, and finite difference methods to solve ordinary differential equations
- **CO-4.** Solve simple problems using finite difference and finite element methods and finite volume methods to solve partial differential equations
- **CO-5.** Solve complex problems arising in real world using numerical solutions to solve partial differential equations

4. Course Contents

Unit 1 (Numerical Solution of ODE): **5 hrs**

Numerical solution of ordinary differential equations by single-step methods – Euler's, modified Euler's and Runge-Kutta methods. Multi-step methods – Milne's and Adams' methods.

Unit 2 (Finite Difference Method): **10 hrs**

Finite difference method: Numerical solution of elliptic equations, difference schemes for Laplace and Poisson's equations. Numerical solution of parabolic equations, explicit and implicit

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schemes. Numerical solution of hyperbolic equations, explicit and implicit schemes. Stability and convergence analyses of finite difference methods.

Unit 3 (Finite Volume Method): **15 hrs**

Finite volume method to solve hyperbolic PDEs and a linear system of hyperbolic PDEs. General formulation of conservation laws. Advection equation, characteristics and Riemann problem for linear hyperbolic equations. Necessary components for convergence and CFL conditions, Lax-Wendroff method and upwind method. Godunov's method for linear hyperbolic systems. Lax-Wendroff and total variation methods for linear hyperbolic system. Convergence, Accuracy, and Stability of various methods.

Unit 4 (Finite Element Method): **10 hrs**

Finite element method for elliptic problems, variational formulation for the Poisson problem. Discretization of the Poisson problem in one dimension, formulation, theory and implementation. FEM for the Poisson problem in two dimensions.

5. Course Map (CO-PO-PSO Map)

	Programme Outcomes (POs)								Programme Specific Outcomes (PSOs)		
	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PSO-1	PSO-2	PSO-3
CO-1	3	2							3		
CO-2	3	2							3	3	
CO-3	3	2	3	3		1	1	1	3		1
CO-4	3	2	3	3		1	1	1	3		1
CO-5	3	2	3	3	2	1	1	1	3	2	1

6. Course Teaching and Learning Methods

Teaching and Learning Methods	Duration in hours	Total Duration in Hours
Face to Face Lectures		45
Demonstrations		00
1. Demonstration using Videos	00	
2. Demonstration using Physical Models / Systems	00	
3. Demonstration on a Computer	00	
Numeracy		15
1. Solving Numerical Problems	15	
Practical Work		00
1. Course Laboratory	00	
2. Computer Laboratory	00	
3. Engineering Workshop / Course/Workshop / Kitchen	00	
4. Clinical Laboratory	00	
5. Hospital	00	
6. Model Studio	00	
Others		00
1. Case Study Presentation	00	
2. Guest Lecture	00	
3. Industry / Field Visit	00	

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4. Brain Storming Sessions	00	
5. Group Discussions	00	
6. Discussing Possible Innovations	00	
Term Tests, Laboratory Examination/Written Examination, Presentations		10
Total Duration in Hours		**70**

7. Course Assessment and Reassessment

The details of the components and subcomponents of course assessment are presented in the Programme Specifications document pertaining to the M. Sc. (Mathematics) Programme. The procedure to determine the final course marks is also presented in the Programme Specifications document.

The evaluation questions are set to measure the attainment of the COs. In either component (CE or SEE) or subcomponent of CE (TSC1, TSC2, TSC3), COs are assessed as illustrated in the following Table.

Focus of COs on each Component or Subcomponent of Evaluation				
	Component 1: CE (50% Weightage)			**Component 2: SEE (50% Weightage)**
Subcomponent▶	**TSC1**	**TSC2**	**TSC3**	**100 Marks**
Subcomponent Type ▶	**Term Test**	**Assignment**	**Innovative**	
Maximum Marks▶	**50**	**25**	**25**	
CO-1	X		X	X
CO-2	X		X	X
CO-3	X		X	X
CO-4		X	X	X
CO-5		X	X	X
The details of TSC1, TSC2, TSC3 are presented in the Programme Specifications Document.				

The Course Leader assigned to the course, in consultation with the Head of the Department, shall provide the focus of COs in each component of assessment in the above template at the beginning of the semester.

Course reassessment policies are presented in the Academic Regulations document.

8. Achieving COs

The following skills are directly or indirectly imparted to the students in the following teaching and learning methods:

S. No	Curriculum and Capabilities Skills	How imparted during the course
1.	Knowledge	Classroom lectures, tutorials, Assignments
2.	Understanding	Classroom lectures, tutorials, Assignments
3.	Critical Skills	Classroom lectures, Assignment
4.	Analytical Skills	Assignment
5.	Problem Solving Skills	Assignment, Examination
6.	Practical Skills	--
7.	Group Work	Assignment
8.	Self-Learning	Self-study, Assignment
9.	Written Communication Skills	Assignment, Examination

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10.	Verbal Communication Skills	--
11.	Presentation Skills	--
12.	Behavioral Skills	Course work
13.	Information Management	Assignment, Examination
14.	Personal Management	Course work
15.	Leadership Skills	--

9. Course Resources

a. Essential Reading

1. Course notes
2. Reddy, J.N., 2005, An Introduction to the Finite Element Method, 3rd Ed., McGraw-Hill Higher Education.
3. Leveque, R.J., 2004, Finite Volume Methods for Hyperbolic Problems, Cambridge University Press.
4. Bathe, K.J., 2007, Finite Element Procedures, Klaus-Jurgen Bathe.

b. Recommended Reading

1. Jain, M.K., 1979, Numerical Solution of Differential Equations, 2nd edition, Wiley Eastern.
2. Smith, G.D., 1978, Numerical Solutions of Partial Differential Equations, 2nd Ed., Oxford University Press.
3. Morton, K.W. and Meyers, D., 2005, Numerical Solution of Partial Differential Equations, 2nd Ed., Cambridge University Press.

c. Magazines and Journals

d. Websites

1. http://ocw.mit.edu/

e. Other Electronic Resources

10. Course Organization

Course Code	MTC533A	
Course Title	Numerical analysis – 2	
Course Leader's Name	As per Timetable	
Course Leader's Contact Details	**Phone:**	+91-804-906-5555
	E-mail:	hod.mt.mp@msruas.ac.in
Course Specifications Approval Date	July 2022	
Next Course Specifications Review Date	June 2024	

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Course Specifications: Numerical Analysis Laboratory – 2

Course Title	Numerical Analysis Laboratory - 2
Course Code	MTL532A
Department	Mathematics and Statistics
Faculty	Mathematical and Physical Sciences

1. Course Summary

The aim of this course is to introduce students to numerical analysis with MATLAB. Students are taught the concepts of solving ordinary and partial differential equations by using MATLAB. Finite element method and finite difference method are discussed by using MATLAB.

2. Course Size and Credits:

Number of Credits	01
Credit Structure (Lecture: Tutorial: Practical)	0:0:1
Total Hours of Interaction	30
Number of Weeks in a Semester	15
Department Responsible	Mathematics and Statistics
Total Course Marks	50
Pass Criterion	As per the Academic Regulations
Attendance Requirement	As per the Academic Regulations

3. Course Outcomes (COs)

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

CO-1. Illustrate fundamentals solving differential equations by using build functions of MATLAB.
CO-2. Implement algorithms and solve ordinary differential equations by using MATLAB.
CO-3. Solve mathematical problems associated with partial differential equations and compare the results with that of solutions obtained using MATLAB.
CO-4. Apply Explicit finite difference method and PDE toolbox to solve partial differential equations and implement the same using MATLAB.
CO-5. Solve real world problems associated partial differential equations by using MATLAB.

4. Course Contents

1. Plotting of second and third order respective solution family of differential equation
2. Euler's Method.
3. Runge - Kutta method.
4. Predictor–Corrector method

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5. Plotting the characteristics for the first order PDE and the integral surfaces of a given first order PDE with initial data.
6. Explicit Finite Difference method to solve PDEs
7. The Crank–Nicolson method
8. Partial Differential Equations tool box
9. Finite element method for one dimensional problems
10. Method of approximation Rayleigh-Ritz method

5. Course Map (CO-PO-PSO Map)

	Programme Outcomes (POs)										Programme Specific Outcomes (PSOs)		
	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PSO-1	PSO-2	PSO-3
CO-1	3	1	1	1	1						3	3	
CO-2	3	1	1	1	2						2	2	
CO-3	2	1	1	1	2						2	3	
CO-4	3	1	2	2	2						3	2	
CO-5	3	1	2	2	2						2	2	

6. Course Teaching and Learning Methods

Teaching and Learning Methods	Duration in hours	Total Duration in Hours
Face to Face Lectures		07
Demonstrations		06
1. Demonstration using Videos	01	
2. Demonstration using Physical Models / Systems	00	
3. Demonstration on a Computer	06	
Numeracy		00
1. Solving Numerical Problems	00	
Practical Work		13
1. Course Laboratory	00	
2. Computer Laboratory	13	
3. Engineering Workshop / Course/Workshop / Kitchen	00	
4. Clinical Laboratory	00	
5. Hospital	00	
6. Model Studio	00	
Others		00
1. Case Study Presentation	00	
2. Guest Lecture	00	
3. Industry / Field Visit	00	
4. Brain Storming Sessions	00	
5. Group Discussions	00	
6. Discussing Possible Innovations	00	
Term Tests, Laboratory Examination/Written Examination, Presentations		04
Total Duration in Hours		**30**

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7. Course Assessment and Reassessment

The details of the components and subcomponents of course assessment are presented in the Programme Specifications document pertaining to the M. Sc. (Mathematics) Programme. The procedure to determine the final course marks is also presented in the Programme Specifications document.

The evaluation questions are set to measure the attainment of the COs. In either component (CE or SEE) or subcomponent of CE (SC1, SC2, SC3 or SC4), COs are assessed as illustrated in the following Table.

Focus of COs on each Component or Subcomponent of Evaluation					
	Component 1: CE (50% Weightage)				Component 2: SEE (50% Weightage)
Subcomponent ▶	SC1	SC2	SC3	SC4	
Subcomponent Type ▶	Term Test	Term Test	Assignment	Assignment	100 Marks
Maximum Marks ▶	25	25	25	25	
CO-1	×	×			×
CO-2	×	×			×
CO-3	×	×			×
CO-4			×	×	×
CO-5			×	×	×
The details of SC1, SC2, SC3 or SC4 are presented in the Programme Specifications Document.					

The Course Leader assigned to the course, in consultation with the Head of the Department, shall provide the focus of COs in each component of assessment in the above template at the beginning of the semester.

Course reassessment policies are presented in the Academic Regulations document.

8. Achieving COs

The following skills are directly or indirectly imparted to the students in the following teaching and learning methods:

S. No	Curriculum and Capabilities Skills	How imparted during the course
1.	Knowledge	Classroom lectures, tutorials, Assignments
2.	Understanding	Classroom lectures, tutorials, Assignments
3.	Critical Skills	Classroom lectures, Assignment
4.	Analytical Skills	Assignment
5.	Problem Solving Skills	Assignment, Examination
6.	Practical Skills	--
7.	Group Work	Assignment
8.	Self-Learning	Self-study, Assignment
9.	Written Communication Skills	Assignment, Examination
10.	Verbal Communication Skills	--

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11.	Presentation Skills	--
12.	Behavioral Skills	Course work
13.	Information Management	Assignment, Examination
14.	Personal Management	Course work
15.	Leadership Skills	--

9. Course Resources

a. Essential Reading

1. Laboratory manual.
2. Rudra Pratap. 2013. Getting started with MATLAB. United Kingdom: Oxford University press.
3. Won Y. Yang, Wenwu Cao, Tae S. Chung, John Morris. Applied numerical methods using MATLAB, John Wiley & Sons, Inc.

b. Recommended Reading

1. Dukkipati, R.V. 2011. Applied Numerical Methods using MATLAB. 1st Ed. New Delhi: New Age publication.
2. Reddy, J. N. (2005) An Introduction to the Finite Element Method, 3rd edition, McGraw-Hill Higher Education.
3. Jain, M. K., Iyengar, S.R.K. and Jain, R.K. 2008. Numerical Methods. New Delhi: New Age.

c. Magazines and Journals

d. Websites

1. https://www.coursera.org/
2. http://nptel.ac.in/

e. Other Electronic Resources

1. https://www.khanacademy.org/
2. tutorial.math.lamar.edu/
3. http://www.sosmath.com/diffeq/diffeq.html
4. http://serc.carleton.edu/sencer/ode_real_world/index.html

10. Course Organization

Course Code	MTL532A	
Course Title	Numerical Analysis Laboratory - 1	
Course Leader's Name	As per Timetable	
Course Leader's Contact Details	**Phone:**	+91-804-906-5555
	E-mail:	hod.mt.mp@msruas.ac.in
Course Specifications Approval Date	July 2022	
Next Course Specifications Review Date	July 2024	

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Course Specifications: Seminar – 1

Course Title	Seminar - 1
Course Code	MTS531A
Course Type	Laboratory
Department	Mathematics and Statistics
Faculty	Mathematical and Physical Sciences

1. Course Summary

The aim of this course is to train students to conduct independent study a topic of relevance and deliver a seminar.

The student is expected choose a topic of relevance and conduct independent study. The student is also expected to submit a report and give a presentation on the chosen topic.

2. Course Size and Credits:

Number of Credits	02
Credit Structure (Lecture: Tutorial: Practical)	0:0:4
Total Hours of Interaction	60
Number of Weeks in a Semester	15
Department Responsible	Mathematics and Statistics
Total Course Marks	50
Pass Criterion	As per the Academic Regulations
Attendance Requirement	As per the Academic Regulations

3. Course Outcomes (COs)

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

CO-1. Make a presentation to a panel of examiners
CO-2. Write a report on the chosen topic

4. Course Contents

1. Choose the relevant research topic
2. Study literature and give seminars
3. Prepare a report and present the same

4. Course Map (CO-PO-PSO Map)

	Programme Outcomes (POs)								Programme Specific Outcomes (PSOs)		
	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PSO-1	PSO-2	PSO-3
CO-1		2		3		2	2	2	2	3	2

CO-2	3	2	2	3	3	2	2	2	3	3	2
3: Very Strong Contribution, 2: Strong Contribution, 1: Moderate Contribution											

5. Course Teaching and Learning Methods

Teaching and Learning Methods	Duration in hours	Total Duration in Hours
Face to Face Lectures		00
Demonstrations		00
1.Demonstration using Videos	00	
2. Demonstration using Physical Models / Systems	00	
3. Demonstration on a Computer	00	
Numeracy		00
1. Solving Numerical Problems	00	
Practical Work		60
1. Course Laboratory	00	
2. Computer Laboratory	60	
3. Engineering Workshop / Course/Workshop / Kitchen	00	
4. Clinical Laboratory	00	
5. Hospital	00	
6. Model Studio	00	
Others		00
1. Case Study Presentation	00	
2. Guest Lecture	00	
3. Industry / Field Visit	00	
4. Brain Storming Sessions	00	
5. Group Discussions	00	
6. Discussing Possible Innovations	00	
Term Tests, Laboratory Examination/Written Examination, Presentations		05
Total Duration in Hours		**65**

6. Course Assessment and Reassessment

The details of the components and subcomponents of course assessment are presented in the Programme Specifications document pertaining to the M. Sc. (Applied Mathematics) Programme. The procedure to determine the final course marks is also presented in the Programme Specifications document.

The evaluation questions are set to measure the attainment of the COs. In either component (CE or SEE) or subcomponent of CE (SC1,), COs are assessed as illustrated in the following Table.

Focus of COs on each Component or Subcomponent of Evaluation		
	Component 1: CE (50% Weightage)	**Component 2: SEE (50% Weightage)**
Subcomponent ▶	**SC1**	
Subcomponent Type ▶	**Report**	**Presentation**

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Maximum Marks ▶	50 Marks	50 Marks
CO-1	X	
CO-2		X
The details of SC1 are presented in the Programme Specifications Document.		

The Course Leader assigned to the course, in consultation with the Head of the Department, shall provide the focus of COs in each component of assessment in the above template at the beginning of the semester.

Course reassessment policies are presented in the Academic Regulations document.

7. Achieving COs

The following skills are directly or indirectly imparted to the students in the following teaching and learning methods:

S. No	Curriculum and Capabilities Skills	How imparted during the course
1.	Knowledge	Literature reading
2.	Understanding	Literature reading
3.	Critical Skills	Literature reading
4.	Analytical Skills	Literature reading
5.	Problem Solving Skills	Drawing conclusions from the literature
6.	Practical Skills	Literature reading, preparation of report
7.	Group Work	
8.	Self-Learning	Literature reading, preparation of report
9.	Written Communication Skills	Preparation of report
10.	Verbal Communication Skills	Presentation of report
11.	Presentation Skills	Presentation of report
12.	Behavioral Skills	Course work
13.	Information Management	Presentation of report
14.	Personal Management	Course work
15.	Leadership Skills	---

8. Course Resources

a. **Essential Reading**
   1. Research Articles /Dissertation Reports / Books

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9. Course Organization

Course Code	MTS531A	
Course Title	Seminar – 1	
Course Leader's Name	As per Timetable	
Course Leader's Contact Details	**Phone:**	+91-804-906-5555
	E-mail:	hod.mt.mp@msruas.ac.in
Course Specifications Approval Date	July 2022	
Next Course Specifications Review Date	July 2024	

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Course Specifications: Research Methodology

Course Title	Research Methodology
Course Code	MPF615A
Course Type	Core Theory
Department	Mathematics and Statistics
Faculty	Mathematical and Physical Sciences

1. Course Summary

The aim of the course is to introduce students to the principles of research, research methodology and significant phases of research.
Students are taught the significant role of Literature Review in a research cycle and the expectations from good literature review as well as procedure for systematic literature review. The essential aspects of technical communication to develop desirable writing skills for the preparation of research document including research paper as well as the skills for an effective presentation are also discussed. The module also emphasizes the desirable close knit relation between innovation and concept of out of the box thinking. Students will get an insight into the privilege, honour and the associated responsibilities of a researcher.

2. Course Size and Credits:

Number of Credits	02
Credit Structure (Lecture: Tutorial: Practical)	2:0:0
Total Hours of Interaction	30
Number of Weeks in a Semester	15
Department Responsible	Chemistry
Total Course Marks	50
Pass Criterion	As per the Academic Regulations
Attendance Requirement	As per the Academic Regulations

3. Course Outcomes (COs)

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

- **CO-1.** Describe the value, scope, relevance and mandatory steps of research as well as principles of effective research
- **CO-2.** Discuss and demonstrate the application and utility of the Systematic approach and out of box thinking concepts for research to be effective
- **CO-3.** Explain and apply the procedures outlined for a systematic Literature Review
- **CO-4.** Outline the principles to prepare a well-structured research proposal and research paper
- **CO-5.** Identify and apply the essential skills desirable for an effective technical presentation

4. Course Contents

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Foundations of Research:

Definitions of Research, Mandatory Steps in Research, Types of Research, Relevance of Research for Innovation and Technology Development, Effective Research and Self Discipline. Out of the Box Thinking and Systematic approach in Research – Transformation to Impossible Thinking, Convergent and Divergent Thinking, Generation, Evaluation and Selection of Ideas.

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Literature Review:

Importance of Literature Review, Constituents of Good Literature Review, Strategies for Literature Search, Referencing, Paraphrasing, and Summarizing Academic Standards and Ethics. Statistical Methods and Data Analysis

Research Proposal:

Structure of a Good Research Proposal, Getting Started, Tips for Compilation of Good Research Proposal. Technical Communication - Research Paper for Publication- Significance of Problem Statement and its scope, Formulation of Hypothesis, Adequacy of Methodology, Significance of Presentation and Discussion of Results, Relevance and Importance of references.

Effective Presentation:

Preparation, Templates, Balance between Good Design and Good Content, Planning and Sequencing, PAMPERS (Projection, Articulation, Modulation, Punctuation, Enunciation, Repetition and Speed) rule, PEOPLE (Position & Gestures, Eye Contact, Orientation, Proximation, Looks & Appearance, and Expressions & Emotion) rule, 4P's Rule (Plan, Prepare, Practice and Present), Essentials of Effectiveness, Effective Pausing and Inclusive Answering.

5. Course Map (CO-PO-PSO Map)

	Programme Outcomes (POs)										Programme Specific Outcomes (PSOs)		
	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PSO-1	PSO-2	PSO-3
CO-1	3										3		
CO-2			3		3				3	3		3	
CO-3			3	3	3				3	3		3	3
CO-4			3		3				3	3		3	3
CO-5				3					3	3		3	3
3: Very Strong Contribution, 2: Strong Contribution, 1: Moderate Contribution													

6. Course Teaching and Learning Methods

Teaching and Learning Methods	Duration in hours	Total Duration in Hours
Face to Face Lectures35		30
Demonstrations		00
1.Demonstration using Videos	00	
2. Demonstration using Physical Models / Systems	00	
3. Demonstration on a Computer	00	
Numeracy		00
1. Solving Numerical Problems	00	
Practical Work		00
1. Course Laboratory	00	
2. Computer Laboratory	00	

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3. Engineering Workshop / Course/Workshop / Kitchen	00	
4. Clinical Laboratory	00	
5. Hospital	00	
6. Model Studio	00	
Others		
1. Case Study Presentation	00	
2. Guest Lecture	00	
3. Industry / Field Visit	00	00
4. Brain Storming Sessions	00	
5. Group Discussions	00	
6. Discussing Possible Innovations	00	
Term Tests, Laboratory Examination/Written Examination, Presentations		05
Total Duration in Hours		**35**

7. Course Assessment and Reassessment

The details of the components and subcomponents of course assessment are presented in the Programme Specifications document pertaining to the M.Sc. (Mathematics) Programme. The procedure to determine the final course marks is also presented in the Programme Specifications document.

The evaluation questions are set to measure the attainment of the COs. In either component (CE or SEE) or subcomponent of CE (SC1, SC2), COs are assessed as illustrated in the following Table.

	Focus of COs on each Component or Subcomponent of Evaluation		
	Component 1: CE (50% Weightage)		**Component 2: SEE (50% Weightage)**
Subcomponent ▶	**SC1**	**SC2**	
Subcomponent Type ▶	**Midterm Test**	**Assignment**	**50 Marks**
Maximum Marks ▶	**25**	**25**	
CO-1	X		X
CO-2	X		X
CO-3	X	X	X
CO-4	X	X	X
CO-5	X		X
	The details of SC1 and SC2 are presented in the Programme Specifications Document.		

The Course Leader assigned to the course, in consultation with the Head of the Department, shall provide the focus of COs in each component of assessment in the above template at the beginning of the semester.

Course reassessment policies are presented in the Academic Regulations document.

8. Achieving COs

The following skills are directly or indirectly imparted to the students in the following teaching and learning methods:

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S. No	Curriculum and Capabilities Skills	How imparted during the course
1.	Knowledge	Classroom lectures
2.	Understanding	Classroom lectures, Self-study
3.	Critical Skills	Assignment
4.	Analytical Skills	Assignment
5.	Problem Solving Skills	Assignment, Examination
6.	Practical Skills	Assignment
7.	Group Work	Group discussions, assignment
8.	Self-Learning	Self-study
9.	Written Communication Skills	Assignment, Examination
10.	Verbal Communication Skills	--
11.	Presentation Skills	--
12.	Behavioral Skills	--
13.	Information Management	Assignment
14.	Personal Management	--
15.	Leadership Skills	--

9. Course Resources

a. Essential Reading

1. Class Notes
2. Booth, W. C, Colomb and G.G Williams., (2005) The Craft of Research, Chicago University Press, USA
3. Willium M.K and Trochim. (2003)Research Methods, 2nd Edition, Biztantra Publicshres, New Delhi
4. Jonathan Grix. (2004) The Foundation of Research, Palgrave Macmillan; Study Guide edition, USA

b. Recommended Reading

1. Wisker Gina. (2001) The Post Graduate Research Handbook, , Palgrave Macmillan, USA.
2. Rugg G. and Petre M. (2004) The Unwritten Rules of Ph.D Research, Open University Press, UK

c. Other Electronic Resources

1. http://nptel.ac.in/

10. Course Organization

Course Code	MPF615A	
Course Title	Research Methodology	
Course Leader's Name	As per Timetable	
Course Leader's Contact Details	**Phone:**	+91-804-906-5555
	E-mail:	hod.cy.mp@msruas.ac.in
Course Specifications Approval Date	July 2022	
Next Course Specifications Review Date	July 2024	

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Course Specifications: Mechanics

Course Title	Mechanics
Course Code	MTE531A
Course Type	Core Elective Theory
Department	Mathematics and Statistics
Faculty	Mathematical and Physical Sciences

1. Course Summary

The purpose of this course is to make student gain thorough knowledge of solid and fluid mechanics and apply the same to real world problems. This course begins with the introduction to classical mechanics and tensors. Fundamental concepts of continuum mechanics as required by fluid dynamics are covered. This course builds a strong foundation of fluid dynamics starting with some basic theorems and conservation laws.

2. Course Size and Credits:

Number of Credits	04
Credit Structure (Lecture: Tutorial: Practical)	3:1:0
Total Hours of Interaction	60
Number of Weeks in a Semester	15
Department Responsible	Mathematics and Statistics
Total Course Marks	100
Pass Criterion	As per the Academic Regulations
Attendance Requirement	As per the Academic Regulations

3. Course Outcomes (COs)

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

- **CO-1.** Demonstrate the basic theory of classical mechanics.
- **CO-2.** Explain the concept of continuum hypothesis and usage of tensorial notions.
- **CO-3.** Illustrate the basic theorems and conservation laws of continuum mechanics.
- **CO-4.** Illustrate the concept of two dimensional flows an complex potential
- **CO-5.** Apply the governing equations to interpret the motions of continuum

4. Course Contents

Unit 1: **15 hrs**

Generalized coordinates, Lagrange's equations, Hamilton's canonical equations, Hamilton's principle and principle of least action. Two-dimensional motion of rigid bodies, Euler's dynamical equations for the motion of a rigid body about an axis. Small oscillations of a mechanical system, normal coordinates and normal modes, normal modes of double pendulum, free vibrations of Cabondioxide molecule

Unit 2: **15 hrs**

Coordinate transformations and Cartesian tensors. Continuum hypothesis. Deformation gradient and strain tensors. Stress tensor: principal, normal and shear stresses, Conservation laws: linear elasticity - Hooke's law, fluid mechanics - Navier-Stokes equation.

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Unit 3: **15 hrs**

Motion of inviscid fluids, Vortex motion, Helmholtz vorticity equation, Permanence of vorticity and circulation - Kelvin's minimum energy theorem, Two dimensional flows. Complex potential, line sources and sinks, line doublets and vortices, images, Milne-Thomson circle theorem, Blasius theorem. Conservation laws of fluid mechanics.

5. Course Map (CO-PO-PSO Map)

	Programme Outcomes (POs)								Programme Specific Outcomes (PSOs)		
	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PSO-1	PSO-2	PSO-3
CO-1	3	2							3	3	
CO-2	3	2							3	3	
CO-3	3	2		1				1	3	3	
CO-4	3	2	2	1	1			1	3	3	
CO-5	3	2	3	1	1			1	3	3	

6. Course Teaching and Learning Methods

Teaching and Learning Methods	Duration in hours	Total Duration in Hours
Face to Face Lectures		45
Demonstrations		00
1. Demonstration using Videos	00	
2. Demonstration using Physical Models / Systems	00	
3. Demonstration on a Computer	00	
Numeracy		15
1. Solving Numerical Problems	15	
Practical Work		00
1. Course Laboratory	00	
2. Computer Laboratory	00	
3. Engineering Workshop / Course/Workshop / Kitchen	00	
4. Clinical Laboratory	00	
5. Hospital	00	
6. Model Studio	00	
Others		00
1. Case Study Presentation	00	
2. Guest Lecture	00	
3. Industry / Field Visit	00	
4. Brain Storming Sessions	00	
5. Group Discussions	00	
6. Discussing Possible Innovations	00	
Term Tests, Laboratory Examination/Written Examination, Presentations		10
Total Duration in Hours		**70**

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7. Course Assessment and Reassessment

The details of the components and subcomponents of course assessment are presented in the Programme Specifications document pertaining to the M. Sc. (Mathematics) Programme. The procedure to determine the final course marks is also presented in the Programme Specifications document.

The evaluation questions are set to measure the attainment of the COs. In either component (CE or SEE) or subcomponent of CE (TSC1, TSC2, TSC3), COs are assessed as illustrated in the following Table.

Focus of COs on each Component or Subcomponent of Evaluation				
	Component 1: CE (50% Weightage)			Component 2: SEE (50% Weightage)
Subcomponent▶	TSC1	TSC2	TSC3	100 Marks
Subcomponent Type ▶	Term Test	Assignment	Innovative	
Maximum Marks▶	50	25	25	
CO-1	X		X	X
CO-2	X		X	X
CO-3	X		X	X
CO-4		X	X	X
CO-5		X	X	X
The details of TSC1, TSC2, TSC3 are presented in the Programme Specifications Document.				

The Course Leader assigned to the course, in consultation with the Head of the Department, shall provide the focus of COs in each component of assessment in the above template at the beginning of the semester.

Course reassessment policies are presented in the Academic Regulations document.

8. Achieving COs

The following skills are directly or indirectly imparted to the students in the following teaching and learning methods:

S. No	Curriculum and Capabilities Skills	How imparted during the course
1.	Knowledge	Classroom lectures, tutorials, Assignments
2.	Understanding	Classroom lectures, tutorials, Assignments
3.	Critical Skills	Classroom lectures, Assignment
4.	Analytical Skills	Assignment
5.	Problem Solving Skills	Assignment, Examination
6.	Practical Skills	--
7.	Group Work	Assignment
8.	Self-Learning	Self-study, Assignment
9.	Written Communication Skills	Assignment, Examination
10.	Verbal Communication Skills	--

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11.	Presentation Skills	--
12.	Behavioral Skills	Course work
13.	Information Management	Assignment, Examination
14.	Personal Management	Course work
15.	Leadership Skills	--

9. Course Resources

a. Essential Reading

1. Class notes.
2. Goldstein, H., Poole, C. and Safko, J., 2000, Classical Mechanics, 3rd Ed., Addison Wesley.
3. Synge, J.L. and Griffith, B. A., 1949, Principles of Mechanics, McGraw Hill Book Company.
4. Chandrasekharaiah, D.S. and Debnath, L., 1994, Continuum Mechanics, Academic Press.

b. Recommended Reading

1. Landau, L.D. and Lifshitz, E.M., 1966, Fluid Mechanics, Pergamon Press, Oxford.
2. Spiegel, M.R., 1967, Theoretical Mechanics, Schaum's Outline Series, McGraw Hill Book Company.
3. Spencer, A.J.M., 1980, Continuum Mechanics, Longman.

c. Magazines and Journals

1. Journal of Mechanics
   http://journals.cambridge.org/action/displayJournal?jid=JOM

d. Websites

1. http://ocw.mit.edu/courses/mechanical-engineering/2-25-advanced-fluid-mechanics-fall-2005/

e. Other Electronic Resources

1. https://archive.org/details/FluidMechanics

10. Course Organization

Course Code	MTE531A	
Course Title	Mechanics	
Course Leader's Name	As per Timetable	
Course Leader's Contact Details	**Phone:**	+91-804-906-5555
	E-mail:	hod.mt.mp@msruas.ac.in
Course Specifications Approval Date	July 2022	
Next Course Specifications Review Date	June 2024	

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Course Specifications: Machine Learning – 1

Course Title	Machine Learning – 1
Course Code	MTE631A
Course Type	Core Elective Theory
Department	Mathematics and Statistics
Faculty	Mathematical and Physical Sciences

1. Course Summary

The aim of this course is to introduce students the concepts of regression, supervised llearning and unsupervised learning. This course also discusses basic concepts of artificial neural networks and support vector machines.

2. Course Size and Credits:

Number of Credits	04
Credit Structure (Lecture: Tutorial: Practical)	3:1:0
Total Hours of Interaction	45
Number of Weeks in a Semester	15
Department Responsible	Mathematics and Statistics
Total Course Marks	100
Pass Criterion	As per the Academic Regulations
Attendance Requirement	As per the Academic Regulations

3. Course Outcomes (COs)

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

CO-1. Describe the concepts of linear, logistic regression and support vector machines
CO-2. Describe the concepts of artificial neural networks, tree models and unsupervised learning
CO-3. Solve simple problems using machine learning algorithms
CO-4. Analyse the performance of machine learning algorithms
CO-5. Solve complex real world problems using machine learning algorithms

4. Course Contents

Unit 1 (Regression): **15 hrs**

Introduction to machine learning: Supervised and unsupervised learning. Linear Regression: Introduction to simple linear regression and gradient descent algorithm. Linear regression with multiple variables and gradient descent for multiple variables. Ridge and Lasso regularization. Logistic Regression: Classification, decision boundary and advanced optimization. Multiclass Classification: One-vs-all. Regularized Logistic Regression.

Unit 2 (Supervised Learning): **15 hrs**

Artificial Neural Networks: Single layer perceptron and multi-layer perceptron. Backpropagation and gradient descent. Support Vector Machines: Introduction to SVM. Introduction to kernels. Tree Models: Decision Trees and Random Forest algorithms.

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Unit 3 (Unsupervised Learning): **15 hrs**

Introduction to clustering and K-means algorithm. Dimensionality Reduction using PCA.

5. Course Map (CO-PO-PSO Map)

	Programme Outcomes (POs)								Programme Specific Outcomes (PSOs)		
	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PSO-1	PSO-2	PSO-3
CO-1	3	2							3		
CO-2	3	2							3		
CO-3	3	2	3						3		
CO-4	3	2		3	1	1	1	1	3	1	1
CO-5	3	2	3	3	1	1	1	1	3	1	1

6. Course Teaching and Learning Methods

Teaching and Learning Methods	Duration in hours	Total Duration in Hours
Face to Face Lectures		45
Demonstrations		00
1. Demonstration using Videos	00	
2. Demonstration using Physical Models / Systems	00	
3. Demonstration on a Computer	00	
Numeracy		15
1. Solving Numerical Problems	15	
Practical Work		00
1. Course Laboratory	00	
2. Computer Laboratory	00	
3. Engineering Workshop / Course/Workshop / Kitchen	00	
4. Clinical Laboratory	00	
5. Hospital	00	
6. Model Studio	00	
Others		00
1. Case Study Presentation	00	
2. Guest Lecture	00	
3. Industry / Field Visit	00	
4. Brain Storming Sessions	00	
5. Group Discussions	00	
6. Discussing Possible Innovations	00	
Term Tests, Laboratory Examination/Written Examination, Presentations		10
Total Duration in Hours		**70**

7. Course Assessment and Reassessment

The details of the components and subcomponents of course assessment are presented in the Programme Specifications document pertaining to the M. Sc. (Mathematics) Programme. The procedure to determine the final course marks is also presented in the Programme Specifications document.

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The evaluation questions are set to measure the attainment of the COs. In either component (CE or SEE) or subcomponent of CE (TSC1, TSC2, TSC3), COs are assessed as illustrated in the following Table.

Focus of COs on each Component or Subcomponent of Evaluation				
	Component 1: CE (50% Weightage)			Component 2: SEE (50% Weightage)
Subcomponent▶	TSC1	TSC2	TSC3	100 Marks
Subcomponent Type ▶	Term Test	Assignment	Innovative	
Maximum Marks▶	50	25	25	
CO-1	X		X	X
CO-2	X		X	X
CO-3	X		X	X
CO-4		X	X	X
CO-5		X	X	X
The details of TSC1, TSC2, TSC3 are presented in the Programme Specifications Document.				

The Course Leader assigned to the course, in consultation with the Head of the Department, shall provide the focus of COs in each component of assessment in the above template at the beginning of the semester.
Course reassessment policies are presented in the Academic Regulations document.

8. Achieving COs

The following skills are directly or indirectly imparted to the students in the following teaching and learning methods:

S. No	Curriculum and Capabilities Skills	How imparted during the course
1.	Knowledge	Classroom lectures, tutorials, Assignments
2.	Understanding	Classroom lectures, tutorials, Assignments
3.	Critical Skills	Classroom lectures, Assignment
4.	Analytical Skills	Assignment
5.	Problem Solving Skills	Assignment, Examination
6.	Practical Skills	--
7.	Group Work	Assignment
8.	Self-Learning	Self-study, Assignment
9.	Written Communication Skills	Assignment, Examination
10.	Verbal Communication Skills	--
11.	Presentation Skills	--
12.	Behavioral Skills	Course work
13.	Information Management	Assignment, Examination
14.	Personal Management	Course work
15.	Leadership Skills	--

9. Course Resources

a. Essential Reading

1. Class notes.

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2. Murphy, K.P., 2012, Machine Learning: A Probabilistic Perspective. The MIT Press.
3. Zurada, J., 1992, Introduction to Artificial Neural Systems. St. Paul, MN, USA. West Publishing Co.

b. Recommended Reading

1. Bishop, C.M., 2007, Pattern Recognition and Machine Learning, Springer.
2. Berg, B.A., 2004, Markov Chain Monte Carlo Simulations and their Statistical Analysis, World Scientific.
3. Haykin, S., 1998, Neural Networks: A Comprehensive Foundation, PTR, Upper Saddle River, NJ, USA, Prentice Hall.

c. Magazines and Journals

d. Websites

1. http://ocw.mit.edu/
2. www.coursera.org/

e. Other Electronic Resources

10. Course Organization

Course Code	MTE631A	
Course Title	Machine Learning - 1	
Course Leader's Name	As per Timetable	
Course Leader's Contact Details	**Phone:**	+91-804-906-5555
	E-mail:	hod.mt.mp@msruas.ac.in
Course Specifications Approval Date	July 2022	
Next Course Specifications Review Date	June 2024	

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Course Specifications: Functional Analysis

Course Title	Functional Analysis
Course Code	MTC541A
Course Type	Core Theory
Department	Mathematics and Statistics
Faculty	Mathematical and Physical Sciences

1. Course Summary

It aims at improving abstract and analytical thinking of students. This course begins with basic functional analysis concepts such as Banach Spaces, Hilbert spaces, are introduced and some applications to linear algebra are discussed. It also lays a foundation to operator theory and their spectral analysis. Finally the course covers the theoretical concepts of the Fourier transform.

2. Course Size and Credits:

Number of Credits	04
Credit Structure (Lecture: Tutorial: Practical)	3:1:0
Total Hours of Interaction	60
Number of Weeks in a Semester	15
Department Responsible	Mathematics and Statistics
Total Course Marks	100
Pass Criterion	As per the Academic Regulations
Attendance Requirement	As per the Academic Regulations

3. Course Outcomes (COs)

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

- **CO-1.** Illustrate the principles of functional analysis
- **CO-2.** Elucidate the fundamental concept of Banach spaces and their applications
- **CO-3.** Demonstrate the principle concept of Hilbert spaces and their applications
- **CO-4.** Analyze the spectrum of linear and the compact operators in Hilbert space
- **CO-5.** Apply the concept of Fourier transform
- **CO-6.** Demonstrate a reasoned argument to the solution of familiar and unfamiliar complex problems relevant to functional analysis solution to solve ordinary and partial differential equations

4. Course Contents

Unit 1: Banach Space **10 Hrs**

Banach Space: Normed linear spaces and convexity; convergence, completeness, and Banach spaces; continuity, open sets, and closed sets; continuous linear transformations; Hahn-Banach Extension Theorem; linear functionally, dual and reflexive spaces, and weak convergence; the Baire Theorem and uniform boundedness; Open Mapping and Closed Graph Theorems.

Unit 2: Hilbert Space **10 Hrs**

Inner product spaces - Bessel's inequality and Schwarz inequality, Parseval's Theorem, the Riesz

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Representation Theorem, Orthogonality, Orthonormal sets, orthogonal sets and Gram-Schmidt orthogonalization process.

Unit 3: Bounded Operators **15 Hrs**

Topologies on bounded operators, Adjoints of bounded operators. Projections and orthogonal projections in Hilbert spaces. Linear Operators and spectral theory of linear operators. Polar decomposition of positive operators. Compact operators, finite rank operators and analytic Fredholm theorem and the Fredholm alternative. Canonical forms for compact operators and application of compact operators to Dirichlet.

Unit 4: Fourier Transform **10 Hrs**

Distributions and Fourier transforms. Test functions and distributions. The Fourier transform and convolution. The range of Fourier transform, the Plancherel theorem and Riemann-Lebesgue Lemma. Analyticity of Fourier transform and Paley-Wiener theorem.

5. Course Map (CO-PO-PSO Map)

	Programme Outcomes (POs)								Programme Specific Outcomes (PSOs)		
	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PSO-1	PSO-2	PSO-3
CO-1	3	2							2	3	
CO-2	3	2						1	2	3	
CO-3	3	2				1	1	1		3	1
CO-4	3	2			1	1	1	1		3	1
CO-5	3	2			1	1	1	1		3	1
CO-6	3	2			1		1	1		3	1

6. Course Teaching and Learning Methods

Teaching and Learning Methods	Duration in hours	Total Duration in Hours
Face to Face Lectures		45
Demonstrations		00
1. Demonstration using Videos	00	
2. Demonstration using Physical Models / Systems	00	
3. Demonstration on a Computer	00	
Numeracy		15
1. Solving Numerical Problems	15	
Practical Work		00
1. Course Laboratory	00	
2. Computer Laboratory	00	
3. Engineering Workshop / Course/Workshop / Kitchen	00	
4. Clinical Laboratory	00	
5. Hospital	00	
6. Model Studio	00	
Others		00
1. Case Study Presentation	00	
2. Guest Lecture	00	
3. Industry / Field Visit	00	
4. Brain Storming Sessions	00	

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5. Group Discussions	00	
6. Discussing Possible Innovations	00	
Term Tests, Laboratory Examination/Written Examination, Presentations		
Total Duration in Hours		**60**

7. Course Assessment and Reassessment

The details of the components and subcomponents of course assessment are presented in the Programme Specifications document pertaining to the M. Sc. (Mathematics) Programme. The procedure to determine the final course marks is also presented in the Programme Specifications document.

The evaluation questions are set to measure the attainment of the COs. In either component (CE or SEE) or subcomponent of CE (TSC1, TSC2, TSC3), COs are assessed as illustrated in the following Table.

Focus of COs on each Component or Subcomponent of Evaluation				
	Component 1: CE (50% Weightage)			**Component 2: SEE (50% Weightage)**
Subcomponent▶	**TSC1**	**TSC2**	**TSC3**	**100 Marks**
Subcomponent Type ▶	**Term Test**	**Assignment**	**Innovative**	
Maximum Marks▶	**50**	**25**	**25**	
CO-1	X		X	X
CO-2	X		X	X
CO-3	X		X	X
CO-4		X	X	X
CO-5		X	X	X
The details of TSC1, TSC2, TSC3 are presented in the Programme Specifications Document.				

The Course Leader assigned to the course, in consultation with the Head of the Department, shall provide the focus of COs in each component of assessment in the above template at the beginning of the semester.
Course reassessment policies are presented in the Academic Regulations document.

8. Achieving COs

The following skills are directly or indirectly imparted to the students in the following teaching and learning methods:

S. No	Curriculum and Capabilities Skills	How imparted during the course
1.	Knowledge	Classroom lectures, tutorials, Assignments
2.	Understanding	Classroom lectures, tutorials, Assignments
3.	Critical Skills	Classroom lectures, Assignment
4.	Analytical Skills	Assignment
5.	Problem Solving Skills	Assignment, Examination
6.	Practical Skills	--
7.	Group Work	Assignment
8.	Self-Learning	Self-study, Assignment
9.	Written Communication Skills	Assignment, Examination
10.	Verbal Communication Skills	--

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11.	Presentation Skills	--
12.	Behavioral Skills	Course work
13.	Information Management	Assignment, Examination
14.	Personal Management	Course work
15.	Leadership Skills	--

9. Course Resources

a. Essential Reading

1. Course notes.
2. Reed, M. and Simon, B., 1980, Methods of Modern Mathematical Physics I: Functional Analysis, 1st Ed., Academic Press.
3. Rudin, W., 2015, Real and complex analysis, McGraw Hill Education.
4. Kreyszig, E., 1989, Introductory Functional Analysis with Applications, 1st Ed., Wiley.
5. Simmons, G.F., 2017, Introduction to Topology and Modern Analysis, McGraw Hill Education.

b. Recommended Reading

1. Jain, P.K., Ahuja, O.P. and Ahmed, K., 1995, Functional Analysis, New Age International Ltd.
2. Halmos, P.R., 1976, Measure theory, 1st Ed., Springer.

c. Magazines and Journals

1. https://www.sciencedirect.com/journal/journal-of-functional-analysis
2. **https://www.springer.com/journal/43034**

d. Websites

1. http://www.journals.elsevier.com/journal-of-functional-analysis/
2. http://www.springer.com/mathematics/analysis/journal/10688
3. http://www.emis.de/journals/AFA/

e. Other Electronic Resources

1. https://www.math.ucdavis.edu/~hunter/measure_theory/measure_theory.html

10. Course Organization

Course Code	MTC541A	
Course Title	Functional Analysis	
Course Leader's Name	As per Timetable	
Course Leader's Contact Details	**Phone:**	+91-804-906-5555
	E-mail:	hod.mt.mp@msruas.ac.in
Course Specifications Approval Date	July 2022	
Next Course Specifications Review Date	July 2024	

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Course Specifications: Fluid Mechanics

Course Title	Fluid Mechanics
Course Code	MTE541A
Course Type	Core Elective Theory
Department	Mathematics and Statistics
Faculty	Mathematical and Physical Sciences

1. Course Summary

The main purpose of this course is to make student gain thorough knowledge of fluid mechanics and apply the same to real world problems. This course begins with the introduction to classical mechanics. Fundamental concepts of continuum mechanics as required by fluid dynamics are covered. The course builds a strong foundation of fluid dynamics starting with some basic theorems and conservation laws. It details about some of the exact analytical solutions of Navier-Stokes' equation concerning viscous flows. Further, this course culminates the ideas of boundary layer theory and instability problems.

2. Course Size and Credits:

Number of Credits	04
Credit Structure (Lecture: Tutorial: Practical)	3:1:0
Total Hours of Interaction	45
Number of Weeks in a Semester	15
Department Responsible	Mathematics and Statistics
Total Course Marks	100
Pass Criterion	As per the Academic Regulations
Attendance Requirement	As per the Academic Regulations

3. Course Outcomes (COs)

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

CO-1. Illustrate the principles of classical and fluid mechanics
CO-2. State and prove important theorems in mechanics such as Lagrange's and Hamilton's theorems, conservation laws, Kelvin's circulation theorem, Circle theorem, Blasius theorem
CO-3. Analyze simple motions of solids and multi-body system, small oscillations, motions of inviscid fluids and two dimensional viscous flows
CO-4. Analyze boundary layers encountered in flow past flat plate and perform stability analysis of various fluid flows
CO-5. Solve complex dynamical problems encountered in fluid mechanics

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4. Course Contents

Unit 1 (Fundamental Basic Physical Laws): **5 Hrs**
Law of conservation of mass - Principles of linear and angular momenta - Balance of energy – Examples.

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Unit 2 (Motion of Non-Viscous Fluids): **10 Hrs**

Stress tensor- Euler equation -Bernoulli's equation- simple consequences -Helmholtz vorticity equation - Permanence of vorticity and circulation - Dimensional analysis - Non dimensional numbers.

Unit 3 (Motion of Viscous Fluids): **15 Hrs**

Stress tensor - Navier-Stokes equation - Energy equation –Simple exact solutions of Navier-Stokes equation: Plane Poiseuille and Hagen-Poiseuille flows, Generalized plane Couette flow. Steady flow between two rotating concentric circular cylinders. Stokes's first and second problems. Diffusion of vorticity - Energy dissipation due to viscosity.

Unit 4 (Boundary Layer Theory): **15 Hrs**

Boundary layer theory, Dimensional analysis – Non dimensional numbers, Blasius solution, Karman's integral equation, Boundary layer separation, Stability of flows: Rayleigh-Bénard instability, Taylor instability, Double diffusive instability, brief discussion about Kelvin-Helmholtz instability and instability of continuously stratified parallel flows.

5. Course Map (CO-PO-PSO Map)

	Programme Outcomes (POs)								Programme Specific Outcomes (PSOs)		
	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PSO-1	PSO-2	PSO-3
CO-1	3	2							3	2	
CO-2	3	2							3	2	
CO-3	3	2	1						3	2	
CO-4	3	2	2	1	1			1	3	2	1
CO-5	3	2	2	1	1			1	3	2	1

6. Course Teaching and Learning Methods

Teaching and Learning Methods	Duration in hours	Total Duration in Hours
Face to Face Lectures		45
Demonstrations		00
1. Demonstration using Videos	00	
2. Demonstration using Physical Models / Systems	00	
3. Demonstration on a Computer	00	
Numeracy		15
1. Solving Numerical Problems	15	
Practical Work		00
1. Course Laboratory	00	
2. Computer Laboratory	00	
3. Engineering Workshop / Course/Workshop / Kitchen	00	
4. Clinical Laboratory	00	
5. Hospital	00	
6. Model Studio	00	
Others		00

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1. Case Study Presentation	00	
2. Guest Lecture	00	
3. Industry / Field Visit	00	
4. Brain Storming Sessions	00	
5. Group Discussions	00	
6. Discussing Possible Innovations	00	
Term Tests, Laboratory Examination/Written Examination, Presentations		10
Total Duration in Hours		**70**

7. Course Assessment and Reassessment

The details of the components and subcomponents of course assessment are presented in the Programme Specifications document pertaining to the M. Sc. (Mathematics) Programme. The procedure to determine the final course marks is also presented in the Programme Specifications document.

The evaluation questions are set to measure the attainment of the COs. In either component (CE or SEE) or subcomponent of CE (TSC1, TSC2, TSC3), COs are assessed as illustrated in the following Table.

Focus of COs on each Component or Subcomponent of Evaluation				
	Component 1: CE (50% Weightage)			**Component 2: SEE (50% Weightage)**
Subcomponent▶	**TSC1**	**TSC2**	**TSC3**	**100 Marks**
Subcomponent Type ▶	**Term Test**	**Assignment**	**Innovative**	
Maximum Marks▶	**50**	**25**	**25**	
CO-1	X		X	X
CO-2	X		X	X
CO-3	X		X	X
CO-4		X	X	X
CO-5		X	X	X
The details of TSC1, TSC2, TSC3 are presented in the Programme Specifications Document.				

The Course Leader assigned to the course, in consultation with the Head of the Department, shall provide the focus of COs in each component of assessment in the above template at the beginning of the semester.

Course reassessment policies are presented in the Academic Regulations document.

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8. Achieving COs

The following skills are directly or indirectly imparted to the students in the following teaching and learning methods:

S. No	Curriculum and Capabilities Skills	How imparted during the course
1.	Knowledge	Classroom lectures, tutorials, Assignments
2.	Understanding	Classroom lectures, tutorials, Assignments

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3.	Critical Skills	Classroom lectures, Assignment
4.	Analytical Skills	Assignment
5.	Problem Solving Skills	Assignment, Examination
6.	Practical Skills	--
7.	Group Work	Assignment
8.	Self-Learning	Self-study, Assignment
9.	Written Communication Skills	Assignment, Examination
10.	Verbal Communication Skills	--
11.	Presentation Skills	--
12.	Behavioral Skills	Course work
13.	Information Management	Assignment, Examination
14.	Personal Management	Course work
15.	Leadership Skills	--

9. Course Resources

a. Essential Reading

1. Course notes.
2. Goldstein, H., Poole, C. and Safko, J., 2000, Classical Mechanics, 3rd Ed., Addison Wesley.
3. Synge, J.L. and Griffith, B.A., 1949, Principles of Mechanics, McGraw Hill Book Company.
4. Chorlton, F., 1967, Text book of Fluid Dynamics, Van Nostrand.
5. Yuan, S.W., 1976, Foundations of Fluid Mechanics, Prentice Hall.

b. Recommended Reading

1. Landau, L.D. and Lifshitz, E.M., 1966, Fluid Mechanics, Pergamon Press, Oxford.
2. Spiegel, M.R., 1967, Theoretical Mechanics, Schaum's Outline Series, McGraw Hill Book Company.
3. Spencer, A. J. M., 1980, Continuum Mechanics, Longman.
4. Kundu, P.K. and Cohen, I.M., 2008, Fluid Mechanics, Academic Press.

c. Magazines and Journals

1. Journal of Mechanics
   http://journals.cambridge.org/action/displayJournal?jid=JOM

d. Websites

1. http://ocw.mit.edu/courses/mechanical-engineering/2-25-advanced-fluid-mechanics-fall-2005/

e. Other Electronic Resources

1. https://archive.org/details/FluidMechanics

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10. Course Organization

Course Code	MTE541A	
Course Title	Fluid Mechanics	
Course Leader's Name	As per Timetable	
Course Leader's Contact Details	**Phone:**	+91-804-906-5555
	E-mail:	hod.mt.mp@msruas.ac.in
Course Specifications Approval Date	July 2022	

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Course Specification: Magnetohydrodynamics

Course Title	Magnetohydrodynamics
Course Code	MTE542A
Course Code	Core Elective Theory
Department	Mathematics and Statistics
Faculty	Mathematical and Physical Sciences

1. Course Summary

It aims at understanding the effect of magnetic field on electrically conducting fluids. This course begins with the introduction of MHD and basic laws of MHD. It also includes the important theorems of classical MHD and various instabilities involved. Finally the course ends with various flow problems of MHD.

2. Course Size and Credits:

Number of Credits	04
Credit Structure (Lecture: Tutorial: Practical)	3:1:0
Total Hours of Interaction	45
Number of Weeks in a Semester	15
Department Responsible	Mathematics and Statistics
Total Course Marks	100
Pass Criterion	As per the Academic Regulations
Attendance Requirement	As per the Academic Regulations

3. Course Outcomes (COs)

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

- **CO 1.** Explain the elementary concepts and basic equations of electrodynamics
- **CO 2.** State and prove important theorems of electrodynamics and magnetohydrodynamics
- **CO 3.** Analyzation of the flow problems in magnetohydrodynamics
- **CO 4.** Solve simple applications of magnetohydrodynamics and Alfven waves
- **CO 5.** Solve real world applications encountered in magnetohydrodynamics

4. Course Contents

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Unit 1 (Electrodynamics): **8 hrs**

Electrostatics and electromagnetic units – derivation of Gauss law Faraday's law- Ampere's law and solenoidal property-conservation of charges-electromagnetic boundary conditions. Dielectric materials- Basic Equations: Derivation of basic equations of MHD - MHD approximations – Non dimensional numbers – Boundary conditions on velocity, temperature and Magnetic field.

Unit 2 (Classical MHD): **7 hrs**

Alfven's theorem - Frozen - in - phenomenon - illustrative examples - Kelvin's circulation theorem - Bernoulli's equations - Analogue of Helmholtz vorticity equation -Ferraro's law of isorotation.

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Unit 3 (Magneto Statics): **7 hrs**

Force free magnetic field and important results thereon-illustrative examples on abnormality parameter -Chandrasekhar's theorem -Bennett pinch and instabilities associated with it.

Unit 5 (Alfven Waves): **8 hrs**

Lorentz force as a sum of two surface forces- cause for Alfven waves-applications.

Unit 6 (Flow Problems): **10 hrs**

Hartmann flow- Hartmann–Couette flow- Temperature distribution for these flows. Alfven wave equations in incompressible fluids-equipartition of energy - experiments on Alfven waves-dispersion relations - Alfven waves in compressible fluids- slow and fast waves Hodographs.

5. Course Map (CO-PO-PSO Map)

	Programme Specific Outcomes (PSOs)										
	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PSO-1	PSO-2	PSO-3
CO-1	3	1							3		
CO-2	3	1							3		
CO-3	3	1	3		3	1	1	3	3	2	1
CO-4	3	1	3		2	1	1	2	3	2	1
CO-5	3	1	3		3	1	1	3	3	3	1

6. Course Teaching and Learning Methods

Teaching and Learning Methods	Duration in hours	Total Duration in Hours
Face to Face Lectures		45
Demonstrations		0
1. Demonstration using Videos	00	
2. Demonstration using Physical Models / Systems	00	
3. Demonstration on a Computer	00	
Numeracy		15
1. Solving Numerical Problems	15	
Practical Work		00
1. Course Laboratory	00	
2. Computer Laboratory	00	
3. Engineering Workshop / Course/Workshop / Kitchen	00	
4. Clinical Laboratory	00	
5. Hospital	00	
6. Model Studio	00	
Others		00
1. Case Study Presentation	00	
2. Guest Lecture	00	
3. Industry / Field Visit	00	
4. Brain Storming Sessions	00	
5. Group Discussions	02	
6. Discussing Possible Innovations	00	
Term Tests, Laboratory Examination/Written Examination, Presentations		10
Total Duration in Hours		**70**

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7. Course Assessment and Reassessment

The details of the components and subcomponents of course assessment are presented in the Programme Specifications document pertaining to the M. Sc. (Mathematics) Programme. The procedure to determine the final course marks is also presented in the Programme Specifications document.

The evaluation questions are set to measure the attainment of the COs. In either component (CE or SEE) or subcomponent of CE (TSC1, TSC2, TSC3), COs are assessed as illustrated in the following Table.

Focus of COs on each Component or Subcomponent of Evaluation				
	Component 1: CE (50% Weightage)			Component 2: SEE (50% Weightage)
Subcomponent▶	TSC1	TSC2	TSC3	100 Marks
Subcomponent Type ▶	Term Test	Assignment	Innovative	
Maximum Marks▶	50	25	25	
CO-1	X		X	X
CO-2	X		X	X
CO-3	X		X	X
CO-4		X	X	X
CO-5		X	X	X
The details of TSC1, TSC2, TSC3 are presented in the Programme Specifications Document.				

The Course Leader assigned to the course, in consultation with the Head of the Department, shall provide the focus of COs in each component of assessment in the above template at the beginning of the semester.

Course reassessment policies are presented in the Academic Regulations document.

8. Achieving COs

The following skills are directly or indirectly imparted to the students in the following teaching and learning methods:

S. No	Curriculum and Capabilities Skills	How imparted during the course
1.	Knowledge	Classroom lectures
2.	Understanding	Classroom lectures, Self-study
3.	Critical Skills	Assignment, Solving Numerical Problems
4.	Analytical Skills	Assignment, Solving Numerical Problems
5.	Problem Solving Skills	Assignment, Examination, Solving Numerical Problems
6.	Practical Skills	Assignment
7.	Group Work	--
8.	Self-Learning	Self-study
9.	Written Communication Skills	Assignment, Examination
10.	Verbal Communication Skills	--
11.	Presentation Skills	--
12.	Behavioral Skills	--
13.	Information Management	Assignment

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14.	Personal Management	--
15.	Leadership Skills	--

9. Course Resources

a. Essential Reading

1. Class notes
2. Davidson, P.A., 2001, An introduction to MHD, Cambridge University Press.
3. Moreau, R.J., 1990, Magnetohydrodynamics, Springer Science and Business Media.
4. Hosking, R.J., and Dewar, R.L., 2015, Fundamental Fluid mechanics and MHD, Springer.

b. Recommended Reading

1. Chandrasekhar, S., 1961, Hydrodynamic and Hydromagnetic Stability, Dover Publications
2. Goedbloed, J.P. and Poedts, S., 2004, Principles of Magnetohydrodynamics, Applications to Laboratory and Astrophysical Plasmas, Springer.

c. Magazines and Journals

Journal of Megnetohydrodynamics http://mhd.sal.lv/

d. Websites

1. https://www.plasma-universe.com/magnetohydrodynamics/
2. https://woodruffscientific.com/mhd

e. Other Electronic Resources

1. https://www.accessscience.com/content/magnetohydrodynamics/399500

10. Course Organization

Course Code	MTE542A	
Course Title	Magnetohydrodynamics	
Course Leader/s Name	As per timetable	
Course Leader Contact Details	**Phone:**	080 4906 5555
	E-mail:	hod.mt.mp@msruas.ac.in
Course Specifications Approval Date	July 2022	
Next Course Specifications Review Date:	July 2024	

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Course Specifications: Machine Learning – 2

Course Title	Machine Learning – 2
Course Code	MTE641A
Course Type	Core Elective Theory
Department	Mathematics and Statistics
Faculty	Mathematical and Physical Sciences

1. Course Summary

The aim of this course is to introduce the concepts of deep learning. In this core course the students are taught basic concepts of CNN and RNN. The course describes Natural Language Processing. Applications of CNN and RNN are also discussed.

2. Course Size and Credits:

Number of Credits	04
Credit Structure (Lecture: Tutorial: Practical)	3:1:0
Total Hours of Interaction	45
Number of Weeks in a Semester	15
Department Responsible	Mathematics and Statistics
Total Course Marks	100
Pass Criterion	As per the Academic Regulations
Attendance Requirement	As per the Academic Regulations

3. Course Outcomes (COs)

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

- **CO-1.** Describe the concepts of deep learning
- **CO-2.** Describe the concepts of natural language processing
- **CO-3.** Solve simple problems using deep learning algorithms
- **CO-4.** Analyse the performance of deep learning algorithms
- **CO-5.** Solve complex real-world problems using deep learning

4. Course Contents

Unit 1 (Deep Learning): **15 hrs**

Introduction, Deep L-layer neural network, Forward and Backward Propagation, Parameters vs Hyperparameters. Stochastic gradient descent algorithm and Hyperparameter tuning. Regularization.

Unit 2 (Convolutional Neural Networks): **10 hrs**

Introduction to CNN and its applications. Introduction to image processing. Convolutions, strides and padding. Features maps and pooling. Architecture of standard CNNs in practice. Transfer learning.

Unit 3 (Recurrent Neural Networks): **10 hrs**

Introduction to sequence models. Recurrent Neural Network Model and Backpropagation through time. Vanishing gradients with RNNs. Variants of RNN: LSTM and GRU.

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Unit 4 (Natural Language Processing): **10 hrs**

Introduction to NLP and its applications. Lexical processing, Syntactic processing and Semantic processing.

5. Course Map (CO-PO-PSO Map)

	Programme Outcomes (POs)								Programme Specific Outcomes (PSOs)		
	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PSO-1	PSO-2	PSO-3
CO-1	3	2							3		
CO-2	3	2							3		
CO-3	3	2	3						3		
CO-4	3	2		3	1	1	1	1	3	1	1
CO-5	3	2	3	3	1	1	1	1	3	1	1

6. Course Teaching and Learning Methods

Teaching and Learning Methods	Duration in hours	Total Duration in Hours
Face to Face Lectures		45
Demonstrations		00
1. Demonstration using Videos	00	
2. Demonstration using Physical Models / Systems	00	
3. Demonstration on a Computer	00	
Numeracy		15
1. Solving Numerical Problems	15	
Practical Work		00
1. Course Laboratory	00	
2. Computer Laboratory	00	
3. Engineering Workshop / Course/Workshop / Kitchen	00	
4. Clinical Laboratory	00	
5. Hospital	00	
6. Model Studio	00	
Others		00
1. Case Study Presentation	00	
2. Guest Lecture	00	
3. Industry / Field Visit	00	
4. Brain Storming Sessions	00	
5. Group Discussions	00	
6. Discussing Possible Innovations	00	
Term Tests, Laboratory Examination/Written Examination, Presentations		10
Total Duration in Hours		**70**

7. Course Assessment and Reassessment

The details of the components and subcomponents of course assessment are presented in the

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Programme Specifications document pertaining to the M. Sc. (Mathematics) Programme. The procedure to determine the final course marks is also presented in the Programme Specifications document.

The evaluation questions are set to measure the attainment of the COs. In either component (CE or SEE) or subcomponent of CE (TSC1, TSC2, TSC3), COs are assessed as illustrated in the following Table.

Focus of COs on each Component or Subcomponent of Evaluation				
	Component 1: CE (50% Weightage)			Component 2: SEE (50% Weightage)
Subcomponent▶	TSC1	TSC2	TSC3	100 Marks
Subcomponent Type ▶	Term Test	Assignment	Innovative	
Maximum Marks▶	50	25	25	
CO-1	X		X	X
CO-2	X		X	X
CO-3	X		X	X
CO-4		X	X	X
CO-5		X	X	X
The details of TSC1, TSC2, TSC3 are presented in the Programme Specifications Document.				

The Course Leader assigned to the course, in consultation with the Head of the Department, shall provide the focus of COs in each component of assessment in the above template at the beginning of the semester.
Course reassessment policies are presented in the Academic Regulations document.

8. Achieving COs

The following skills are directly or indirectly imparted to the students in the following teaching and learning methods:

S. No	Curriculum and Capabilities Skills	How imparted during the course
1.	Knowledge	Classroom lectures, tutorials, Assignments
2.	Understanding	Classroom lectures, tutorials, Assignments
3.	Critical Skills	Classroom lectures, Assignment
4.	Analytical Skills	Assignment
5.	Problem Solving Skills	Assignment, Examination
6.	Practical Skills	--
7.	Group Work	Assignment
8.	Self-Learning	Self-study, Assignment
9.	Written Communication Skills	Assignment, Examination
10.	Verbal Communication Skills	--
11.	Presentation Skills	--
12.	Behavioral Skills	Course work
13.	Information Management	Assignment, Examination
14.	Personal Management	Course work
15.	Leadership Skills	--

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9. Course Resources

a. Essential Reading

1. Course notes
2. Deng, L. and Yu, D., 2014, Deep Learning: Methods and Applications. Foundations and Trends in Signal Process. 7(3, 4).
3. Zurada, J., 1992, Introduction to Artificial Neural Systems. St. Paul, MN, USA. West Publishing Co.

b. Recommended Reading

1. Haykin, S., 1998, Neural Networks: A Comprehensive Foundation. PTR, Upper Saddle River, NJ, USA, Prentice Hall.
2. Hagan M.T., Demuth H. B., and Beale M., 1997, Neural Network Design. Boston, MA, USA. PWS Pub. Co.

c. Magazines and Journals

1. IEEE Transactions on Neural Networks and Learning Systems
2. Microtome Journal of Machine Learning Research

d. Websites

3. www.coursera.org

e. Other Electronic Resources

10. Course Organization

Course Code	MTE641A	
Course Title	Machine Learning – 2	
Course Leader's Name	As per Timetable	
Course Leader's Contact Details	**Phone:**	+91-804-906-5555
	E-mail:	hod.mt.mp@msruas.ac.in
Course Specifications Approval Date	July 2022	
Next Course Specifications Review Date	July 2024	

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Course Specifications: Probability and Stochastic Processes

Course Title	Probability and Stochastic Processes
Course Code	MTE642A
Course Type	Core Elective Theory
Department	Mathematics and Statistics
Faculty	Mathematical and Physical Sciences

1. Course Summary

The aim of the course is to introduce the advanced concepts of probability theory and stochastic processes. In this elective course the students are taught the measure theoretic concepts of probability theory. The course describes various stochastic processes and their applications.

2. Course Size and Credits:

Number of Credits	04
Credit Structure (Lecture: Tutorial: Practical)	3:1:0
Total Hours of Interaction	45
Number of Weeks in a Semester	15
Department Responsible	Mathematics and Statistics
Total Course Marks	100
Pass Criterion	As per the Academic Regulations
Attendance Requirement	As per the Academic Regulations

3. Course Outcomes (COs)

After the successful completion of this course, the studentwill be able to:

- **CO-1.** Describe the concepts of probability theory
- **CO-2.** Describe the concepts of stochastic processes
- **CO-3.** Solve simple problems using probability theory and stochastic processes
- **CO-4.** State and prove theorems related to probability theory and stochastic processes
- **CO-5.** Solve complex real-world problems using probability theory and stochastic processes

4. Course Contents

Unit 1 (Introductory Probability): **5 hrs**
Defining Random Variables (RVs), Events, Measurability, Independence, Conditional probability, Bayes' theorem.

Unit 2 (Random Variables): **10 hrs**
Random variables of Bernoulli, Binomial, Geometric, Poisson; Uniform, Exponential, Normal, Lognormal distributions. Expectations, Moments and Moment generating functions.

Unit 3 (Convergence of RVs): **5 hrs**
Weak and Strong laws, Central limit theorem, Distributions of extreme.

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Unit 4 (Random Vectors): **5 hrs**
Joint and Marginal distributions, Dependence, Covariance, Copulas. Transformations of random vectors, Order statistics.

Unit 5 (Intermediate Probability): **5 hrs**
Manipulating RVs, Conditioning RVs, Conditional Distribution of a RV, Computing probabilities and expectations by conditioning.

Unit 6 (Stochastic Processes): **10 hrs**
Indexing RVs, Markov Chains, Markovian property and Transition probabilities. Irreducibility and Steady-State probabilities, Generic Applications: Hidden Markov Chains.

Unit 7 (Exponential Distribution and Poisson Process): **5 hrs**
Construction of Poisson Process from Exponential Distribution. Thinning and Conditional Arrival Times.

Unit 8 (Normal Distribution and Brownian Process): **5 hrs**
Construction of Brownian Process from Normal Distribution. Hitting Times and Maximum Values.

5. Course Map (CO-PO-PSO Map)

	Programme Outcomes (POs)								Programme Specific Outcomes (PSOs)		
	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PSO-1	PSO-2	PSO-3
CO-1	3	3							1		
CO-2	3	3							1		
CO-3	3	3	3	3	3				3	3	1
CO-4	3	3	3		3				3		1
CO-5	3	3	3	3	3				3	3	1
3: Very Strong Contribution, 2: Strong Contribution, 1: Moderate Contribution											

6. Course Teaching and Learning Methods

Teaching and Learning Methods	Duration in hours	Total Duration in Hours
Face to Face Lectures		45
Demonstrations		00
1.Demonstration usingVideos	00	
2. Demonstration using Physical Models / Systems	00	
3. Demonstration on a Computer	00	
Numeracy		15
1. Solving Numerical Problems	15	
Practical Work		00
1. Course Laboratory	00	
2. Computer Laboratory	00	
3. Engineering Workshop / Course/Workshop / Kitchen	00	
4. Clinical Laboratory	00	

5. Hospital	00	
6. Model Studio	00	
Others		
1. Case Study Presentation	00	
2. Guest Lecture	00	
3. Industry / Field Visit	00	00
4. Brain Storming Sessions	00	
5. Group Discussions	00	
6. Discussing Possible Innovations	00	
Term Tests,Laboratory Examination/Written Examination,Presentations		10
Total Duration in Hours		**70**

7. Course Assessment and Reassessment

The details of the components and subcomponents of course assessment are presented in the Programme Specifications document pertaining to the M. Sc. (Mathematics) Programme. The procedure to determine the final course marks is also presented in the Programme Specifications document.

The evaluation questions are set to measure the attainment of the COs. In either component (CE or SEE) or subcomponent of CE (TSC1, TSC2, TSC3), COs are assessed as illustrated in the following Table.

Focus of COs on each Component or Subcomponent of Evaluation				
	Component 1: CE (50% Weightage)			**Component 2: SEE (50% Weightage)**
Subcomponent▶	**TSC1**	**TSC2**	**TSC3**	**100 Marks**
Subcomponent Type ▶	**Term Test**	**Assignment**	**Innovative**	
Maximum Marks▶	**50**	**25**	**25**	
CO-1	X		X	X
CO-2	X		X	X
CO-3	X		X	X
CO-4		X	X	X
CO-5		X	X	X
The details of TSC1, TSC2, TSC3 are presented in the Programme Specifications Document.				

The Course Leader assigned to the course, in consultation with the Head of the Department, shall provide the focus of COs in each component of assessment in the above template at the beginning of the semester.

Course reassessment policies are presented in the Academic Regulations document.

8. Achieving COs

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The following skills are directly or indirectly imparted to the students in the following teaching and learning methods:

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S. No	Curriculum and Capabilities Skills	How imparted during the course
1.	Knowledge	Classroom lectures
2.	Understanding	Classroom lectures, Self-study
3.	Critical Skills	Assignment
4.	Analytical Skills	Assignment
5.	Problem Solving Skills	Assignment, Examination
6.	Practical Skills	Assignment
7.	Group Work	--
8.	Self-Learning	Self-study
9.	Written Communication Skills	Assignment, Examination
10.	Verbal Communication Skills	--
11.	Presentation Skills	--
12.	Behavioral Skills	--
13.	Information Management	Assignment
14.	Personal Management	--
15.	Leadership Skills	--

9. Course Resources

a. Essential Reading

1. Class notes
2. Loève, M., 1995, Probability Theory, New York, Springer-Verlag.
3. Doob, J.L., 1990, Stochastic Processes, New York, Wiley.
4. Øksendal, B.K., 2013, Stochastic Differential Equations: An Introduction with Applications, Heidelberg, Springer.

b. Recommended Reading

3. Solomon, F., 1987, Probability and Stochastic Processes, Englewood Cliffs, Nj, Prentice-Hall.
4. Yates, R.D., 2018, Probability and Stochastic Processes: A Friendly Introduction For Electrical And Computer Engineers, John Wiley.
5. Durrett, R., 2018, Essentials of Stochastic Processes, Springer.

c. Magazines and Journals

d. Websites

1. https://ocw.mit.edu/

e. Other Electronic Resources

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10. Course Organization

Course Code	MTE642A	
Course Title	Probability and Stochastic Processes	
Course Leader's Name	As per Timetable	
Course Leader's Contact Details	**Phone:**	+91-804-906-5555
	E-mail:	hod.mt.mp@msruas.ac.in
Course Specifications Approval Date	July 2022	
Next Course Specifications Review Date	July 2024	

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Course Specifications: Dissertation

Course Title	Dissertation
Course Code	MTH600A
Course Type	Laboratory
Department	Mathematics and Statistics
Faculty	Mathematical and Physical Sciences

1. Course Summary

The aim of this course is to train a student to carry out research work.

The research work will be carried out at MSRUAS or in any other laboratory of student's choice under the supervision of a senior researcher. The duration of the research work is for six months. The student is expected to submit a dissertation and make a presentation to the examiners in the faculty.

2. Course Size and Credits:

Number of Credits	8
Credit Structure (Lecture: Tutorial: Practical)	0:0:20
Total Hours of Interaction	300
Number of Weeks in a Semester	15
Department Responsible	Mathematics and Statistics
Total Course Marks	300
Pass Criterion	As per the Academic Regulations
Attendance Requirement	As per the Academic Regulations

3. Course Outcomes (COs)

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

- **CO-1.** Recognize the need for developing a new or improving an existing scientific problem through an organized survey of literature
- **CO-2.** Define scientific problem
- **CO-3.** Design and perform the experiments
- **CO-4.** Analyse the results obtained
- **CO-5.** Write a technical Report and give presentation

4. Course Contents

1. Selection of topic for research
2. Critical review on the chosen topic
3. Performance of experiments
4. Collection of relevant data
5. Interpretation of data
6. Preparation of dissertation report and presentation of the same

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5. Course Map (CO-PO-PSO Map)

	Programme Outcomes (POs)								Programme Specific Outcomes (PSOs)		
	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PSO-1	PSO-2	PSO-3
CO-1	3				3			2	3	3	
CO-2	3				3			2	3	3	
CO-3	3		3	3	3	3		2	3	3	
CO-4			3	3	3	3		2		3	
CO-5				3	3	3	3	2			3

6. Course Teaching and Learning Methods

Teaching and Learning Methods	Duration in hours	Total Duration in Hours
Face to Face Lectures		300
Demonstrations		00
1.Demonstration using Videos	00	
2. Demonstration using Physical Models / Systems	00	
3. Demonstration on a Computer	00	
Numeracy		00
1. Solving Numerical Problems	00	
Practical Work		00
1. Course Laboratory	00	
2. Computer Laboratory	00	
3. Engineering Workshop / Course/Workshop / Kitchen	00	
4. Clinical Laboratory	00	
5. Hospital	00	
6. Model Studio	00	
Others		300
1. Case Study Presentation / Solving Research Problem	300	
2. Guest Lecture	00	
3. Industry / Field Visit	00	
4. Brain Storming Sessions	00	
5. Group Discussions	00	
6. Discussing Possible Innovations	00	
Term Tests, Laboratory Examination/Written Examination, Presentations		10
Total Duration in Hours		**310**

7. Course Assessment and Reassessment

The details of the components and subcomponents of course assessment are presented in the Programme Specifications document pertaining to the M. Sc. (Applied Mathematics) Programmes. The procedure to determine the final course marks is also presented in the Programme Specifications document.

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The evaluation questions are set to measure the attainment of the COs. In either component (CE or SEE) or subcomponent of CE (SC1,), COs are assessed as illustrated in the following Table.

Focus of COs on each Component or Subcomponent of Evaluation		
	Component 1: CE (33% Weightage)	Component 2: (67% Weightage)
Subcomponent ▶	SC1	
Subcomponent Type ▶	Pre-project (40 marks) and Mid Term (60 Marks) Presentation	Final Project Presentation (25 Marks), Report (25 Marks) Journal Article (50 Marks)
Maximum Marks ▶	100	100
CO-1	X	X
CO-2	X	X
CO-3	X	X
CO-4	X	X
CO-5		X
The details of SC1 are presented in the Programme Specifications Document.		

The Course Leader assigned to the course, in consultation with the Head of the Department, shall provide the focus of COs in each component of assessment in the above template at the beginning of the semester.

Course reassessment policies are presented in the Academic Regulations document.

8. Achieving COs

The following skills are directly or indirectly imparted to the students in the following teaching and learning methods:

S. No	Curriculum and Capabilities Skills	How imparted during the course
1.	Knowledge	Literature reading
2.	Understanding	Literature reading
3.	Critical Skills	Literature reading
4.	Analytical Skills	Literature reading
5.	Problem Solving Skills	Drawing conclusions from the literature
6.	Practical Skills	Literature reading, preparation of report
7.	Group Work	
8.	Self-Learning	Literature reading, preparation of report
9.	Written Communication Skills	Preparation of report
10.	Verbal Communication Skills	Presentation of report
11.	Presentation Skills	Presentation of report
12.	Behavioral Skills	Course work
13.	Information Management	Presentation of report
14.	Personal Management	Course work
15.	Leadership Skills	---

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9. Course Resources

a. **Essential Reading**
   1. Research Articles / Dissertation Reports / Books
   2. Lecture Sessions on individual project, Thesis Preparation delivered by the concerned Head of Department.

10. Course Organization

Course Code	MTH600A	
Course Title	Dissertation	
Course Leader's Name	As per Timetable	
Course Leader's Contact Details	**Phone:**	+91-804-906-5555
	E-mail:	hod.mt.mp@msruas.ac.in
Course Specifications Approval Date	July 2022	
Next Course Specifications Review Date	July 2024	

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