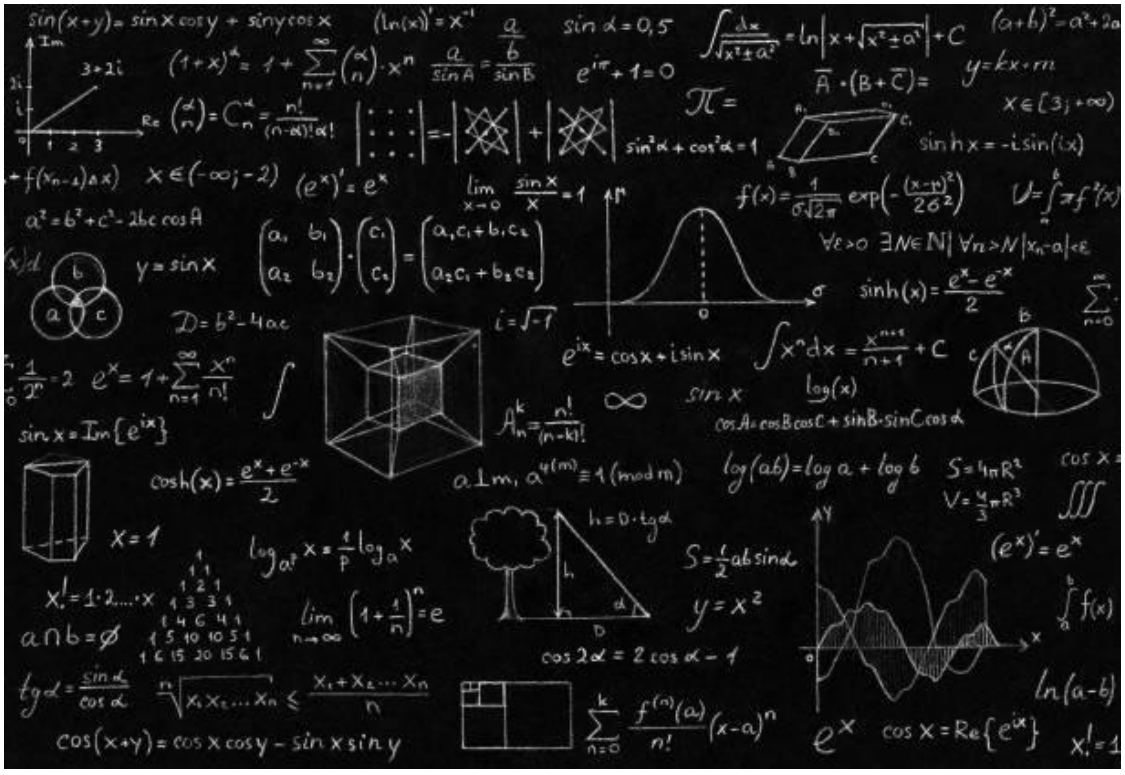
# PROGRAMME PROJECT REPORT

## Master's in Science (Mathematics) Programme
## &
## Master of Arts (Mathematics) Programme
## (2 Year Programme in accordance with NEP-2020)



## School of Sciences

## U. P. Rajarshi Tandon Open University, Prayagraj

# Contents

## 1. Master's Degree Programme

The National Education Policy (NEP) 2020 envisions a new vision that enable an individual to study one or more specialized areas of interest at a deep level, and also develop capabilities across a range of disciplines including sciences, social sciences, arts, humanities, languages, as well as professional, technical, and vocational subjects. The NEP 2020 focuses on the formulation of expected learning outcomes for all higher education programmes. It states that "National Higher Education Qualifications Framework (NHEQF)" shall be align with the National Skills Qualifications Framework (NSQF) to ease the integration of vocational education into higher education. It also points out that higher education qualifications leading to a degree/diploma/certificate shall be described by the NHEQF in terms of Outcome Based Education (OBE).

The design of M.Sc.- Mathematics programme in line with NHEQF offers opportunities and avenues to learn core subjects but also to explore additional avenues of learning beyond the core subjects for holistic development of a learner.

The uniform grading system will also enable potential employers in assessing the performance of the learner. In order to bring uniformity in evaluation system and computation of the Cumulative Grade Point Average (CGPA) based on learner's performance in examinations, guidelines framed by the UGC are followed. Hence, adoption of NHEQF helps to overcome the gap between university degree and employability by introducing skills and competencies in the graduates.

## 2. M.Sc.- Mathematics Programme

The structure and duration of postgraduate programme of Master's in Mathematics in accordance with NEP 2020 includes multiple exit options within this period, with appropriate certifications:

- Level 8: a **Bachelor' Degree (Research)** for 4 year programme after completing 4th year of 4-year B.Sc. programme **OR PG Diploma in Mathematics** after completing 1st year (2 semesters) of study of M.Sc. programme.
- Level 9: a **Master in Science (Mathematics) / Master in Arts (Mathematics)** programme after 2 years (4 semesters) of study;

### 2.1 Programme Mission & Objectives

In line with the mission of the University to provide flexible learning opportunities to all, particularly to those who could not join regular colleges or universities owing to social, economic and other constraints, the 2-year Post-Graduate Programme in Mathematics aims at providing holistic and value based knowledge and guidance to promote scientific temper in everyday life. The program offers a platform to the learners to fulfill the eligible criteria in various scientific jobs in government and private sector.

The Master of Mathematics Programme aims at the following objectives:

- Develop a broad academic and practical literacy in mathematics, computer science, statistics, and optimization, with relevance in data science, machine learning and artificial intelligence, so that students are able to critically select and apply appropriate methods and techniques to extract relevant and important information from data.
- Provide strong core training so that graduates can adapt easily to changes and new demands from industry.
- Enable students to understand not only how to apply certain methods, but when and why they are appropriate.
- Integrate fields within mathematics, computer science, optimization, and statistics to create adept and well-rounded data scientists.

- Expose students to real-world problems in the classroom and through experiential learning.

These program objectives acknowledge the interdisciplinary of mathematical science and the importance of building a strong foundation with our students.

## 2.2 Relevance of the Programme with Mission and Goals

The 2-year Post-Graduate Programme in Science, M.Sc./MA- Mathematics is designed with the objective of equipping learners to cope with the emerging trends and challenges in the scientific domain. In congruence with goals of the University, the Programme also focuses to provide skilled manpower to the society to meet global demands. The Programme is designed in such a manner so that a successful learner can go for higher studies as well as join the research and development industries, software industry, mathematics monitoring projects and different (NGOs) organizations.

## 2.3 Nature of Prospective Target Group of Learners

The Program is targeted to all individuals looking to earn a postgraduation degree for employment, further higher education, promotion in career, professional development.

## 2.4 Appropriateness of Programme to be conducted in ODL mode to acquire specific skills & competence

| **Learning outcomes after Level 8** | | |
|---|---|---|
| **Learning Outcomes** | **Elements of the descriptor** | **Level 8**<br>**Bachelor' Degree (Research)**<br>OR<br>**PG Diploma in Mathematics** |
| LO 1 | Knowledge and understanding | • advanced knowledge about a specialized field of enquiry, with depth in one or more fields of learning within a broad multidisciplinary/interdisciplinary context.<br>• a coherent understanding of the established methods and techniques of research and enquiry applicable to the chosen fields of learning. |
| LO 2 | Skills required to perform and accomplish tasks | • a range of cognitive and technical skills required for performing and accomplishing complex tasks relating to the chosen fields of learning,<br>• cognitive and technical skills relating to the established research methods and techniques, |
| LO 3 | Application of knowledge and skills | • apply the acquired advanced technical and/or theoretical knowledge and a range of cognitive and practical skills to analyze the quantitative and qualitative data gathered drawing on a wide range of sources for identifying problems and issues relating to the chosen fields of learning,<br>• apply advanced knowledge relating to research methods to carryout research and investigations to formulate evidence-based solutions to complex and unpredictable problems. |
| LO 4 | Generic learning outcomes | • listen carefully, read texts and research papers analytically and present complex information in a clear and concise manner to different groups/audiences,<br>• communicate technical information and explanations, and the findings/results of the research studies relating to specialized fields of learning,<br>• present in a concise manner one's views on the relevance and applications of the findings of research and evaluation studies in |

| | | |
|---|---|---|
| | | the context of emerging developments and issues.<br>• pursue self-paced and self- directed learning to upgrade knowledge and skills that will help accomplish complex tasks and pursue higher level of education and research.<br>• problematize, synthesize and articulate issues and design research proposals,<br>• define problems, formulate appropriate and relevant research questions, |
| LO 5 | Constitutional, humanistic, ethical and moral values | • embrace and practice constitutional, humanistic, ethical, and moral values in one's life.<br>• adopt objective, unbiased, and truthful actions in all aspects of work related to the chosen field(s) of learning and professional practice. |
| LO 6 | Employment ready skills, and entrepreneurship skills and mindset | • managing complex technical or professional activities or projects, requiring the exercise of full personal responsibility for output of own work as well as for the outputs of the group as a member of the group/team.<br>• exercising supervision in the context of work having unpredictable changes. |

| **Learning outcomes after Level 9** | | |
|---|---|---|
| **Learning Outcomes** | **Elements of the descriptor** | **Level 9 (Master's in - Mathematics)** |
| LO 1 | Knowledge and understanding | • advanced knowledge about a specialized field of enquiry with a critical understanding of the emerging developments and issues relating to one or more fields of learning,<br>• advanced knowledge and understanding of the research principles, methods, and techniques applicable to the chosen fields of learning or professional practice,<br>• procedural knowledge required for performing and accomplishing complex and specialized professional tasks relating to teaching, and research and development. |
| LO 2 | Skills required to perform and accomplish tasks | • advanced cognitive and technical skills required for performing and accomplishing complex tasks related to the chosen fields of learning,<br>• advanced cognitive and technical skills required for evaluating research findings and designing and conducting relevant research that contributes to the generation of new knowledge,<br>• specialized cognitive and technical skills relating to a body of knowledge and practice to analyse and synthesize complex information and problems. |
| LO 3 | Application of knowledge and skills | • apply the acquired advanced theoretical and/or technical knowledge about a specialized field of enquiry or professional practice and a range of cognitive and practical skills to identify and analyse problems and issues, including real-life problems, associated with the chosen fields of learning. |
| LO 4 | Generic learning outcomes | • listen carefully, read texts and research papers analytically and present complex information in a clear and concise manner to different groups/audiences,<br>• communicate, in a well-structured manner, technical information and explanations, and the findings/ results of the research studies undertaken in the chosen field of study,<br>• meet one's own learning needs relating to the chosen fields of learning, work/vocation, and an area of professional practice, |

| | | |
|---|---|---|
| | | • pursue self-paced and self- directed learning to upgrade knowledge and skills, including research-related skills, required to pursue higher level of education and research. |
| LO 5 | Constitutional, humanistic, ethical and moral values | • embrace and practice constitutional, humanistic, ethical and moral values in one's life,<br>• adopt objective and unbiased actions in all aspects of work related to the chosen fields/subfields of study and professional practice,<br>• participate in actions to address environmental protection and sustainable development issues, |
| LO 6 | Employment ready skills, and entrepreneurship skills and mindset | • adapting to the future of work and responding to the demands of the fast pace of technological developments and innovations that drive shift in employers' demands for skills, particularly with respect to transition towards more technology-assisted work involving the creation of new forms of work and rapidly changing work and production processes.<br>• exercising full personal responsibility for output of own work as well as for group/ team outputs and for managing work that are complex and unpredictable requiring new strategic approaches. |

## 2.5 Instructional Design

### 2.5.1 2-year M.Sc./M.A.- Mathematics Programme Structure

The University follows the credit system in all its programmes. One credit is equal to 30 hours of learner's study time which is equivalent to 15 lectures in conventional system. To earn a Master's Degree, a learner has to earn 80 credits in minimum four semesters (two years) with 20 credits per semester. For earning 80 credits, a learner has to go through the following Programme Structure:

**Programme Structure of M.Sc./ M.A.- Mathematics under NHEQF**

| Level | Year | Sem | Core Course 1 | Core Course 2 | Core Course 3 | Research component | Practical Lab/ Dissertation with viva voce | Total credit |
|---|---|---|---|---|---|---|---|---|
| 8 | 1 | 1st | 4 | 4 | 4 | 4 | 4 | **20** |
| | | 2nd | 4 | 4 | 4 | 4 | 4 | **20** |
| 9 | 2 | 3rd | 4 | 4 | 4 | 4 | 4 | **20** |
| | | 4th | 4 | 4 | 4 | 4 | 4 | **20** |
| **Total credit** | | | | | | | | **80** |

**Explanation of terms used for categorization of courses:**

A. **Course 1 to 4:** A course, which should compulsorily be studied by a learner as a core requirement is termed as a Core course.

B. **Research Component:** The components included in this categories are Basics in Research (PGBR-01), Mini Project (PGMP-02), Basic Research Tools (PGRT-03).

C. **Practical Lab:** Lab based on theory courses for implementing the algorithms discussed in theory papers.

D. **Industrial Training/ Survey/ Research Project/ Field Work/Apprenticeship/ Dissertation/Internship:** A course designed to acquire special/advanced knowledge, such as supplement study/support study to a project work, and a learner studies such a course on his own with an advisory support by a counsellor/faculty member.

**2.5.2 Course curriculum:** The details of syllabus is given in Appendix-I

**2.5.3 Language of Instruction:** English. However, learner can write assignment and give Term End Examination (TEE) either in Hindi or English.

**2.5.4 Duration of the Programme**

Minimum duration in years: 02 Maximum duration in years: 04

**2.5.5 Faculty & Support Staff**

Professor (1), Assistant Professor/academic Consultant (4) and support staff (3)

## 2.6 Instructional Delivery Mechanisms

The Open University system is more learner-oriented, and the student is an active participant in the teaching-learning process. Most of the instructions are imparted through distance rather than face-to-face communication.

The University follows a multi-media approach for instruction. It comprises of:

- self-instructional printed material (Self Learning Material)
- audio and video lectures
- face-to-face counselling
- assignments
- laboratory work
- Project work in some courses
- teleconference/web conference
- Web Enabled Academic Support Portal
- e-GYANSANGAM (Open Educational Repository): http://gyansangam.uprtou.ac.in
- e-GYANARJAN: Its a Learning Management System based on Moodle (http://gyanarjan.uprtou.ac.in) to aid the learner through web conferencing, sharing of learning resources, counselling classes etc.

### 2.6.1 Self-Learning Material

The Self Learning Material (SLMs) are prepared in line with the UGC guidelines on preparation of SLMs. The prepared study materials are self-instructional in nature.

The course material is divided into blocks. Each block contains a few units. Lessons, which are called Units, are structured to facilitate self-study. The units of a block have similar nature of contents. The first page of each block indicates the numbers and titles of the units comprising the block. In the first block of each course, we start with course introduction. This is followed by a brief introduction to the block. After the block introduction, emphasis is given on contribution of ancient Indian knowledge into that specific course. Next, each unit begins with an introduction to talk about the contents of the unit. The lists of objectives are outlined to expect the learning based outcome after working through the unit. This is followed by the main body of the unit, which is divided into various sections and sub-sections. Each unit is summarized with the main highlights of the contents.

Each unit have several “Check Your Progress” Questions and Terminal Questions /exercises. These questions help the learner to assess his/her understanding of the subject contents. At the end of units, additional references/books/suggested online weblink for MOOCs/Open Educational Resources for additional reading are suggested.

### 2.6.2 Audio and Video lectures

Apart from SLM, audio and video lectures have been prepared for some courses. The audio-video material is supplementary to print material. The video lectures are available at YouTube channel of university(https://www.youtube.com/channel/UCj2XTEB6iCZwwIqmKw_jzYg).

### 2.6.3 Counselling Classes

The face to face (F2F) counselling classes are conducted at head quarter and study centers. The purpose of such a contact class is to answer some of questions and clarify the doubts of learner which may not be possible through any other means of communication. Well

experienced counsellors at study centers provide counselling and guidance to the learner in the courses that (s)he has chosen for study. The counselling sessions for each of the courses will be held at suitable intervals throughout the whole academic session. The time table for counselling classes are displayed at head quarter as well as by the coordinator of study center, however, attending counselling sessions is not compulsory. It is noted that to attend the counselling sessions, learner has to go through the course materials and note down the points to be discussed as it is not a regular class or lectures.

### 2.6.4 Assignments

The purpose of assignments is to test the comprehension of the learning material that learner receives and also help to get through the courses by providing self-feedback to the learner. The course content given in the SLM will be sufficient for answering the assignments.

Assignments constitute the continuous evaluation component of a course. The assignments are available at the SLM section of the home page of university website. In any case, learner has to submit assignment before appearing in the examination for any course. The assignments of a course carry 30% weightage while 70% weightage is given to the term-end examination (TEE). The marks obtained by learner in the assignments will be counted in the final result. Therefore, It is advised to take assignments seriously. However, there will be no written assignments for Lab courses.

### 2.6.5 Laboratory Work

Laboratory courses are an integral component of the M.Sc. programme. While designing the curricula for laboratory courses, particular care has been taken to weed out experiments not significant to the present-day state of the discipline. Importance has been given to the utility of an experiment with respect to real life experience, development of experimental skills, and industrial applications. It is planned to phase the laboratory courses during suitable periods (such as summer or autumn vacations) so that in-service persons can take them without difficulty. Laboratory courses worth 2 credits will require full-time presence of the student at the Study Centre for one week continuously. During this time a student has to work for around 60 hours. Around 40 hours would be spent on experimental work and the remaining time will be used for doing calculations, preparations of records, viewing or listening to the video/audio programmes.

### 2.6.6 Teleconference/Web conference

Teleconference/web conference, using done through ZOOM/webex in form of online special counselling sessions is another medium to impart instruction to and facilitate learning for a distance learner. The students concerned would be informed about the teleconferencing schedule and the place where it is to be conducted by sending bulk SMS.

### 2.6.7 Web Enabled Academic Support Portal

The University also provide Web Enabled Academic Support Portal to access the course materials, assignments, and other learning resources.

### 2.6.8 e-GYANSANGAM

The e-GYAMSANGAM (UPRTOU-OER REPOSITORY) is an open access platform for educational resources that rely on the concept of 5Rs namely; Reuse, Revise, Remix, Retain and Redistribute. Uttar Pradesh Rajarshi Tandon Open University in support with Commonwealth Educational Media Centre for Asia initiated the implementation of philosophy behind the NEP-2020 to provide equitable use of technology to support learners (SDG4). This not only ensure inclusive and equitable quality education opportunities but also provide faculty to repurpose high quality open educational resources (OER) such that innovative, interactive and collaborative learning environment is built. UPRTOU believes the philosophy of Antyoday (reaching to last person of the society) and facilitate the learner by providing Self Learning Materials, Lecture Notes, Audio/video Lectures, Assignments, Course materials etc. through face-to-face mode as well as distance mode. This e-GYANSANGAM depository will fulfill the educational facilities through equitable use of

technology to the learners.

## Objectives

- To provide low-cost access model for learners. To foster the policy of reaching to unreached.
- To break down barriers of affordability and accessibility of educational resources.
- To give faculty the ability to customize course materials for learners.
- To provide equal access to affordable technical, vocational and higher education resources (SDG 4.3).
- To provide ubiquitous access to anyone. This will facilitate the quick availability of educational resources and reduces time.
- To supplement Self Learning Material (SLM).
- To reduce the mentor-mentee gap as depository provide access to number of local access as well as global access to educational resources.

**2.6.9** e-GYANARJAN: It's a Learning Management System based on Moodle (http://gyanarjan.uprtou.ac.in) to aid the learner through web conferencing, sharing of learning resources, counselling classes etc.

**2.6.10 Learner Support Service Systems**

**(a) Study Centre**

A Study Centre has following major functions:

(i) **Counselling:** Counselling is an important aspect of Open University System. Face to face contact-cum-counselling classes for the courses will be provided at the Study Centre. The detailed programme of the contact-cum-counselling sessions will be sent to the learner by the Coordinator of the Study Centre. In these sessions learner will get an opportunity to discuss with the Counsellors his/her problems pertaining to the courses of study.

(ii) **Evaluation of Assignments:** The evaluation of Tutor Marked Assignments (TMA) will be done by the Counsellors at the Study Centre. The evaluated assignments will be returned to the learner by the Coordinator of Study Centre with tutor comments and marks obtained in TMAs. These comments will help the learner in his/her studies.

(iii) **Library:** Every Study Centre will have a library having relevant course materials, reference books suggested for supplementary reading prepared for the course(s).

(iv) **Information and Advice:** The learner will be given relevant information about the courses offered by the University. Facilities are also provided to give him/her guidance in choosing courses.

(v) **Interaction with fellow-students:** In the Study Centre learner will have an opportunity to interact with fellow students. This may lead to the formation of self-help groups.

**(b) Learner Support Services (LSS)**

The University has formed an LSS cell at the head quarter. The LSS cell coordinate with the Study Centre to get rid of any problem faced by the learner.

## 2.7 Procedure for admissions, curriculum transaction and evaluation

### 2.7.1 Admission Procedure

**(a)** The detailed information regarding admission will be given on the UPRTOU website and on the admission portal. Learners seeking admission shall apply online.

**(b)** Direct admission to 2-year M.Sc. / **M.A.** (Mathematics) program is offered to the interested candidates.

**(c)** Eligibility: Bachelor degree in concerned subject (B.Sc.-Mathematics OR Any 4 year Graduate Degree in Mathematics OR B.Tech. (CS/IT/EC etc.)

**2.7.2 Programme Fee:** Rs. 12000 / year. The fee is deposited through online admission portal only.

### 2.7.3 Evaluation

The evaluation consists of two components: (1) continuous evaluation through assignments, and (2) term-end examination. Learner must pass both in continuous evaluation as well as in the term-end examination of a course to earn the credits assigned to that course. For each course there shall be one written Terminal Examination. The evaluation of every course shall be in two parts that is 30% internal weightage through assignments and 70% external weightage through terminal exams.

| **(a) Theory course** | **Max. Marks** |
|---|---|
| Terminal Examination | 70 |
| Assignment | 30 |
| **Total** | **100** |

| **(b) Practical course:** | **Max. Marks** |
|---|---|
| Terminal Practical Examination | 100 |

Marks of Terminal Practical Examination shall be awarded as per following scheme:

| | | |
|---|---|---|
| i. | Write up /theory work | 30 |
| ii. | Viva-voce | 30 |
| iii. | Execution/Performance/Demonstration | 20 |
| iv. | Lab Record | 20 |

The following 10-Point Grading System for evaluating learners' achievement is used for CBCS programmes:

**10-Point Grading System in the light of UGC-CBCS Guidelines**

| Letter Grade | Grade Point | % Range |
|---|---|---|
| O (Outstanding) | 10 | 91-100 |
| A+ (Excellent) | 9 | 81-90 |
| A (Very Good) | 8 | 71-80 |
| B+ (Good) | 7 | 61-70 |
| B (Above Average) | 6 | 51-60 |
| C (Average) | 5 | 41-50 |
| P (Pass) | 4 | 36-40 |
| NC (Not Completed) | 0 | 0-35 |
| Ab (Absent) | 0 | |
| Q | Qualified | Applicable only for Non-Credit courses |
| NQ | Not Qualified | |

Learner is required to score at least a 'P' grade (36% marks) in both the continuous evaluation (assignments) as well as the term-end examination. In the overall computation also, learner must get at least a 'P' grade in each course to be eligible for the M. Sc. degree.

**Computation of CGPA and SGPA**

(a) Following formula shall be used for calculation of CGPA and SGPA

| | |
|---|---|
| For jth semester<br><br>SGPA (Sj) = Σ (Ci *Gi)/ Σ Ci | where,<br>Ci = number of credits of the ith course in jth semester<br>Gi= grade point scored by the learner in the ith course in jth semester. |
| CGPA = Σ (Cj *Sj)/ Σ Cj | where,<br>Sj = SGPA of the jth semester<br>Cj = total number of credits in the jth semester |

The CGPA and CGPA shall be rounded off up to the two decimal points. (For e.g., if a learner obtained 7.2345, then it will be written as 7.23 or if s(he) obtained 7.23675 then it be will written as 7.24)

CGPA will be converted into percentage according to the following formula:
Equivalent Percentage = CGPA * 9.5
(b) Award of Division
The learner will be awarded division according to the following table:

| Division | Classification |
|---|---|
| 1st Division | 6.31 or more and less than 10 CGPA |
| 2nd Division | 4.73 or more and less than 6.31 CGPA |
| 3rd Division | 3.78 or more and less than 4.73 CGPA |

### 2.7.4 Multiple Entry and Multiple Exit options

The 2-year M.Sc. programme is an Outcome-Based Education (OBE) for qualifications of different types. The qualification types and examples of title/nomenclature for qualifications within each type are indicated in Table 1.

**Table 1**

| Level | Qualification title | Programme duration | Entry Option | Exit option |
|---|---|---|---|---|
| 8 | B.Sc. (Research) OR PG Diploma in Mathematics | Programme duration: First year (first two semesters) of the M.Sc. programme | Bachelor degree in concerned subject (B.Sc. (Mathematics OR Any 4 year Graduate Degree in Mathematics OR B.Tech. (CS/IT/EC etc.) | **Exit** Awarded with Bachelor' Degree (Research) for 4 year programme OR Exit awarded with PG Diploma in Mathematics |
| 9 | Master in (Mathematics) | Programme duration: First two years (first four semesters) of the of the M.Sc. programme | B.Sc. (Research) OR PG Diploma in Mathematics obtained after completing the first year (two semesters) of the M.Sc. / **M.A.** Mathematics programme. | **Exit** awarded with Master's in (Mathematics) |

## 2.8 Requirement of the laboratory support and Library Resources

The practical sessions are held in the science laboratories of the Study Centre. In these labs, the learner will have the facility to use the equipment and consumables relevant to the syllabus. The SLM, supplementary text audio and video material of the various courses of the program is available through the online study portal of the University. The University also have a subscription of National Digital Library to provide the learners with the ability to enhance access to information and knowledge of various courses of the programme.

## 2.9 Cost estimate of the programme and the provisions

2-year M.Sc./M.A. programme consists of 18 theory courses, and (basic research, mini and major project, and Dissertation) research activities. One course is of 4 credits which consists of approx. 12 units. The total approximated expenditure on the development of 15 courses is:

| S. No. | Item | Cost per Unit (writing & editing) | Total cost (Rs.) |
|---|---|---|---|
| 1 | Total no. of units in 18 courses = 18*12=216 | 5000 | 1080000 |
| 2 | BOS Meetings etc. | 100000 | 100000 |
| | | **Total** | **1180000** |

## 2.10 Quality assurance mechanism and expected programme outcomes

(a) **Quality assurance mechanism:** The program structure is developed under the guidance of the Board of studies comprising external expert members of the concerned subjects followed by the School board. The program structure and syllabus is approved by the Academic Council of the University. The course structure and syllabus is reviewed time to time according to the feedback received from the stakeholders and societal needs.

The Centre for Internal Quality Assurance will monitor, improve and enhance effectiveness of the program through the following:

- ✓ Annual academic audit
- ✓ Feedback analysis for quality improvement
- ✓ Regular faculty development programs
- ✓ Standardization of learning resources
- ✓ Periodic revision of program depending upon the changing trends by communicating to the concerned school

(b) **Expected programme outcomes (POs)**

| | | |
|---|---|---|
| Knowledge and understanding | **PO1** | Apply knowledge of a wide range of mathematics and scientific computing techniques to solve complex scientific and real-life problem. |
| Skills related to specialization | **PO 2** | To develop the problem-solving skills and apply them independently in pure and applied mathematics, statistics and computer science. |
| Application of knowledge and skills | **PO 3** | To provide students with strong mathematical knowledge and capability in formulating & analysis of real-life problem using modern tools of mathematics. |
| | **PO 4** | To provide knowledge and insight in mathematics so that students can work as excellent mathematical professional. |
| Generic learning outcomes | **PO 5** | To prepare the students to as per the need of software industry through knowledge of mathematics and scientific computational techniques. |
| | **PO 6** | To prepare and motivate the students to pursue their higher studies and conduct fundamental and applied research for the welfare of society and mankind |

| **Newly Introduced programme : Yes** | |
|---|---|
| Programme: | **Master in Science/Master of Arts** |
| Year: NA | First Introduction year:**2023** |
| Programme prerequisites: Bachelor degree in concerned subject (B.Sc.-Mathematics OR Any 4 year Graduate Degree in Mathematics OR B.Tech. (CS/IT/EC etc.) | |

## Academic Year 2023-24
## Detailed Programme Structure & Syllabus

# M.Sc. /M.A. (Mathematics) (MSCMM/MAMM)

| Year | Semester | Course Code | Title of Papers | Credit | Max. Marks |
|---|---|---|---|---|---|
| 1 | 1st SEM | MSCMM-101N/MAMM-101N | Advanced Real Analysis and Integral Equations | 4 | 100 |
| | | MSCMM-102N/ MAMM-102N | Classical Optimization Techniques | 4 | 100 |
| | | MSCMM-103N/ MAMM-103N | Discrete Mathematics | 4 | 100 |
| | | MSCMM-104N/ MAMM-104N | Numerical Analysis | 4 | 100 |
| | | PGBR-01 | Basic in Research | 4 | 100 |
| | **Total Credit of 1st Semester** | | | **20** | **500** |
| | 2nd SEM | MSCMM-106N/ MAMM-106N | Advanced Algebra | 4 | 100 |
| | | MSCMM-107N/ MAMM-107N | Complex Analysis | 4 | 100 |
| | | MSCMM-108N/ MAMM-108N | Mathematical Statistics | 4 | 100 |
| | | MSCMM-109N/ MAMM-109N | Topology | 4 | 100 |
| | | PGMP-02 | Mini Project | 4 | 100 |
| | **Total Credit of 2nd Semester** | | | **20** | **500** |
| 2 | 3rd SEM | MSCMM-111N/ MAMM-111N | Advanced Differential Equations | 4 | 100 |
| | | MSCMM-112N/ MAMM-112N | Functional Analysis | 4 | 100 |
| | | MSCMM-113N/ MAMM-113N | Measure Theory and Integration | 4 | 100 |
| | | MSCMM-114N/ MAMM-114N | Theory of Probability | 4 | 100 |
| | | PGRT-03 | Basic Research Tools | 4 | 100 |
| | **Total Credit of 3rd Semester** | | | **20** | **500** |
| | 4th SEM | MSCMM-116N/ MAMM-116N | Operation Research | 4 | 100 |
| | | MSCMM-117N/ MAMM-117N | Fluid Dynamics | 4 | 100 |
| | | MSCMM-122N/ MAMM-122N | Dissertation with Viva-voce | 4 | 100 |
| | | **Discipline Centric Electives** | | | |
| | | **Select any one of the following** | | | |
| | | MSCMM-118N/ MAMM-118N | Soft Computing | 4 | 100 |
| | | MSCMM-119N/ MAMM-119N | Number Theory and Cryptography | 4 | 100 |
| | | **Select any one of the following** | | | |
| | | MSCMM-120N/MAMM-120N | Machine Learning Techniques | 4 | 100 |
| | | MSCMM-121N/MAMM-121N | Vedic Mathematics | 4 | 100 |
| | **Total Credit of 4th Semester** | | | **20** | **500** |
| | **Total Credit/Max. Marks** | | | **80** | **2000** |

**Course prerequisites:** To study this course, a student must have qualified graduation with Mathematics.

| | | |
|---|---|---|
| **Programme:** M.Sc. | **Year:** I | **Semester:** I |
| **Subject:** Mathematics | | |
| **Course Code:** MSCMM-101N/MAMM-101N | **Course Title:** Advanced Real Analysis and Integral Equations | |
| **Course Objectives:** The course covers three important areas with the objectives to acquaint students with new techniques namely advanced real analysis, Fourier series and Integral equations. After reading this course, the students will be able to apply the real analysis, Fourier series and integral equations to many physical problems in science and engineering. | | |
| **Course Outcomes:**<br>**CO1:** To study the advanced real analysis and its applications.<br>**CO2:** The student will be able to understand the basic concepts of function of several variables and its applications.<br>**CO3:** Able to understand the Fourier series and its applications in boundary value problems.<br>**CO4:** Able to understand and use of eigenvalues and Eigen functions in linear integral equations. | | |
| **Credits:** 4 | **Type of Course:** Core | |
| **Max. Marks:** 100 | **Min. Passing Marks:** 36 | |

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|---|---|
| **Block 1** | **Real Analysis** |
| Unit I | **Riemann Integral**<br>Partition, lower and upper Riemann-Stieltjes sums, lower and upper Riemann-Stieltjes integrals, Definition of Riemann-Stieltjes integral, necessary and sufficient condition for Riemann-Stieltjes integrability, algebra of Riemann-Stieltjes integrable functions. |
| Unit II | **Integration and Differentiation**<br>Integral Function, primitive, fundamental theorem of integral calculus, integration by parts, Integration of vector-valued functions. |
| Unit III | **Uniform Convergence of Sequences**<br>Uniformly bounded sequence, uniform convergence of sequences, Uniform convergence of a series of function, Cauchy's general principle of uniform convergence, test for uniform convergence, Uniform convergence and integration, Uniform convergence and differentiation. |
| Unit IV | **Power Series**<br>Power series, Cauchy's theorem on limits, Radius of convergence, Uniform convergence of power series. Abel's and Tauber's theorems. |
| **Block 2** | **Function of Several Variables** |
| Unit V | **Limit and continuity of function of two variables**<br>Introduction, simultaneous limit, Limit of a function of two variables, continuity of a function of two variables. |
| Unit VI | **Partial Differentiation**<br>Introduction, Partial derivatives, partial derivative of higher order, example based on partial derivatives. |
| Unit VII | **Euler's Theorem**<br>Introduction, Homogeneous function, Euler's theorem on Homogeneous function, some deductions from Euler's theorem, Jacobians. |
| **Block 3** | **Fourier Series** |
| Unit VIII | **Introduction to Fourier series**<br>Trigonometric Fourier series, Periodic function, even and odd function, Euler formula for the Fourier coefficients, Convergence of Fourier series and Dirichlet's conditions. |
| Unit IX | **Half Range Fourier series**<br>Half-range expansions, Fourier sine series, Fourier Cosine series, Change of Interval, Parseval's identity for Fourier series. |

| **Block 4** | **Integral Equations** |
|---|---|
| Unit X | **Classifications of Integral Equations**<br>Introduction, Integral equation, differentiation of a function under and integral sign, relation between differential and integral equation. |
| Unit XI | **Fredholm Integral Equations**<br>Fredholm Integral equation, Fredholm first theorem, Fredholm second theorem, Fredholm third theorem, Fredholm Integral equation with separable kernel. |
| Unit XII | **Volterra Integral Equations**<br>Volterra Integral equation, Solution of non-homogeneous Volterra integral equation of second kind by the method of successive substitution and successive approximation, iterated kernels. |

**Suggested Text Book Readings:**


1. M. D. Raisinghania, Integral Equations and Boundary Value Problems, S. Chand Publishing, 2007.
2. Apostol, T. M. Mathematical Analysis. Fifth edition. Wesley Publishing Co. 1981.
3. Walter, R. Principles of Mathematical Analysis. 3rd edition, McGraw-Hill, 1976.
4. Malik, S. C. and Arora, S. Mathematical Analysis. 2nd edition reprint. New Age International Publishers 2005.
5. Royden, H. L. Real Analysis, Macmillan Pub. Co., Inc. 4th edition, New York, 1993.
6. Somasundram, D. and Chaudhary, B. A First Course in Mathematical Analysis. Narosa Publishing House, 1996.
7. Malik, A. K., Mathur, P, Purohit, S.D., A text Book of Engineering Mathematics-I, Manakin Press, 2020.


**This course can be opted as an elective by the students of following subjects:** NA

**Suggested equivalent online courses (MOOCs) for credit transfer:** NA

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|---|---|---|
| **Course prerequisites:** To study this course, a student must have qualified graduation with Mathematics. | | |
| **Programme:** M.Sc. | **Year:** I | **Semester:** I |
| **Subject:** Mathematics | | |
| **Course Code:** MSCMM-102N/MAMM-102N | **Course Title:** Classical Optimization Techniques | |
| **Course Objectives:** The main objective of the course is presents the theory and applications of classical optimization techniques. It extends the theory of optimization methods to more realistic problems. | | |
| **Course Outcomes:**<br>**CO1:** To distinguish between single objective and multiple objective functions.<br>**CO2:** To have deep insight in solving optimization problems which are non-linear,<br>**CO3:** The formulation and solving of problems arising from practical, real-life settings.<br>**CO4:** Able to know the mathematical structure and properties of fundamental problem classes (e.g., linear, non-linear,integer programming, dynamic programming and game theory). | | |
| **Credits:** 4 | **Type of Course:** Core | |
| **Max. Marks:** 100 | **Min. Passing Marks:** 36 | |

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| **Block 1** | **Optimization Techniques** |
| Unit I | **Introduction to Optimization Techniques**<br>Introduction, Optimization techniques, applications of optimization techniques, optimization problems, classification of optimization problems. |
| Unit II | **Unconstrained Optimization Problem**<br>Introduction, unconstrained optimization problem, single and multi-variable optimization problems. |
| Unit III | **Constrained Optimization Problem**<br>Introduction, constrained optimization problem, constrained multi-variable optimization problem with equality and inequality constraints. |
| **Block 2** | **Non-Linear Programming Problem** |
| Unit IV | **Non-Linear Programming-I**<br>Introduction, unconstrained non-linear optimization problems, direct search method: Fibonacci method of search, Golden section method, univariate method and pattern search method, indirect search method: steepest descent method. |
| Unit V | **Non-Linear Programming-II**<br>Introduction, constraints non-linear optimization problem, direct methods: complex method and zoutendijk method, indirect methods: transformation techniques and penalty function methods. |
| Unit VI | **Quadratic Programming**<br>Introduction, Kuhn-Tucker conditions, Quadratic programming: Wolfe's modified simplex method, Beale's method and separable programming problem. |
| **Block-3** | **Dynamic Programming Problem** |
| Unit VII | **Introduction to Dynamic Programming**<br>Introduction, multi-decision process, Bellman's principle of optimality, dynamic programming algorithm. |
| Unit VIII | **Applications of Dynamic Programming**<br>Introduction, solution of linear programming problem using dynamic programming and applications of dynamic programming problem. |
| **Block 4** | **Advanced Optimization Techniques** |
| Unit IX | **Networking**<br>Introduction, shortest route problem, minimum spanning tree problem and maximum flow problem. |

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| Unit X | **Game Theory**<br>Introduction, Game theory, lower and upper value of game, procedure to find saddle point, games without saddle point. |
| Unit XI | **Goal Programming**<br>Introduction, formulation of Goal programming, single goal models, goal-programming algorithm and multi goal models. |
| Unit XII | **Integer Programming**<br>Introduction, formulation of Integer programming problem, Gomory'scutting plane method, and Branch and Bound Techniques. |

**Suggested Text Book Readings:**


1. Yadav, S. R. and Malik, A. K., Operations Research, Oxford University Press, 2014.
2. Malik, A. K, Yadav, S. K. and Yadav, S. R. and., Optimization Techniques, Dreamtech Press, 2020.
3. Rao, S.S.: Optimization Theory and Applications ($2^{nd}$ Edition), New Age Int., New Delhi, 1995.
4. Taha, H. A. Operation Research: An Introduction. 9 th edition, Pearson, 2010.
5. Gupta, P.K. and Hira, D.S. Introduction to Operations Research, S. Chand & Co. 2008.
6. Hardy, G.: Nonlinear and Dynamic Programming ($4^{th}$ edition), Addison-Wesley, Reading Mass, 1974.
7. Sharma, J. K., Mathematical Model in Operation Research, Tata McGraw Hill, 1989.


**This course can be opted as an elective by the students of following subjects:**
MCA/MBA/M.Sc.(Data Science & Analytics/Statistics)

**Suggested equivalent online courses (MOOCs) for credit transfer:** NA

| | | |
|---|---|---|
| **Course prerequisites:** To study this course, a student must have qualified graduation with Mathematics. | | |
| **Programme:** M.Sc. | **Year:** I | **Semester:** I |
| **Subject:** Mathematics | | |
| **Course Code:** MSCMM-103N/MAMM-103N | **Course Title:** Discrete Mathematics | |
| **Course Objectives:** The main aim of the course is provide the basic knowledge of mathematical logic, lattice theory, Boolean algebra, and graph theory and apply for solving the real life problems. | | |
| **Course Outcomes:**<br>**CO1:** Able to use this theory in the development of many computer languages.<br>**CO2:** To solve many engineering and science problems using mathematical logic and methods.<br>**CO3:** To know about the Boolean algebra for solving the problems of coding theory, reliability and others.<br>**CO4:** To solve many research problems and real-world problems by using graph theory. | | |
| **Credits:** 4 | **Type of Course:** Core | |
| **Max. Marks:** 100 | **Min. Passing Marks:** 36 | |

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|---|---|
| **Block 1** | **Set Theory** |
| Unit I | **Sets**<br>Introduction, Representation of sets, types of sets, subset, universal set, Venn diagram, operations on sets, and algebra of sets. |
| Unit II | **Relations**<br>Introduction, inverse relation, representation of relations, types of relations, equivalence relation, and partial order relation. |
| Unit III | **Functions**<br>Introduction, inverse function, types of functions, real valued function, identity function, constant function, composition of functions. |
| Unit IV | **Techniques of counting**<br>Introduction, partition, principle of inclusion-exclusion, pigeonhole principle, permutations and combinations. |
| **Block 2** | **Logic** |
| Unit V | **Mathematical Logic**<br>Introduction, proposition, basic logical operations, truth table, logical equivalence, algebra of propositions, Tautology, contradiction. |
| Unit VI | **Normal Form**<br>Introduction, normal form, disjunctive normal form, conjunctive normal form, logic in proof, universal and existential quantifiers. |
| Unit VII | **Mathematical Induction**<br>Introduction, methods of proof, principle of mathematical induction. |
| Unit VIII | **Recurrence Relations**<br>Introduction, generating function, properties of generating functions, numeric function, recurrence relation, solution of recurrence relation. |
| **Block 3** | **Boolean Algebra** |
| Unit IX | **Boolean Algebra**<br>Introduction, binary operations, algebraic structure, Boolean algebra, Boolean expression, Boolean functions and logic gates. |
| Unit X | **Lattices**<br>Introduction, Lattice, properties of lattice, principle of duality, semi and complete lattice, sublattice, isomorphic and bounded lattice. |
| **Block 4** | **Graph Theory** |

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| Unit XI | **Introduction to Graph**<br>Definition of a graph, simple and multi-graph, degree of a vertex, types of graph: null graph, complete graph, regular graph, path, cycle and circuit, Eulerian and Hamiltonian graph, matrix representation of graph, planner graph, graph coloring. |
| Unit XII | **Tree**<br>Introduction, tree, types of tree, rooted tree, spanning tree, minimal spanning tree, binary tree. |

**Suggested Text Book Readings:**


1. Rosen, K. H. Discrete Mathematics and Its Applications. 7th edition, Tata McGraw Hill, 2011.
2. Trembley, J. P. and Manohar, R. A First Course in Discrete Structure with applications to Computer Science. Tata McGraw Hill, 1999.
3. Khanna, V. K. Lattices and Boolean Algebras. PHI Publication, 2004.
4. Liu, C. L. Elements of Discrete Mathematics. Tata McGraw Hill, 2000.
5. Ram, B. Discrete Mathematics, Pearson Education, 2012.
6. Lipschutz, S., Lipson, M. L. and Patil, V. H. Discrete Mathematics. Schaum's Outline Series, Tata McGraw-Hill Education, 2006.


**This course can be opted as an elective by the students of following subjects:**
MCA/M.Sc. (Data Science & Analytics/Statistics)

**Suggested equivalent online courses (MOOCs) for credit transfer:** NA

| | | |
|---|---|---|
| **Course prerequisites:** To study this course, a student must have qualified graduation with Mathematics. | | |
| **Programme:** M.Sc. | **Year:** I | **Semester:** I |
| **Subject:** Mathematics | | |
| **Course Code:** MSCMM-104N/MAMM-104N | **Course Title:** Numerical Analysis | |
| **Course Objectives:** The main aim of this course is provide the numerical techniques in solving the complex mathematical problems for approximate solution whenever exact and appropriate solution are not exist. | | |
| **Course Outcomes:**<br>**CO1:** Able to be understand the numerical methods and how they are used to determine the approximate solution.<br>**CO2:** To know about the analysis and modification of numerical problems used in science and engineering.<br>**CO3:** The formulation and solving of numerical problems arising from practical, real-life settings.<br>**CO4:** Able to know the solution of linear and non-linear equations and solution of differential equations and integrations. | | |
| **Credits:** 4 | **Type of Course:** Core | |
| **Max. Marks:** 100 | **Min. Passing Marks:** 36 | |

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| **Block 1** | **Calculus of Finite Differences** |
| Unit I | **Finite Differences**<br>Introduction, finite differences, forward differences, backward differences, central differences, shift operator, relations between the relations. |
| Unit II | **Application of Finite Differences**<br>Fundamental theorem of the difference calculus, factorial function, properties of factorial function. |
| **Block 2** | **Interpolation** |
| Unit III | **Newton's Interpolation formula with Equal Intervals**<br>Introduction, to find one missing terms, to find two missing terms, Newton's forward and backward interpolation with equal intervals. |
| Unit IV | **Gauss' and Stirling Interpolation formula with Equal Intervals**<br>Introduction, Gauss's forward and backward interpolation with equal intervals, Stirling's difference formula. |
| Unit V | **Lagrange's Interpolation Formula for Unequal Intervals**<br>Introduction, Lagrange's interpolation with unequal intervals. |
| **Block 3** | **Solution of Linear Simultaneous Equations** |
| Unit VI | **Solution of Linear Simultaneous equations-I**<br>Introduction, Linear equations, Gauss elimination method, Gauss-Seidel method. |
| Unit VII | **Solution of Linear Simultaneous equations-II**<br>Introduction, LU Decomposition method or triangular method, Crout's method and Choleski's method. |
| **Block 4** | **Solving Algebraic and Transcendental Equations** |
| Unit VIII | **Numerical Method for solving Algebraic and Transcendental Equations-I**<br>Introduction, Polynomial, algebraic and transcendental equations, Bisection method and Newton Method. |
| Unit IX | **Numerical Method for solving Algebraic and Transcendental Equations-II**<br>Introduction, Regula-Falsi method and Secant method. |
| **Block 5** | **Numerical Differentiation and Integration** |
| Unit X | **Numerical Differentiation** |

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| | Introduction, derivatives using forward difference formula, derivatives using backward difference formula, derivatives using Stirling difference formula, derivatives using Newton's Divided difference formula. |
| Unit XI | **Numerical Integration**<br>Introduction, general quadrature formula for equally spaced arguments, Trapezoidal rule, Simpson's 1/3 rule, Simpson's 3/8 rule. |
| Unit XII | **Numerical Solution of Ordinary Differential Equations**<br>Introduction, Euler's method, Euler's modified method, Taylor Series method, Picard's method. Runge-Kutta method for fourth order, Milne's predictor-corrector method. |

**Suggested Text Book Readings:**


1. Atkinson, K. and Han, W. Theoretical Numerical Analysis, Springer Science & Business Media, 2010.
2. Jain, M.K., Iyengar, S.R.K and Jain, R.K.: Numerical Methods for Scientific and Engineering Computations, New Age International (P) Ltd. New Delhi, 2014.
3. Sastry, S.S.: Introductory Methods of Numerical Analysis, UBS Publishers, 2012.
4. Bradie, B. A friendly introduction to Numerical Analysis. Pearson Education, 2007.
5. Gupta. R. S., Elements of Numerical Analysis, 2nd Edition, Cambridge University Press, 2015


**This course can be opted as an elective by the students of following subjects:**
MCA/M.Sc. (Data Science & Analytics/Statistics)

**Suggested equivalent online courses (MOOCs) for credit transfer:** NA

| | | |
|---|---|---|
| **Course prerequisites:** To study this course, a student must have qualified graduation with Mathematics. | | |
| **Programme:** M.Sc. | **Year:** I | **Semester:** I |
| **Subject:** Mathematics | | |
| **Course Code:** PGBR-01 | **Course Title:** Basics in Research | |
| **Course Objectives:** The main objective of this course is to develop a research orientation among the scholars and to acquaint them with fundamentals of research methods, survey, Plagrism and copyright issue. | | |
| **Course Outcomes:**<br>**CO1:** To write a good qualitative research statement and design the research questions.<br>**CO2:** To know about the hypothesis, conduct the survey and a qualitative case study.<br>**CO3:** Able to know the Plagrism and copyright issue for writing research paper and project. | | |
| **Credits:** 4 | **Type of Course:** Core | |
| **Max. Marks:** 100 | **Min. Passing Marks:** 36 | |
| Unit I | **Introduction to Research**<br>Meaning of Research, Purpose, Characteristics and Types of Research, Process of Research, Formulation of objectives. | |
| Unit II | **Hypothesis**<br>Formulation of Hypotheses, Types of Hypotheses, Methods of testing Hypotheses, Research plan and its components, Methods of Research (Survey, Observation, case study, experimental, historical and comparative methods). | |
| Unit III | **Survey**<br>Scientific research and literature survey, History of mathematics, finding and solving research problems, role of a supervisor, a survey of a research topic. | |
| Unit IV | **Plagrism and Copy Right Issue**<br>Publishing a paper, reviewing a paper, research grant proposalwriting, copyright issues, ethics and plagiarism. | |
| **Suggested Text Book Readings:**<br>1. C.R. Kothari, Gaurav Garg. Research Methodology: Methods and Techniques, New Age International Publishers, 2019.<br>2. Kumar. R: Research Methodology: A Step-by-Step Guide for Beginners, (3rd Edition), SAGE, Inc., 2011.<br>3. https://onlinecourses.swayam2.ac.in/cec22_ge28/preview | | |
| **This course can be opted as an elective by the students of following subjects:** Open for all | | |
| **Suggested equivalent online courses (MOOCs) for credit transfer:** NA | | |

**Note:-** In this paper, learner itself study the objectives and prepare a report. The report will be submitted along with assignment to respective study center for evaluation. The maximum marks for evaluation are 100.

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| **Course prerequisites:** To study this course, a student must have qualified graduation with Mathematics. | | |
| **Programme:** M.Sc. | **Year:** I | **Semester:** II |
| **Subject:** Mathematics | | |
| **Course Code:** MSCMM-106N/MAMM-106N | **Course Title:** Advanced Algebra | |
| **Course Objectives:** Acquiring ability for defining set, relation, function, algebraic structures, groups, subgroups, ring, Extension Fields, Galois Theory and their applications. | | |
| **Course Outcomes:**<br>**CO1:** The student will be able to know about set theory and its applications.<br>**CO2:** The student shall understand the group theory with their applications.<br>**CO3:** Ability to apply advanced algebra to solve problems in other branches of mathematics and in other disciplines.<br>**CO4:** Processing pre-requisites for pursuing research in group theory and cryptography. | | |
| **Credits:** 4 | **Type of Course:** Core | |
| **Max. Marks:** 100 | **Min. Passing Marks:** 36 | |

| | |
|---|---|
| **Block 1** | **Group Theory** |
| Unit I | **Basic Set Theory**<br>Introduction, Representation of sets, types of sets, subset, universal set, Venn diagram, operations on sets, and algebra of sets, relations, equivalence relation, and partial order relation, functions. |
| Unit II | **Introduction of Group Theory**<br>Introduction, algebraic structure, group, Abelian group, finite and infinite group, composition tables for finite sets. |
| Unit III | **Permutations and Isomorphism on Groups**<br>Introduction, permutations, groups of permutations, cyclic permutations, even and odd permutations, order of an element of a group, isomorphism on groups. |
| Unit IV | **Subgroup and Cosets**<br>Introduction, complexes and subgroups of a group, intersection of subgroups, cosets, Lagrange's theorem, Fermat's theorem, Cayley's theorem. |
| Unit V | **Cyclic Group**<br>Introduction, Cyclic groups, subgroup generated by a subset of a group, generating system of a group. |
| **Block 2** | **Advanced Group Theory** |
| Unit VI | **Normal Subgroup**<br>Introduction to Normal subgroup, simple group, conjugate element, centre of a group, conjugate subgroup and quotient groups. |
| Unit VII | **Homomorphism**<br>Homomorphism on groups, Kernel of a homomorphism, fundamental theorem on homomorphism of groups, automorphisms and inner automorphisms, Maximal subgroup, Composition series of a group, Jordon Holder's theorem, Solvable groups, Direct products, Sylow's theorem. |
| **Block 3** | **Rings and Field Theory** |
| Unit VIII | **Rings**<br>Introduction, Rings, elementary properties of a ring, ring with or without zero divisors, integral domain, field, subrings and subfields. |
| Unit IX | **Ideals**<br>Introduction, ideals, principal ideal, divisibility in an integral domain, greatest common divisor, polynomials rings, unique factorization domain and reminder theorem. |

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| Unit X | **Advanced Rings Theory**<br>Quotient rings, homomorphism on rings, kernel of a ring homomorphism, maximal ideals, prime ideals and Euclidean rings. |
| **Block-4** | **Extension Fields and Galois Theory** |
| Unit XI | **Extension Fields**<br>Introduction, field extensions, field adjunctions, simple and algebraic field extensions, separable extension and perfect field. |
| Unit XII | **Galois Theory**<br>The elements from Galois theory, fixed field, normal extension, Galois group, fundamental theorem of Galois theory. |

**Suggested Text Book Readings:**


1. David S. Dummit & Richard M. Foote (2008). Abstract Algebra (2nd edition). Wiley.
2. P. B. Bhattacharya, S. K. Jain & S. R. Nagpaul (2003). Basic Abstract Algebra ($2^{nd}$ edition). Cambridge University Press.
3. Khanna, Vijay K & Bhambri, S K A Course in Abstract Algebra, S Chand and Company Ltd; $5^{th}$ edition,2022.
4. John B. Fraleigh, A First Course in Abstract Algebra (7th edition). Pearson, 2007.
5. Joseph A. Gallian, Contemporary Abstract Algebra (9th edition). Cengage, 2017.
6. I. N. Herstein, Topics in Algebra (2nd edition). Wiley India, 2006.


**This course can be opted as an elective by the students of following subjects:** NA

**Suggested equivalent online courses (MOOCs) for credit transfer:** NA

| | | |
|---|---|---|
| **Course prerequisites:** To study this course, a student must have qualified graduation with Mathematics. | | |
| **Programme:** M.Sc. | **Year:** I | **Semester:** II |
| **Subject:** Mathematics | | |
| **Course Code:** MSCMM-107N/MAMM-107N | **Course Title:** Complex Analysis | |
| **Course Objectives:** The main aim of this course is provide the basic concepts of complex analysis, derivatives and integrals of functions of a complex variable, conformal mapping and use of complex analysis to evaluate complicated real integrals via residue calculus. | | |
| **Course Outcomes:**<br>**CO1:** The student will be able to know about fundamental concepts of complex analysis.<br>**CO2:** The student shall understand the Cauchy-Riemann equations and apply them to complex functions in order to determine whether a given continuous function is complex differentiable.<br>**CO3:** Ability to apply complex analysis techniques in engineering and science.<br>**CO4:** Processing pre-requisites for pursuing research in complex analysis. | | |
| **Credits:** 4 | **Type of Course:** Core | |
| **Max. Marks:** 100 | **Min. Passing Marks:** 36 | |

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| **Block 1** | **Function of Complex Variables** |
| Unit I | **Complex Numbers**<br>Introduction, Graphical representation, exponential functions of complex numbers, circular and hyperbolic functions of complex numbers. |
| Unit II | **Analytic Functions**<br>Introduction, single and multivalued functions, analytic functions, Cauchy Riemann equations, Polar form of C-R equation, Derivative of w in polar form. |
| Unit III | **Harmonic Functions**<br>Orthogonal system, Laplace equations, harmonic functions, conjugate functions, Milne's Thomson method. |
| **Block 2** | **Conformal Mappings** |
| Unit IV | **Introduction to Conformal Mappings**<br>Mappings or Transformations, Jacobian of a transformations, ordinary and critical points, conformal mappings, some general transformations: Translation, Rotation, Magnification, Inversion. |
| Unit V | **Bilinear Transformations**<br>Bilinear transformations, Fixed points of the Bilinear Transformations, Some important properties of Bilinear Transformations, Special conformal transformations, Joukowski's transformation and Schwarz-Christoffel transformation. |
| **Block 3** | **Complex Integration and Series** |
| Unit VI | **Introduction to Complex Integration**<br>Complex integration, Arc, Regular Arc, Contour, Connected and Non-connected region, simple and multi connected region, Cauchy Fundamental theorem, and Cauchy-Goursat theorem. |
| Unit VII | **Important Theorems in Complex Integration**<br>Cauchy's integral formula, An extension of the Cauchy's integral formula, Cauchy's integral formula for derivative, Morera's Theorem, Cauchy's inequality, Liouville's theorem and its applications, The fundamental theorem of Algebra, Maximum modulus principle. |
| Unit VIII | **Series**<br>Introduction, Entire functions, Taylor's theorem and its applications, Laurent's Theorem and its applications. |

| **Block 4** | **The calculus of residues** |
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| Unit IX | **Singularities and Residues**<br>Zero of analytic functions, singularities of analytic functions, isolated and non-isolated singularities, removable singularities, pole, residue at pole, Cauchy's Residue theorem. |
| Unit X | **Applications of Complex Integration-I**<br>Evaluation of real definite integrals, Integration round the unit circle, Jorden's inequality, Jordan's lemma, Evaluation of integrals in which poles lie on the real axis. |
| Unit XI | **Applications of Complex Integration-II**<br>Introduction, Evaluation of integrals in which poles lie on the real axis, integral involved many valued functions. |
| Unit XII | **Meromorphic Functions**<br>Meromorphic functions, Mittag Leffler's expansion theorem, number of poles and zeroes of a meromorphic function, Principle of argument, Rouche's theorem. |

**Suggested Text Book Readings:**


1. Ponnusamy, Foundations of Complex Analysis. 2nd Edition, Narosa Book Publication, 2008.
2. K.P. Gupta, Functions of complex variable, Sixteen Edition, Pragati Prakashan, 2002.
3. J. B. Conway, Functions of One Complex Variable, Narosa Publishing House, New Delhi, 2002.
4. Priestly, H. A.: Introduction to Complex Analysis, Oxford University Press, 2008.
5. Ahlfors, L.V.: Complex Analysis, McGraw Hill Education; 3rd Edition, 2017.
6. M. Spiegel, J. Schiller, S. Lipschutz, Schaum's Outline of Complex Variables, 2ed (Schaum's Outlines)
7. James W. Brown & R. V. Churchill: Complex variables and applications, McGraw-Hill, 2006.


**Suggested online link:**

1. https://epgp.inflibnet.ac.in/Home/ViewSubject?catid=ZLCHeZEhCZ8yCri36nSF3A==

**This course can be opted as an elective by the students of following subjects:** M.Sc. (Data Science & Analytics/Statistics)

**Suggested equivalent online courses (MOOCs) for credit transfer:**

https://archive.nptel.ac.in/courses/111/103/111103070/ by Prof. P. A. S. Sree Krishna IIT Guwahati

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|---|---|---|
| **Course prerequisites:** To study this course, a student must have qualified graduation with Mathematics. | | |
| **Programme:** M.Sc. | **Year:** I | **Semester:** II |
| **Subject:** Mathematics | | |
| **Course Code:** MSCMM-108N/MAMM-108N | **Course Title:** Mathematical Statistics | |
| **Course Objectives:** The aim of this course is to extend the students' knowledge of statistical methods and to provide theoretical background for studying advanced statistical methods. | | |
| **CO1:** The student will be able to know about fundamental concepts of statistical methods.<br>**CO2:** The student shall understand the data collection, measures of central tendency and dispersion and apply them in various day-to day life problems.<br>**CO3:** Ability to apply the correlation and regression techniques in engineering and science.<br>**CO4:** The students will be able to study, correctly apply and interpret different statistical methods. | | |
| **Credits:** 4 | **Type of Course:** Core | |
| **Max. Marks:** 100 | **Min. Passing Marks:** 36 | |

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|---|---|
| **Block 1** | **Data Collection and its Representation** |
| Unit I | **Data Collection and Tabulation**<br>Meanings, Definitions and Applications of Statistics, Measurements and Scale, Measurements of qualitative data, Methods of data collection, Types of data. |
| Unit II | **Representation of Data- I (Diagrammatical representation)**<br>Frequency distribution, Tabulation of data, Diagrammatical Representation of data, Bar diagram, Multiple bar diagram, Divided bar diagram, Percentage bar diagram, Pie chart, Pictogram, leaf chart. |
| Unit III | **Representation of Data- II (Graphical representation)**<br>Graphical representation of frequency distribution, Histogram, Frequency polygon, Frequency curve, Ogive. |
| **Block 2** | **Measures of Central Tendency and Dispersion** |
| Unit IV | **Measures of Central Tendency**<br>Types of measures of central tendency, Arithmetic mean, Fundamental Theorems on Arithmetic mean, Geometric mean, Harmonic mean, Median, Mode, Percentiles, Deciles, and Quartiles. |
| Unit V | **Measures of Dispersion**<br>Types of measures of Dispersion, Range, Mean Deviation, Variance and Standard deviation, Effect of change of origin and scale, Relationship between measures of central tendency and measures of dispersion, Coefficient of variation. |
| **Block 3** | **Moments, Skewness and Kurtosis** |
| Unit VI | **Moments, Raw Moments and Central Moments**<br>Definition of moments, raw moments for ungrouped data, raw moments for grouped data, Central moments, Factorial moments, Interrelationship between various moments, effect of change of origin and scale on moments, Charlier's checks, Sheppard's correction for moments. |
| Unit VII | **Skewness and Kurtosis**<br>Definition of skewness, Measures of skewness, Pearson's coefficient, Bowley's coefficients, Kurtosis, Measures of Kurtosis, effect of change of origin and scale. |
| **Block 4** | **Correlation and Regression** |
| Unit VIII | **Bivariate Data and Correlation**<br>Scatter Diagram, Karl Pearson's coefficient of correlation, Properties of correlation coefficient, limits of correlation coefficient, Effect of change of origin and scale on correlation coefficient |
| Unit IX | **Regressions** |

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| | Regressions, linear regression model, principal of least square, Regression lines, Regression coefficient, Properties of Regression coefficients. |
| Unit X | **Correlation and Intra Class Correlation**<br>Rank correlation coefficient, Spearman's rank correlation coefficients, rank correlation coefficient for tied ranks, Intra-class correlation, some remarks on Intra-class correlation. |
| Unit XI | **Theory of Attributes**<br>Combinations, Classes and Class frequencies of Attributes, Dichotomous Classification, Consistency of data, joint distribution of attributes, Contingency tables, Independence and Association of Attributes, Measures of Association, Yates Correction. |

**Suggested Text Book Readings:**


1. Irwin Miller & Marylees Miller, John E. Freund's Mathematical Statistics with Applications ($8^{th}$ edition). Pearson. Dorling Kindersley Pvt. Ltd. India, 2014.
2. Robert V. Hogg, Joseph W. McKean & Allen T. Craig, Introduction to Mathematical Statistics ($7^{th}$ edition), Pearson Education, 2013.
3. Sheldon M. Ross, Introduction to Probability Models ($11^{th}$ edition). Elsevier, 2014.
4. V.K. Kapoor and S. C. Gupta, Fundamental of Mathematical Statistics, S. Chand & Sons, 2018.
5. Gupta, C. B., Malik, A. K., Kumar, V., Random-Variables and Stochastic Processes, Neelkanth Publisher Jaipur, 2011.
6. Mood, A.M. and Grayville, F.: Introduction to the Theory of Statistics**,** McGraw Hill Education; $3^{rd}$ edition, 2017.


**This course can be opted as an elective by the students of following subjects:**
M.Sc. (Data Science & Analytics/Statistics)

**Suggested equivalent online courses (MOOCs) for credit transfer:** NA

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| **Course prerequisites:** To study this course, a student must have qualified graduation with Mathematics. | | |
| **Programme:** M.Sc. | **Year:** I | **Semester:** II |
| **Subject:** Mathematics | | |
| **Course Code:** MSCMM-109N/MAMM-109N | **Course Title:** Topology | |
| **Course Objectives:** This course puts forward some basic concepts of topology and its applications. The main emphasis on the explanations of some important concepts; metric spaces and topological spaces; to show how the theory and concepts grow naturally from idea of distance. | | |
| **Course Outcomes:**<br>**CO1:** Able to use this theory and concepts, development naturally from the idea of distance.<br>**CO2:** To apply the metric space, pseudo and discrete metric space, and its properties.<br>**CO3:** To know about the concepts of topological spaces and its use in solving engineering and science problems.<br>**CO4:** To understand the sequentially compact spaces, countable compactness, compactness, and Separation Axioms in Topological Spaces. | | |
| **Credits:** 4 | **Type of Course:** Core | |
| **Max. Marks:** 100 | **Min. Passing Marks:** 36 | |

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| **Block 1** | **Metric Spaces** |
| Unit I | **Elements of Set Theory**<br>Sets, subset, index set, power set, operations on set, relations, functions, finite and infinite sets, Countable and uncountable sets. |
| Unit II | **Introduction to Metric Spaces**<br>Metric space, Pseudo Metric Space, Discrete Metric Space, Bounded and Unbounded Metric Space, Usual and Quasi Metric Space, inequalities. |
| Unit III | **Spaces in Metric**<br>Sequence spaces $l^{\infty}$, Function space, sequence space $l^{p}$, Hilbert sequence space $l^{2}$, Open and closed ball, sphere, neighbourhood of a point, limit point, equivalent Metrics. |
| Unit IV | **Sequence in Metric Spaces**<br>Sequence in a Metric Space, Convergent Sequence in a Metric Space, Bounded Set, Cauchy Sequence, Complete Metric Space, Incomplete Metric Space, Completeness of C, Continuity and Homeomorphism of metric spaces, Homeomorphic Spaces. |
| **Block 2** | **Introduction to Topological Spaces** |
| Unit V | **Topological Spaces-I**<br>Topological Spaces, Trivial topology, Non-Trivial topologies, Comparison of Topologies, Algebra of Topologies, Open Set, Neighbourhood, Usual Topology, Limit Points, Derived Set, Closed Sets, Door Space. |
| Unit VI | **Topological Spaces-II**<br>Closure of a Set, Separated Set, Interior points and the Interior of a Set, Exterior of a Set, Boundary Points, Dense Set. |
| Unit VII | **Base and Sub-base**<br>Relative Topology, Subspace, Base for a topology, Sub-bases, Local base, First Countable Space, Second Countable Space, Topologies Generated by Classes of Sets, Separable Space, Cover of a Space, Lindelof Space. |
| Unit VIII | **Continuous Maps and Homeomorphism**<br>Continuous Function, Open Mapping, Closed Mapping, Bicontinuous Mapping, Bijective Mapping, Sequential Continuity, The pasting Lemma, Homeomorphism. |
| **Block 3** | **Separation Axioms on Topological Spaces** |
| Unit IX | **Separation Axioms-I** |

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| | Separation axioms – $T_0$, $T_1$, $T_2$, $T_3$, $T_{3/2}$, regular space, completely regular space, their characterizations and basic properties. |
| Unit X | **Separation Axioms-II**<br>Separation axioms: normal space, completely normal space, $T_4$ and $T_5$, their characterizations and basic properties. Urysohn's lemma and Teitze Extension Theorem, Urysohn's Metrization Theorem. |
| Unit XI | **Connectedness**<br>Separated Sets, Connected Set, Disconnected Set, Connectedness on the Real Line, components, Maximal Connected Set, Locally Connected Space and Totally Disconnected Set. |
| Unit XII | **Compactness**<br>Cover, Open Cover, Compact Space, Compact Set, Finite Intersection Property, Locally Compact Space, Lindelof Space, Bolzano Weierstrass Property, Sequentially Compact, Uniformly Continuous, Lebesgue Covering Lemma, Heine-Borel Theorem, Product Topology, Projection Mappings. |

**Suggested Text Book Readings:**


1. G. F. Simmons: Introduction to Topology and Modern Analysis, McGraw Hill, 1963.
2. Singh, S. R. & Malik, A. K. Topology Dreamtech Press, 2020.
3. James R Munkres, Topology, A first course, Prentice Hall, New Delhi, 2000
4. J. L. Kelly, Topology, Von Nostrand Reinhold Co. New York, 1995.
5. K.D. Joshi, Introduction to General Topology, Wiley Eastern Ltd.
6. J. V. Deshpande, Introduction to Topology, Tata McGraw Hill, 1988.


**This course can be opted as an elective by the students of following subjects:**
M.Sc. (Data Science & Analytics/Statistics)

**Suggested equivalent online courses (MOOCs) for credit transfer:** NA

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| **Course prerequisites:** To study this course, a student must have qualified graduation with Mathematics. | | |
| **Programme:** M.Sc. | **Year:** I | **Semester:** II |
| **Subject:** Mathematics | | |
| **Course Code:** PGMP-02 | **Course Title:** Mini Project | |

**Course Objectives:** In the second semester of Masters the main objectives of the exposure of students towards the project is to elevate their understanding into the applications areas of Mathematics. This course will develop their analytical ability, will provide them an apt exposure to work in any research group, and will motivate them to execute research in the area of their interest in Mathematical sciences.

**Course Outcomes:**

**CO1:** Students will be able to plan and strategize a scientific problem, and implement it within a reasonable time frame.

**CO2:** It is expected that after completing this project dissertation, students will learn to work independently and how to keep accurate/readable record of assigned project.

**CO3:** In addition, students will be able to know the library search and handle the data in a meaningful way. Also, the students will be able to interpret the spectral data independently.

**CO4:** Subsequently, the students should be able to critically examine research articles, and improve their scientific writing/communication skills and power point presentation.

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| **Credits:** 4 | **Type of Course:** Core |
| **Max. Marks:** 100 | **Min. Passing Marks:** 36 |

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| **Topic** | Students shall make mini project on selected topic of their own choice (with or without any, Supervisor) and prepare the report and submit it to the University Examination Department and School of Science of the University for evaluation. |

**Suggested Text Book Readings:**

1. Use different searching engine to get relevant information (Google scholar, Wiki-databases, Science Direct, SciFinder, Scopus, and YouTube.
2. Access to different online research library and research portal (Web resources, E-journals, journal access, TOC alerts)

**Note:** Students shall make mini project on selected topic of their own choice studied so far (with or without any, Supervisor) and prepare the report. The report will be submitted along with assignment to respective study center for evaluation. The maximum marks for evaluation are 100.

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| **Course prerequisites:** To study this course, a student must have qualified graduation with Mathematics. | | |
| **Programme:** M.Sc. | **Year:** II | **Semester:** III |
| **Subject:** Mathematics | | |
| **Course Code:** MSCMM-111N/MAMM-111N | **Course Title:** Advanced Differential Equations | |
| **Course Objectives:** The main objective of this course is to develop the student level to understand the use of ordinary differential equation in real-life problems. | | |
| **Course Outcomes:**<br>**CO1:** To study the power series and special function with its applications.<br>**CO2:** The student will be able to understand the basic concepts of partial differential equation and its applications.<br>**CO3:** Able to understand the two-dimensional Laplace equation, one-dimensional heat equation and wave equation and its applications in boundary value problems.<br>**CO4:** Able to formulate and solve the difference equation and use of calculus of variations in science and engineering. | | |
| **Credits:** 4 | **Type of Course:** Core | |
| **Max. Marks:** 100 | **Min. Passing Marks:** 36 | |

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| **Block 1** | **Ordinary Differential Equations** |
| Unit I | **Power Series**<br>Introduction to power series method, Ordinary points, Singularities, Regular and Irregular singular points, Frobenius method, Series solutions about ordinary points and regular singular points. |
| Unit II | **Legendre's Function**<br>Legendre's function, generating function, orthogonal properties of Legendre's function, recurrence relations, Rodrigues's formula. |
| Unit III | **Bessel's Function**<br>Bessel's Function of first and second kind, generating function, orthogonal properties of Bessel's function, recurrence relations. |
| **Block 2** | **Partial Differential Equations of First Order** |
| Unit IV | **Partial Differential Equations of First Order and First Degree**<br>Introduction to Partial Differential Equations, Order and Degree of Partial Differential Equations, Derivation of Partial Differential Equations. |
| Unit V | **Lagrange Method**<br>Standard form of Linear Partial Differential Equations of order one, Lagrange method for solving first order Partial Differential Equations. |
| Unit VI | **Standard Form**<br>Non-linear Partial Differential Equations, Standard form, Standard form-I, II, III & IV (Clairaut's form). |
| Unit VII | **Charpit's Method**<br>Charpit's method for first order Partial Differential Equations, working procedure for solving Partial Differential Equations using Charpit's Method. |
| **Block 3** | **Partial Differential Equations of Higher Order** |
| Unit VIII | **Partial Differential Equations of Higher Order-I**<br>Introduction, Partial differential equations of higher order, classification of linear Partial differential equations, Separation of variable method. |
| Unit IX | **Partial Differential Equations of Higher Order-II**<br>Two-dimensional Laplace equation in Cartesian coordinates, one-dimensional Heat equation, one-dimensional Wave equation. |
| **Block 4** | **Difference Equations and Calculus of Variations** |

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| Unit X | **Introduction to Difference equations**<br>Introduction to difference equations, order and degree of difference equations, formulation of difference equations. |
| Unit XI | **Application of Difference Equations**<br>Linear difference equations, homogeneous linear difference equations with constant coefficient, non-homogeneous linear difference equations with constant coefficient. |
| Unit XII | **Calculus of Variations**<br>Introduction, functional, Euler's equation, equivalent forms of Euler's equation, solution of Euler's equations, strong and weak variations, isoperimetric problems, variational problems involving several dependent variables, functional involving second order derivatives. |

**Suggested Text Book Readings:**


1. Shepley L. Ross, Differential Equations (3rd edition), Wiley India, 2007.
2. E.A. Coddington and N. Levinson, Theory of Ordinary Differential Equations, Tata McGraw-Hill, 2016.
3. Ross. S. L., Differential Equations, 3rd Edition, Wiley, 1980.
4. Rai, B., Chaudhary, D.P. and Freedman, H.I., A Course in Ordinary Differential Equations, NarosaPublishing House, New Delhi 2013.
5. George F. Simmons, Differential Equations with Applications and Historical Notes (3rd edition). CRC Press. Taylor & Francis, 2017.


**This course can be opted as an elective by the students of following subjects:**
M.Sc. (Data Science & Analytics/Statistics)

**Suggested equivalent online courses (MOOCs) for credit transfer:** NA

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|---|---|---|
| **Course prerequisites:** To study this course, a student must have qualified graduation with Mathematics. | | |
| **Programme:** M.Sc. | **Year:** II | **Semester:** III |
| **Subject:** Mathematics | | |
| **Course Code:** MSCMM-112N/MAMM-112N | **Course Title:** Functional Analysis | |
| **Course Objectives:**<br>The main objective of this course is to introduce the concepts of vector space, normed linear space, Banach space, Hilbert space, fixed-point theory and Housdorff space. This course lays a foundation for solving many research problems in different areas such as quantum physics and dynamical system theory. | | |
| **Course Outcomes:**<br>**CO1:** To study the different concepts of vector and normed linear space with its applications.<br>**CO2:** The student will be able to understand the basic concepts of linear operators, linear functional on Banach and Hilbert spaces.<br>**CO3:** Able to understand the basic tool to solve the problems of integral equations, fluid dynamics and optimization theory.<br>**CO4:** Processing pre-requisites for pursuing research in pure and applied mathematics. | | |
| **Credits:** 4 | **Type of Course:** Core | |
| **Max. Marks:** 100 | **Min. Passing Marks:** 36 | |

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| **Block 1** | **Vector Space and Normed Linear Space** |
| Unit I | **Vector Space**<br>Introduction, Vector or Linear Space, linear subspace, linear combination, linear span, linear dependence and linear independence, basis, finite and infinite dimensional vector spaces, dimension of a subspace. |
| Unit II | **Normed Linear Space**<br>Normed linear space, sequence of series, $l^p$ space, $l^\infty$ space, unit sphere, closed and open ball, subspace of a Banach space. |
| Unit III | **Completeness**<br>Introduction, completeness, closeness, equivalent norms, completeness and finite dimension, compactness, Friesz's lemma. |
| Unit IV | **Linear Operators**<br>Introduction, linear operators, null space, linear operator, identity operator, zero operator, inverse of a linear operator, bounded linear operator. |
| Unit V | **Linear Functional**<br>Continuity and null space, linear functional, bounded linear functional, dot product, algebraic dual space, isomorphic. |
| Unit VI | **Hilbert Spaces**<br>Inner product spaces, Hilbert spaces, some properties of Hilbert spaces, orthonormal sets, conjugate space and adjoint of an operator. |
| **Block 2** | **Fixed Point Theory** |
| Unit VII | **Banach Fixed Point**<br>Introduction, Banach fixed point, contraction, Banach fixed point theorem, Kannon contraction theorem, Reich contraction, Hardy and Rogers's contraction theorem. |
| Unit VIII | **Applications of Banach theorem**<br>Applications of Banach theorem to linear equations, Applications of Banach theorem to differential equations, Picard's existence and uniqueness theorem, Applications of Banach theorem to integral equations. |
| Unit IX | **Approximation in Normed Spaces**<br>Introduction, best approximation, polynomials, uniqueness, convexity. |

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| Unit X | **Housdorff Space**<br>Introduction, distance, Housdorff metric space, Nadler's contraction theorem. |
| **Block 3** | **Applied Functional Analysis** |
| Unit XI | **Differentiation and Integration in normed space**<br>Integration, Gateaux derivative, Frechet derivative, Bochner integral. |
| Unit XII | **Spectral Theory of Linear Operators in Normed Space**<br>Introduction, Eigen values and Eigen vectors, resolvent operators, regular value, resolvent set, spectrum, spectral properties of bounded linear operators, holomorphic. |

**Suggested Text Book Readings:**


1. Goffan, C. and Pedrick, G.: A First course in Functional Analysis, AMS Chelsea Publishing: AnImprint of the American Mathematical Society, New York, 1983.
2. Jain, P.K. and Ahuja, O.P.: Functional Analysis, New Age (International P, Ltd,) New Delhi, 2010.
3. Kreyszig, E.: Introductory Functional Analysis with Applications, John Wiley and Sons, New York, 2007.
4. Simmons, G.F.: Introduction to Topology and Modern Analysis, McGraw Hill Book Co., New York, 2013.
5. Taylor, A.E. Introduction to Functional Analysis, John Wiley and Sons, New York, 2013.
6. Bollobas, B.: Linear Analysis, An Introductory Course, Cambridge University Press, Cambridge, 1999.
7. Berbarian, S.K.: Introduction to Hilbert Spaces, Oxford University Press, New York, 1961.
8. Fixed Point Theory Andrzej Granas Springer-Verlag, New York Volume I (see below) and the unpublished Volume II (in a major Volume) and will be appearing in the Spring of 2003.


**This course can be opted as an elective by the students of following subjects:** NA

**Suggested equivalent online courses (MOOCs) for credit transfer:** NA

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| **Course prerequisites:** To study this course, a student must have qualified graduation with Mathematics. | | |
| **Programme:** M.Sc. | **Year:** II | **Semester:** III |
| **Subject:** Mathematics | | |
| **Course Code:** MSCMM-113N/MAMM-113N | **Course Title:** Measure Theory and Integration | |
| **Course Objectives:** The objective of the course is to give an introduction to Lebesgue measure on the set of real numbers R and the concept of measure in general, indicating its role in the theory of integration. | | |
| **Course Outcomes:**<br>**CO1:** To study the basic concepts of sets, relations, functions and countability of sets.<br>**CO2:** The student will be able to understand the concept of Lebesgue measure is used in developing the theory of Lebesgue integration, which gives better results as compared to the theory of Riemann integration.<br>**CO3:** Understand the basic tool to solve the problems of integral equations, fluid dynamics and optimization theory.<br>**CO4:** Able to understand the measure and integration has numerous applications in other branches of pure and applied mathematics like as probability theory, partial differential equations, and functional analysis. | | |
| **Credits:** 4 | **Type of Course:** Core | |
| **Max. Marks:** 100 | **Min. Passing Marks:** 36 | |

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| **Block 1** | **Set Theory** |
| Unit I | **Sets**<br>Introduction, Representation of sets, types of sets, subset, universal set, Venn diagram, operations on sets, and algebra of sets. |
| Unit II | **Relations**<br>Introduction, inverse relation, representation of relations, types of relations, equivalence relation, and partial order relation. |
| Unit III | **Functions**<br>Introduction, inverse function, types of functions, real valued function, identity function, constant function, composition of functions. |
| Unit IV | **Open and Closed Sets**<br>Zorn Lemma, axiom of choice, Schroder-Bernstein's equivalence theorem, Open and closed sets, Bolzano-Weierstrass theorem. |
| Unit V | **Countability of Sets**<br>Finite and infinite sets, cardinal number and cardinality of a set, countable and uncountable sets, ordered pairs, ordinal numbers, Cantor's theorem, Continuum hypothesis, Algebraic and Transcendental numbers. |
| **Block 2** | **Lebesgue Measure** |
| Unit VI | **Measure**<br>Length of an interval, measure of interval, Borel set, Boolean Ring, Boolean algebra, measure, Outer Measure, Carathedory's Postulates for Outer Measure. |
| Unit VII | **Lebesgue Measure**<br>Measurable set, Exterior and Interior Measure of a set, Measurable space, First Fundamental Theorem, Cantor's Ternary set. |
| Unit VIII | **Measurable Functions**<br>Measurable function, Borel Measurability, pointwise convergence, convergence in measure, uniform convergence, F. Riesz theorem, Egoroff's theorem and Lusin's theorem. |
| **Block 3** | **Lebesgue Integral** |

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| Unit IX | **Lebesgue Integral**<br>Riemann Theory of Integral, Lebesgue integral, First Mean Value Theorem, Lebesgue Bounded Convergence Theorem, Lebesgue Dominated Convergence Theorem, Beppo-Levi's Theorem and Fatou's Lemma. |
| Unit X | **Differentiation and Integration**<br>Function of bounded variation, Vitali's Lemma, Lebesgue point and Lebesgue set, Fundamental Theorem of Integral Calculus. |
| Unit XI | $l^p$ **Space**<br>Introduction to $l^p$ space, conjugate number, convergent sequence, Cauchy sequence, $l^p$-space with properties, Riesz Holder Inequalities, Minkowski's Inequality and Schwarz's Inequality. |
| **Block 4** | **Product measures and Signed measures** |
| Unit XII | **Product measures and Signed measures**<br>Introduction to product measures and signed measures, Fubini's theorem, Tonelli's theorem, Hahn Decomposition theorem, Radon Nikodym theorem and Lebesgue Decomposition theorem. |

**Suggested Text Book Readings:**


1. Malik, A.K., Kumar, S., Singh, S. R, Malik, S. C., Measure Theory and Integration, Dreamtech Press, 2020.
2. Barra, G de: Measure Theory and Integration, 2nd Edition, New Age International (P) Ltd., 2011.
3. Goldberg, Richard R: Real analysis, Oxford and IBH, 2012.
4. Jain, P.K. & Gupta, V.P.: Lebesgue Measure and Integration, New Age International (P) Ltd., New Delhi.
5. Rana, Inder K., An Introduction to Measure and Integration, Narosa Publishing House, 2007
6. Royden, H.L.: Real analysis, 4th Edition, Pearson, 2018.
7. Rudin, Walter, Real & Complex Analysis, McGraw Hill Education, 3rd Edition, 2017.


**This course can be opted as an elective by the students of following subjects:**
M.Sc. (Data Science & Analytics/Statistics)

**Suggested equivalent online courses (MOOCs) for credit transfer:** NA

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| **Course prerequisites:** To study this course, a student must have qualified graduation with Mathematics. | | |
| **Programme:** M.Sc. | **Year:** II | **Semester:** III |
| **Subject:** Mathematics | | |
| **Course Code:** MSCMM-114N/MAMM-114N | **Course Title:** Theory of Probability | |
| **Course Objectives:** The main aim of this course is to extend and master students' knowledge of probability theory and to provide theoretical background for studying advanced probabilistic and statistical method. | | |
| **Course Outcomes:**<br>**CO1:** To study the fundamental concepts of probability theory.<br>**CO2:** The student will be able to understand the concept of random variable and probability distributions, expectation.<br>**CO3:** Able to understand the discrete and continuous distribution with their applications in other branches of pure and applied mathematics.<br>**CO4:** Understand the basic tool to solve the problems related to statistical interference and check the test of significance. | | |
| **Credits:** 4 | **Type of Course:** Core | |
| **Max. Marks:** 100 | **Min. Passing Marks:** 36 | |

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| **Block 1** | **Introduction to Probability Theory** |
| Unit I | **Random experiments and Probability**<br>Deterministic and random experiments, Sample space, Events, Algebra of Events, Axiomatic definition of Probability, Classical definition of Probability, Statistical definition of probability, Addition Theorem of Probability. |
| Unit II | **Conditional Probability**<br>Conditional probability, Multiplicative theorem of Probability, Independent events, Partition of sample space, Baye's Theorem. |
| **Block 2** | **Probability Distributions and Expectations** |
| Unit III | **Random Variables and Probability Distributions**<br>Definition and types of random variables, Cumulative distribution function and its properties, Probability Mass Function, Probability Density Function. |
| Unit IV | **Expectation**<br>Definition and types of Mathematical Expectation, Moments in terms of expectation, Mathematical and Multiplication theorems of Expectation, other theorems on expectation. |
| Unit V | **Inequalities for Moments**<br>Cauchy-Schwartz Inequality, Markov's inequality, Chebyshev's inequality. |
| **Block 3** | **Concept of Probability Distributions** |
| Unit VI | **Univariate Distributions**<br>Bernoulli Distribution, Binomial Distribution, mean and variance of binomial distribution, Moments, Moments Generating Function, Additive and Multiplicative property, Recurrence relation for moments, Fitting of Binomial Distribution, Poisson Distribution, Poisson Distribution as a limiting case of Binomial Distribution, mean and variance of Poisson distribution, Moments, Moment Generating Function, Additive and Reproductive property, Recurrence relation for moments, fitting of Poisson Distribution. |
| Unit VII | **Discrete Distributions**<br>Geometric Distribution, mean and variance, moment generating function of geometric distribution, Negative Binomial Distribution, Moment Generating Function, Mean and Variance, Recurrence formulae for negative Binomial Distribution, Poisson Distribution as a limiting case of Negative Binomial Distribution, Hyper Geometric |

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| | Distribution, Mean and Variance, Recurrence relation for Hyper Geometric distribution. |
| Unit VIII | **Normal Distribution**<br>Normal Distribution and its parameters, Standard Normal Distribution, Moments, Moments Generating Function, Area Property, properties of normal curve, Standard Scores, Advantages and Characteristics of Z Scores. |
| Unit IX | **Continuous Distributions**<br>Uniform Distribution, Moment Generating Function, Distribution Function, Moments of Uniform Distribution, Exponential Distribution, Moments, Moment Generating Function, Lack of Memory Property. |
| Unit X | **Sampling Distribution**<br>Sampling distribution of a statistic, Parameter, Derivation of $\chi^2$, t, F, z distributions, Beta, Gamma, Cauchy densities. |
| **Block 4** | **Basic Principles of Statistical Inference** |
| Unit XI | **Estimation**<br>Point Estimation, properties of a good estimators, Consistency, Unbiasedness, Efficiency, Sufficiency, Confidence Interval Estimation. |
| Unit XII | **Method of Estimation**<br>Procedures of Estimation, Method of Moments, method of Maximum Likelihood, Method of Scoring, Properties of Estimators |
| Unit XIII | **Testing of Hypothesis**<br>Statistical Hypothesis, Simple and Composite Hypothesis, Critical Region, Two kinds of Error, One-tailed and Two-tailed tests, Test of Significance, Most Powerful Test, Uniformly Most Powerful Test. |
| **Block 4** | **Test of Significance** |
| Unit XIV | **Exact Tests and Fisher's transformations**<br>Tests of Significance based on Chi-Square Distribution, Tests of Significance based on t–Distribution, Tests of Significance based on F–Distribution, Tests of Significance based on Fisher's Z–Distribution. |
| Unit XV | **Large Sample Tests**<br>Testing Significance of Mean, Testing Equality of Means, Testing Significance of Proportion, Testing Equality of Proportions, Testing Significance of Standard Deviation, Testing Equality of Standard Deviation. |
| Unit XVI | **Non-Parametric Tests**<br>Non-Parametric Tests, Sign Test, Wilcoxon Signed- Rank Test, Mann- Whitney U-Test, Run Test. |

**Suggested Text Book Readings:**


1. Rohatgi, V.K., Saleh, A.K. Md. Ehsanes, An Introduction to Probability and Statistics, Second Edition Wiley-Inderscience, 2008.
2. Mayer, P.L., Introductory Probability and Statistical Applications, IBH. 2nd Edition, 1970.
3. Sheldon M. Ross, Introduction to Probability Models (11th edition), Elsevier, 2014.
4. V.K. Kapoor and S. C. Gupta, Fundamental of Mathematical Statistics, S. Chand & Sons, 2018.
5. Gupta, C. B., Malik, A. K., Kumar, V., Random-Variables and Stochastic Processes, Neelkanth Publisher Jaipur, 2011.


**This course can be opted as an elective by the students of following subjects:**
M.Sc. (Data Science & Analytics/Statistics)

**Suggested equivalent online courses (MOOCs) for credit transfer:** NA

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|---|---|---|
| **Course prerequisites:** To study this course, a student must have qualified graduation with Mathematics. | | |
| **Programme:** M.Sc. | **Year:** II | **Semester:** III |
| **Subject:** Mathematics | | |
| **Course Code:** PGRT-03 | **Course Title:** Basics Research Tools | |
| **Course Objectives:** The main objective of this course is to develop a research orientation among the scholars and to acquaint them with fundamentals of basic computer tools, research tools, indexing of research paper and scientific report writing. | | |
| **Course Outcomes:**<br>**CO1:** To know about the research tools and indexing of a research paper.<br>**CO2:** To know about the fundamentals of basic computer tools and how to use it in research.<br>**CO3:** Able to know the writing the research paper and scientific report writing. | | |
| **Credits:** 4 | **Type of Course:** Core | |
| **Max. Marks:** 100 | **Min. Passing Marks:** 36 | |

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| **Block 1** | **Introduction to Research Tools** |
| Unit I | **Research Tools**<br>Introduction, Research tools: Searching google (query modifiers), MathSciNet, ZMATH. |
| Unit II | **Indexing of Research Paper**<br>Scopus, ISI, Web of Science, Impact factor, h-index, Google Scholar, ORCID, Online and open access journals, Virtual library of various countries. |
| **Block 2** | **Computer tools and software** |
| Unit III | **Basic computer tools**<br>Computer Networking, Internet, Web Browsers, Search Engines, MS Word: Handling graphics tables and charts, Formatting in MS-Word, MS PowerPoint: Creating Slide Show, Screen Layout and Views, Applying Design Template, MS Excel: Features, Formulas and Functions, Data Analysis and Data Visualization in Excel. |
| Unit IV | **Scientific Report Writing**<br>Scientific writing and presentation, writing a research paper, survey article, thesis writing; LaTeX, PS Tricks etc., use and application of Mendeley-software, software for Mathematics: Mathematica /MATLAB /Scilab/GAP. |

**Suggested Text Book Readings:**


1. C.R. Kothari, Gaurav Garg. Research Methodology: Methods and Techniques, New Age International Publishers, 2019.
2. Kumar. R: Research Methodology: A Step-by-Step Guide for Beginners, (3rd Edition), SAGE, Inc., 2011.
3. Creswell. W.: Research Design, Qualitative, Quantitative and Mixed Methods Approaches (3rdEdition), SAGE,Inc., 2018.
4. Shortis, T.: The Language of ICT: Information and Communication Technology, Taylor & Francis, 2016.
5. Lamport. L., LaTeX, a Document Preparation System, 2nd Ed., Addison-Wesley, 1994.
6. Shortis, T.: The Language of ICT: Information and Communication Technology, Taylor & Francis, 2016.
7. https://onlinecourses.swayam2.ac.in/cec22_ge28/preview


Note:- In this paper, learner itself study the objectives and prepare a report. The report will be submitted along with assignment to respective study center for evaluation. The maximum marks for evaluation are 100.

| | | |
|---|---|---|
| **Course prerequisites:** To study this course, a student must have qualified graduation with Mathematics. | | |
| **Programme:** M.Sc. | **Year:** II | **Semester:** IV |
| **Subject:** Mathematics | | |
| **Course Code:** MSCMM-116N/MAMM-116N | **Course Title:** Operations Research | |
| **Course Objectives:** The main objective of the course is to presents the theory and techniques of solving operations research problems in linear programming, inventory, simulation, queuing and reliability theory. | | |
| **Course Outcomes:**<br>**CO1:** To solve the linear programming problem with revised simplex method, which is very useful for in given problem having large number of variables or constrains involved.<br>**CO2:** To have deep insight in solving linear programming problem with duality and sensitivity analysis of the linear programming problem.<br>**CO3:** The formulation and solving of applications of operations research like as sequencing, project scheduling, simulation and reliability theory.<br>**CO4:** Able to know the inventory, queuing and replacement models with their real life applications. | | |
| **Credits:** 4 | **Type of Course:** Core | |
| **Max. Marks:** 100 | **Min. Passing Marks:** 36 | |

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| **Block 1** | **Introduction to Operations Research** |
| Unit I | **History of Operations Research**<br>Introduction, Historical development, Scope and phases of Operation Research, applications of operations research. |
| Unit II | **Revised Simplex method**<br>Introduction, Revised Simplex method, Computational procedure for solving linear programming problem by Revised Simplex method. |
| Unit III | **Duality in Linear Programming Problem**<br>Introduction, Symmetric form, dual of linear programming problem, primal dual relationship, fundamental theorem of duality, Dual Simplex method. |
| Unit IV | **Sensitivity Analysis**<br>Introduction, Sensitivity analysis, Change in $c_{ij}$'s (the coefficients of $x_{ij}$'s in the objective function), Change in $b_{ij}$'s (the right hand side of constraints), Change in $a_{ij}$'s (the columns of coefficient matrix, deletion and addition of constraints, deletion and addition of decision variables. |
| **Block 2** | **Applications of Operations Research** |
| Unit V | **Sequencing**<br>Introduction, sequencing, Johnson's algorithm for processing n jobs through two machines, Johnson's algorithm for processing n jobs through k machines, processing two jobs through k machines. |
| Unit VI | **Project Scheduling-I**<br>Introduction, network, project development, network, activity, event, Fulkerson's rule for numbering events. |
| Unit VII | **Project Scheduling-II**<br>Introduction, program evaluation and review techniques, optimum scheduling by critical path method, time-cost optimization algorithm. |
| Unit VIII | **Simulation**<br>Introduction, random numbers and pseudo random numbers, Monte Carlo simulation, applications of simulation. |
| Unit IX | **Reliability Theory** |

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| | Introduction, basic concept of reliability, Hazard rate function, system reliability: series and parallel, redundancy, reliability of preventive maintenance. |
| **Block 3** | **Models in Operations Research** |
| Unit X | **Inventory Models**<br>Introduction, inventory, inventory control, inventory costs, economics order quantity, deterministic inventory models with shortages. |
| Unit XI | **Queuing Models**<br>Introduction, markovian queues, probability distribution of n arrivals, distribution of inter-arrivals time, birth and death process. |
| Unit XII | **Replacement Models**<br>Introduction, replacement policy model, replacement policy when the value of money does not change with time, replacement policy when the value of money changes with time. |

**Suggested Text Book Readings:**


1. Yadav, S. R. and Malik, A. K., Operations Research, Oxford University Press, 2014.
2. Malik, A. K, Yadav, S. K. and Yadav, S. R. and., Optimization Techniques, Dreamtech Press, 2020.
3. Taha, H. A. Operation Research: An Introduction. 9 th edition, Pearson, 2010.
4. Gupta, P.K. and Hira, D.S. Introduction to Operations Research, S. Chand & Co. 2008.
5. Hardy, G.: Nonlinear and Dynamic Programming ($4^{th}$ edition), Addison-Wesley, Reading Mass, 1974.
6. Sharma, J. K., Mathematical Model in Operation Research, Tata McGraw Hill, 1989.
7. Swarup, K., Gupta, P.K. and Mohan Man: Operations Research ($9^{th}$ Edition), S.Chand and Sons, NewDelhi, 2002.
8. Frederick S. Hillier & Gerald J. Lieberman (2015). Introduction to Operations Research (10th edition). McGraw-Hill Education.


**This course can be opted as an elective by the students of following subjects:**
MBA/M.Sc. (Data Science & Analytics/Statistics)

**Suggested equivalent online courses (MOOCs) for credit transfer:** NA

| | | |
|---|---|---|
| **Course prerequisites:** To study this course, a student must have qualified graduation with Mathematics. | | |
| **Programme:** M.Sc. | **Year:** II | **Semester**: IV |
| **Subject:** Mathematics | | |
| **Course Code:** MSCMM-117N/MAMM-117N | **Course Title:** Fluid Dynamics | |
| **Course Objectives:** The main aim of this course is to develop the fundamental knowledge and understanding of the mechanics of fluid at rest andin motion to develop the ability to demonstrate and formulate the physical problems encountered in different branches of engineering in mathematical form and arrive at useful solutions. | | |
| **Course Outcomes:**<br>**CO1:** Able to understand and apply the basic concepts of fluid mechanics.<br>**CO2:** To convert the physical laws of conservation of mass, momentum, moment of momentum and energy into mathematical equations and apply them to describe the fluid motion.<br>**CO3:** To describe the motion of ideal and real fluids with different techniques including complex variable technique.<br>**CO4:** Able to know and apply the basic flow equations, such as the Navier-Stokes equations to evaluate velocity, pressure drop in simple geometries like laminar flows between parallel plates, axial and transverse flows in pipes and flows in annular region produced. | | |
| **Credits:** 4 | **Type of Course:** Core | |
| **Max. Marks:** 100 | **Min. Passing Marks:** 36 | |

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| **Block 1** | **Motion in One Dimension** |
| Unit I | **Kinematic (Equations of Motion)**<br>Hydrodynamics, Shearing stress, Viscosity, Lagrangian method, Eulerian method, Local and Individual time rates of change, Acceleration, Kinds of motion, Definition of some curves , Stream line ,Path line, Streak line, Velocity potential, Vorticity vector, Beltrami flow. |
| Unit II | **Kinematic of Fluid in Motion**<br>Boundary surface, Lagrangian and Eulerian Equation of continuity, Equation of Continuity in different co-ordinates, Symmetrical forms of the equation of continuity. |
| Unit III | **Equation of Motion**<br>Equation of motion, Pressure equation, Lagrangian equation of motion, Bernoulli`s equation of motion. |
| Unit IV | **Equation of Motion of Inviscid Fluid**<br>Helmholtz vorticity equation, Cauchy`s integrals, Equations for impulsive action, Kelvin`s circulation theorem, Equation of energy. |
| **Block 2** | **Motion in Two Dimension** |
| Unit V | **Source, Sink & Doublets (I)**<br>Motion in two dimension, Lagrange`s stream function, Irrotational motion in two dimensions, Complex potential, Definition of Source, sinks, doublets, Complex potential due to a source, Complex potential due to doublet. |
| Unit VI | **Source, Sink & Doublets (II)**<br>Image w.r.t straight line, Images w.r.t. to circle, Circle theorem of Milne –Thomson, Blasius Theorem. |
| Unit VII | **Motion of Sphere**<br>Equation of continuity, $\phi$ for the motion of a sphere with velocity U in a liquid, liquid streaming past a fixed sphere, Equation of sphere. |
| Unit VIII | **Motion of Cylinder** |

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| | General motion of a cylinder, Kinetic energy, motion of circular cylinder, liquid streaming past a fixed circular cylinder. |
| Unit IX | **Motion of Elliptic & Parabolic Cylinder**<br>Elliptic co-ordinate, Motion of an elliptic cylinder, liquid streaming past a fixed elliptic cylinder, Motion of a parabolic cylinder, liquid streaming past a fixed parabolic cylinder. |
| **Block 3** | **Applications of Fluid Dynamics** |
| Unit X | **The Navier Stokes Equations and the Energy Equation**<br>The Navier-stokes equation of motion of a viscous fluid(Fundamental equation of motion), The energy equation- conservation of energy, Equation of state for perfect fluid, Diffusion of vorticity, equation for vorticity and circulation, Dissipation of energy, Dissipation of energy in Cartesian form. |
| Unit XI | **Elementary Notions of Fluid Flow**<br>Body forces and surface forces, Nature of stresses, Transformation of stress components, Stress invariants, Principal stresses, Nature of strains, Rates of strain components, Relation between stress and rate of strain components, General displacement of a fluid element, Newton's law of viscosity, Navier- Stokes equation (sketch of proof). |
| Unit XII | **Normal and Oblique Shock**<br>Normal and oblique shocks. Plane Poiseuille and Couette flows between two parallel plates. Unsteady flow over a flat plate, Reynold's number. |

**Suggested Text Book Readings:**


1. O'Neil, M. E., and Chorlton, F. Ideal and Incompressible Fluid Dynamics. John Wiley & Sons, 1986.
2. Kundu, P. K., Cohen, I. M. and Dowling, R. David. Fluid Mechanics, 6th edition, Academic Press, 2015.
3. Raisinghania, M.D.: Fluid Dynamics: with Complete Hydrodynamics and Boundary Layer Theory, S. ChandPublishing, 2014
4. Yuan, S. W. Foundations of Fluid Mechanics. Prentice Hall of India Private Limited, New Delhi, 1976.
5. Betchelor, G.K. An Introduction of Fluid Mechanics, Oxford University Books, NewDelhi, 2000.
6. Besaint, W.H. and Ramsey, A. S. A Treatise on Hydromechanics, Part II. CBS Publishers, Delhi, 1988.
7. Curle, N. and Davies, H. J. Modern Fluid Dynamics. Vol 1, D Van Nostrand Company Ltd, London, 1968.


**This course can be opted as an elective by the students of following subjects:** NA

**Suggested equivalent online courses (MOOCs) for credit transfer:** NA

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|---|---|---|
| **Course prerequisites:** To study this course, a student must have qualified graduation with Mathematics. | | |
| **Programme:** M.Sc. | **Year: I**I | **Semester:** IV |
| **Subject:** Mathematics | | |
| **Course Code:** MSCMM-122N/MAMM-122N | **Course Title:** Dissertation with viva-voce | |
| **Course Objectives:** In the last semester of Masters the main objectives of the exposure of students towards project/dissertation is to elevate their understanding into the applications areas of Mathematics. This course will develop their analytical ability, will provide them an apt exposure to work in any research group, and will motivate them to execute research in the area of their interest in Mathematical sciences. | | |
| **Course Outcomes:**<br>**CO1:** Students will be able to plan and strategize a scientific problem, and implement it within a reasonable time frame.<br>**CO2:** It is expected that after completing this project dissertation, students will learn to work independently and how to keep accurate/readable record of assigned project.<br>**CO3:** In addition, students will be able to know the library search and handle the data in a meaningful way. Also, the students will be able to interpret the spectral data independently.<br>**CO4:** Subsequently, the students should be able to critically examine research articles, and improve their scientific writing/communication skills and power point presentation. | | |
| **Credits:** 4 | **Type of Course:** Core | |
| **Max. Marks:** 100 | **Min. Passing Marks:** 36 | |
| Unit I | For project work and dissertation, the area of the work to be decided by the advisor/mentor.<br>On completion of the project work, students have to submit the work in the form of a dissertation followed by oral presentation in the presence of faculty members of the School in the University Campus Prayagraj. | |
| **Suggested Text Book Readings:**<br>1. Use different searching engine to get relevant information (Google scholar, Wiki-databases, Science Direct, SciFinder, Scopus, and YouTube.<br>2. Access to different online research library and research portal (Web resources, E-journals, journal access, TOC alerts) | | |
| **This course can be opted as an elective by the students of following subjects:** Open for all | | |
| **Suggested equivalent online courses (MOOCs) for credit transfer:** NA | | |

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|---|---|---|
| **Course prerequisites:** To study this course, a student must have qualified graduation with Mathematics. | | |
| **Programme:** M.Sc. | **Year:** II | **Semester:** IV |
| **Subject:** Mathematics | | |
| **Course Code:** MSCMM-118N/MAMM-118N | **Course Title:** Soft Computing | |
| **Course Objectives**: The aim is to equip students with some state-of-the-art artificial intelligence and soft computing technology to prepare them in a better way for the rapidly evolving high-tech information-based modern industry and market. | | |
| **Course Outcomes:**<br>**CO1:** The students will be able to know about the concepts of artificial intelligence and implement it.<br>**CO2:** This theory provides an excellent tool to handle the vagueness in modern science and technology problems such as optimization techniques, computer science, statistics, economics and medical science.<br>**CO3:** Able to know and apply the fuzzy theory, neural network and genetic algorithm in solving applications of real life situations.<br>**CO4:** On the basis of this theory many real-life based problems can be solved such as robotics, industrial, management etc. | | |
| **Credits:** 4 | **Type of Course:** Core | |
| **Max. Marks:** 100 | **Min. Passing Marks:** 36 | |

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| **Block 1** | **Artificial Intelligence & Soft Computing** |
| Unit I | **Introduction of Artificial Intelligence**<br>Definitions, Theoretical background, AI problem domain, General AI techniques, Underlying assumptions, possible goal of AI, Criteria of success. Problem state, state space, search space, State space representation, Production system, control strategy, water jug problem, 8-puzzle problem, Heuristic searching. |
| Unit II | **Knowledge Representation Model**<br>First order predicate logic, clauses, inference, rule base system, natural deduction and resolution, monotonic reasoning. |
| Unit III | **Non-Monotonic Reasoning**<br>Uncertainty, Bay's theorem, Bayesian network, dependency network, limitation of probabilistic reasoning, Soft computing definition, soft computing paradigm, applications, Pattern recognition, pattern classification, association and mapping. |
| **Block 2** | **Fuzzy Set Theory** |
| Unit IV | **Introduction of Fuzzy Logic**<br>Uncertainty, Fuzzy set, Crisp vs. fuzzy sets, Membership function, Fuzzy sets and operations, Operations and relations; fuzzy relations, cardinalities, membership functions. |
| Unit V | **Fuzzy Relations**<br>Fuzzy Cartesian product, fuzzy membership function formulation and parameterization, Fuzzy rules and reasoning, Formulation on fuzzy rules, extension principle and nested fuzzy relations. |
| Unit VI | **Fuzzy Rule Base System**<br>Fuzzy if-then rules, fuzzy inference, Fuzzy inference system, Defuzzification methods, Fuzzy control systems, and Applications of Fuzzy control systems. |
| **Block 3** | **Neural Network** |
| Unit VII | **Introduction of Neural Networks**<br>Limitations of Rule based system, characteristics of neural networks, simple structure of biological neuron and modeling of artificial neuron. Difference between ANN and |

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| | biological neural networks, artificial neuron models, artificial neural networks terminology, topology of ANN, Characteristics of ANN and its applications. |
| Unit VIII | **Activation and Synaptic Dynamics**<br>Basic learning laws, Artificial neural network architectures, Basic artificial neural network models, perceptron architecture, Perceptron learning rule, ADLINE architecture, LMS learning rule, Linear classifier, convergence theorem, limitation of perceptron learning, Multi-layer perceptron architecture. |
| Unit IX | **Pattern Mapping Network**<br>Multilayer feed forward neural network architecture, Generalized delta learning rule, Backpropagation learning algorithm and issues, limitation of Backpropagation learning rule, improvement in BP algorithms, momentum term, conjugate descent, reuse gradient, generalization and approximation, ill posing, Radial basis network. |
| **Block-4** | **Genetic Algorithm** |
| Unit X | **Introduction of Genetic Algorithm**<br>Fundamental and basic concepts, terminology, Applications and advantages, Representation of chromosomes and gens, Population representation, working principle, search space, solution state, global vs local optimization, encoding methods. |
| Unit XI | **Population Representation**<br>Selection criteria and methods, fitness evaluation function, reproduction, basic genetic operators, Mutation, selection, crossover. Fitness criteria, convergence of GA, combinatorial optimization. |
| Unit XII | **Problem Solution and Genetic Modeling**,<br>Inheritance operator, crossover operator and its various forms, inversion & deletion, mutation operator, bitwise operator, Generation cycle, Differences & similarities between GA & other traditional method. |

**Suggested Text Book Readings:**


1. Dubosis Didler and Prade, Henri, Fuzzy Sets and systems Theory and Applications, Academioc Press, NewYork, 1980
2. Klir . Georage. J and Yuan Bo, Fuzzy Sets and Fuzzy Logic: Theory and Applications, Prentice Hall of India, New Delhi. 2009
3. Lee, Kwang H., First Course on Fuzzy Theory and Applications, Springer International Edition, 2009.
4. Ross, Timothy J., Fuzzy Logic with Engineering Applications, McGraw Hills inc., 2004 New Delhi
5. Roger, Jyh-Shing; Sun, Chuen-Tsai; Mizutani, Eiji, Neuro-fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligence, MATLAB curriculum series, illustrated, reprint, Prentice Hall, 1997
6. Zimmermann,H.J. Fuzzy Set Theory & its Applications, Allied Publishers Ltd. New Delhi, 2006.
7. Bart Kosko, Neural Network and Fuzzy Systems- Prentice Hall, Inc., Englewood Cliffs, 1992.
8. Simon Haykin, Neural Network- A Comprehensive Foundation- Prentice Hall International, Inc.1998.
9. Sivanandam, S.N., Deepa, S. N., Introduction to Genetic Algorithms, Springer India, 2013.


**This course can be opted as an elective by the students of following subjects:**
**MCA**/M.Sc. (Data Science & Analytics)

**Suggested equivalent online courses (MOOCs) for credit transfer:** NA

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|---|---|---|
| **Course prerequisites:** To study this course, a student must have qualified graduation with Mathematics. | | |
| **Programme:** M.Sc. | **Year:** II | **Semester:** IV |
| **Subject:** Mathematics | | |
| **Course Code:** MSCMM-119N/ MAMM-119N | **Course Title:** Number Theory and Cryptography | |
| **Course Objectives:** The main aim of the course is to provide the knowledge of number theory and cryptography and how to apply them in solving real life problems. | | |
| **Course Outcomes:**<br>**CO1:** The student will be able to understand about the basics concept of number theory.<br>**CO2:** The student shall understand the importance and applications of the Fermat's little theorem and Wilson's theorem.<br>**CO3:** The student will get to know about Riemann Zeta Function and Algebraic Number Theory.<br>**CO4:** The student shall understand the Secret key cryptography and Public key cryptography. | | |
| **Credits:** 4 | **Type of Course:** Core | |
| **Max. Marks:** 100 | **Min. Passing Marks:** 36 | |

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| **Block 1** | **Introduction to Number Theory** |
| Unit I | **Divisibility**<br>Definition of divisibility, the division algorithm, Greatest common divisor, Euclidean algorithm in Z, Diophantine equation ax + by = C, Primes and their distribution, Fundamental Theorem of Arithmetic. |
| Unit II | **Congruence's**<br>Congruence's, Properties of Congruence's, linear congruence's, Special divisibility tests, Fermat's factorization method, Fermat's little theorem, Wilson's theorem. |
| Unit III | **Theoretical Function**<br>Definition and properties of the Dirichlet's product, Arithmetic and Number theoretic functions, functions $\tau$ and $\sigma$, Mobius Inversion formula, greatest integer function, Euler's Generalization of Fermat's theorem Euler's $\phi(n)$ function, Euler's theorem, properties of $\phi(n)$ function. |
| Unit IV | **Primitives**<br>Primitive roots, the order of an integer modulo n, primitive roots for primes, composite numbers having primitive roots, the theory of Indices. |
| **Block 2** | **Fermat Numbers** |
| Unit V | **Fermat numbers and Mersenne numbers**<br>Primes in certain arithmetical progressions, Fermat numbers and Mersenne numbers, System of linear congruence's Chinese Remainder Theorem, Congruence to prime power modulus. |
| Unit VI | **Quadratic residue and non-residue**<br>Legendre's Symbol, Gauss Lemma and its applications, Quadratic Law of Reciprocity Jacobi's Symbol, arithmetic in Zp, group Un, Primitive roots, group Upn (p-odd) and $U_2n$, existence of primitive roots, group of quadratic residue, Quadratic residue for prime power modulii and arbitrary modulii. |
| Unit VII | **Riemann Zeta Function**<br>Riemann Zeta Function $\xi(s)$ and its convergence, Application to prime numbers, $\xi$ (s) as Euler's product, Evaluation of $\xi(2)$ and $\xi(2k)$, Dirichlet's series with simple properties, Dirichlet's series as analytic function and its derivative, Euler's products, Introduction to modular forms. |
| **Block 3** | **Algebraic Number Theory** |
| Unit VIII | **Diophantine equations** |

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| | Diophantine equations, $x^2 + y^2 = z^2$ and $x^4 + y^4 = z^4$, representation of number by two or four squares, Waring's problem, Four square theorem, number g(k) & G(k), Lower bounds for g(k) & G(k). |
| Unit IX | **Algebraic number and Integers**<br>Gaussian integers and its properties, Primes and fundamental theorem in the ring of Gaussian integers, Integers and fundamental theorem in Q(ω) where ω is third root of unity, algebraic fields, Primitive polynomials, general quadratic field Q(√m), Units of Q(√2), Fields in which fundamental theorem is false, Real and complex Euclidean fields, Fermat's theorem in the ring of Gaussian integers, Primes of Q(2) and Q(5), Luca's test for the primality of the Mersenne number. |
| **Block 4** | **Cryptography** |
| Unit X | **Public Key Cryptography**<br>Public-Key Cryptography Principles, RSA, Key Management: Diffi-Hellman key exchange. |
| Unit XI | **Message Authentication and Hash Functions**<br>Authentication requirements, Authentication Functions, Message Authentication codes, Hash Functions, SHA-1 and MD5. |
| Unit XII | **Digital Signatures**<br>Digital signatures, Authentication protocols, Digital Signature standard. |

**Suggested Text Book Readings:**


1. Burton, D. M. Elementary Number Theory. Tata McGraw Hill Publishing House, 2006.
2. Apostol, T. M. Introduction to Analytic Number Theory. Springer 2014.
3. Davenport, H. Higher Arithmetic. Cambridge University Press, 1999.
4. Hardy, G. H. and Wright, E. M. Theory of Numbers. Oxford Science Publications, 2003.
5. Niven, I. and Zuckerman, H. S. Introduction to the Theory of Numbers. John Wiley & Sons, 2008.


**This course can be opted as an elective by the students of following subjects:**
MCA/M.Sc. (Data Science & Analytics)

**Suggested equivalent online courses (MOOCs) for credit transfer:** NA

| | | |
|---|---|---|
| **Course prerequisites:** To study this course, a student must have qualified graduation with Mathematics. | | |
| **Programme:** M.Sc. | **Year:** II | **Semester:** IV |
| **Subject:** Mathematics | | |
| **Course Code:** MSCMM-120N/MAMM-120N | **Course Title:** Machine Learning Techniques | |
| **Course Objectives**: The aim is to equip students with some state-of-the-art machine learning techniques to prepare them in a better way for the rapidly evolving high-tech information-based modern industry and market. | | |
| **Course Outcomes:**<br>**CO1:** The students will be able to know about the concepts of machine learning techniques and implement it.<br>**CO2:** This theory provides an excellent tool to handle the vagueness in modern science and technology problems such as optimization techniques, computer science, statistics, economics and medical science.<br>**CO3:** Able to know and solve many research problems and real-world problems by using machine-learning techniques.<br>**CO4:** This course has high rate of employability due to its great applicability in engineering. | | |
| **Credits:** 4 | **Type of Course:** Core | |
| **Max. Marks:** 100 | **Min. Passing Marks:** 36 | |
| **Block 1** | **Artificial Intelligence & Soft Computing** | |
| Unit I | **Introduction**<br>What is machine learning; Types of learning, Problems, Definition of learning systems. Goals and applications of machine learning. Aspects of developing a learning system: training data, concept representation, function approximation. | |
| Unit II | **Computational Learning Theory**<br>Data, probably approximately correct (PAC) learning model, Probabilistic Data Model, Loss Function and Expected Risk, Stability, Overfitting, Regularization, Bias variance, Cross validation, Nearest centroid, Least squares. Computational complexity. | |
| Unit III | **Memory based methods**<br>**N**earest neighbour, k-nearest neighbours, Feature maps, Representer theorem, Kernels, Hypothesis space, Loss function, Target function. | |
| Unit IV | **Regression**<br>Introduction to regression, usage of regression, types of regression, linear regression, multi-linear regression, Logistic regression, Polynomial regression, Ridge and Lasso regression, Evaluation of regression. | |
| Unit V | **Classification**<br>Introduction to classification, Multi-class classification, Decision boundaries; Probability and classification, Bayes optimal decisions, Naive Bayes and Gaussian class-conditional distribution, Linear classifiers, Bayes' Rule and Naive Bayes Model, Gradient descent. | |
| Unit VI | **Decision Tree Learning**<br>Representing concepts as decision trees, Recursive induction of decision trees, Picking the best splitting attribute: entropy and information gain, Searching for simple trees and computational complexity, Overfitting, noisy data, and pruning. | |
| Unit VII | **Ensemble Learning**<br>Standard ensemble learning strategies, Bagging, Boosting, Stacking, Decorate, Active learning with ensembles, Boosting: Concept of boosting, weak learnability, AdaBoost, AdaBoost for classification, Model selection, Validation, Train-validation split, Regularization, Stability. | |

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| Unit VIII | **Bagging and Random Forest**<br>Bagging for classification, Issues with Bagging, Introduction to Random forest, Bagging vs. Random Forest, Out-of-Bag (OOB) error estimation, Variable importance measures, Majority voting, Soft Majority Voting, Random Forest Algorithm, Tuning random forest, Random forest issues. |
| Unit IX | **Support Vector Machines**<br>Support vectors, Hyperplane, Kernel for learning non-linear functions, Different types of kernels, Parameter tuning, Generative vs. discriminative training, Multi-class support vector machine (SVM), SVM for classification, Support vector for regression. |
| Unit X | **Clustering and Unsupervised Learning**<br>Learning from unclassified data. Clustering. Hierarchical Aglomerative clustering, k-means clustering, partitional clustering, Expectation maximization (EM) for soft clustering, Semi-supervised learning with EM using labeled and unlabled data. |
| Unit XI | **Language Learning**<br>Classification problems in language: word-sense disambiguation, sequence labeling. Hidden Markov models (HMM's). Veterbi algorithm for determining most-probable state sequences. Forward-backward EM algorithm for training the parameters of HMM's. Use of HMM's for speech recognition, part-of-speech tagging, and information extraction. |
| Unit XII | **Programming Languages for Machine Learning**<br>Python Ecosystem for Machine Learning: Python, SciPy, scikit-learn, Python Ecosystem Installation. Crash Course in Python: Assignment, Flow Control, Data Structures. NumPy Crash Course: Create Array, Access Data, and Arithmetic. Matplotlib Crash Course: Line Plot, Scatter Plot. Pandas Crash Course: Series, Data Frame. |

**Suggested Text Book Readings:**


1. Goldberg D.E., Genetic Algorithms in Search, Optimization, and Machine Learning, Addison Wesley, 1989.
2. Deisenroth, M. P., Faisal, A, A, Ong, C. S., Mathematics for Machine Learning, Cambridge University Press, 2020
3. Shing, Jyh., Jang Roger, Mizutani Eiji., Sun, Chuen-Tsai, Neuro-fuzzy and Soft Computing: A Computational, Prentice Hall, Inc., 2007
4. Miroslav Kubat, An Introduction to Machine Learning, Springer International Publishing AG, 2016.
5. Roger, Jyh-Shing; Sun, Chuen-Tsai; Mizutani, Eiji, Neuro-fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligence, *MATLAB curriculum series*, illustrated, reprint, Prentice Hall,1997
6. Zimmermann, H.J. Fuzzy Set Theory & its Applications, Allied Publishers Ltd.New Delhi, 2006.


**This course can be opted as an elective by the students of following subjects:**
MCA/M.Sc. (Data Science & Analytics)

**Suggested equivalent online courses (MOOCs) for credit transfer:** NA

| | | |
|---|---|---|
| **Course prerequisites:** To study this course, a student must have qualified graduation with Mathematics. | | |
| **Programme:** M.Sc. | **Year:** II | **Semester:** IV |
| **Subject:** Mathematics | | |
| **Course Code:** MSCMM-121N/MAMM-121N | **Course Title:** Vedic Mathematics | |
| **Course Objectives:** The aim of this course is to develop fast mathematical thinking and enhance computational abilities. | | |
| **Course Outcomes:**<br>**CO1:** The students will be able to know about the concepts of Vedic mathematics and use it.<br>**CO2:** This theory is provide in order to speed up calculations in internet security and cryptographic algorithms, Vedic mathematics division,exponentiation, and multiplication are being used.<br>**CO3:** Able to know the arithmetic and logic unit in a computer handles all aspects of logical and mathematical calculations.Various sutras including udharvtriyakbhyam and nikhilam are used for multiplication methods.<br>**CO4:** Students will be able to utilize Vedic sutras to enhance their skills for competitive exams and able to solve examinations more efficiently. | | |
| **Credits:** 4 | **Type of Course:** Core | |
| **Max. Marks:** 100 | **Min. Passing Marks:** 36 | |

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| **Block 1** | **Indian Mathematician and their contributions** |
| Unit I | **Contribution of the Indian Mathematician**<br>(1) Bhaskarachaary-II (2) Arya Butta (3) Varahmihir (4) Bodhayan (5) Srinivas Ramanujan<br>(6) Bharti Krishna Tirtha |
| Unit II | **Introduction of Vedic Mathematics**<br>Introduction of Vedic Mathematics, Sankalan, Vyavkalan, Friend and Fast Friend, Complements, Beejank, Deviation Methods |
| Unit III | **Basic Vedic Mathematics**<br>Vedic Mathematics Sutra and Subsutra with explanation. |
| **Block 2** | **Vedic Arithmetic** |
| Unit IV | **Simple Calculation on Vedic Mathematics**<br>Forward Counting, Backward Counting, Vinnuculum, Tables Writing, Addition, Subtraction. |
| Unit V | **Multiplication and Division in Vedic Mathematics**<br>Multiplication by Vedic Sutras, Division by Vedic Sutras, Flag Method, Test of Divisibility, Mixed Operations. |
| Unit VI | **Squaring and Cubing Method**<br>Square of Numbers and Square roots of perfect square numbers. Cubing: Cube of Numbers and Cube roots of perfect cube numbers, mixed operation. |
| **Block 3** | **Vedic Algebra** |
| Unit VII | **Recognizable patterns on Vedic Mathematics**<br>Addition, Subtraction, Multiplication, Division of Algebraic Expression. |
| Unit VIII | **Algebraic Expansion of Vedic Mathematics**<br>LCM, HCF of algebraic expressions, Partial Fractions. |
| Unit IX | **Solution of Algebraic Equations**<br>Solution of Quadratic Equation, Solution of rational fraction. |
| **Block 4** | **Vedic Geometry and Trigonometry** |
| Unit X | **Bhodhayan Numbers**<br>Bhodhayan Numbers and its application to find trigonometrical ratios. |

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| Unit XI | **Vedic Geometry**<br>Co-ordinate geometry, Area of Triangles, Collinear points, Area of Quadrilateral. |
| Unit XII | **Introduction of Meruprastara**<br>Meruprastara, Importance and applications of Meruprastara. |

**Suggested Text Book Readings:**


1. Bharti Krishna Trith Ji "Vedic Ganit" Moti Lal Banarasi Das , Delhi, India, 1991,First Edition.
2. Uppadhya B.L. "Prachin Bharatiya Ganit" Vigyan Bharti, New Delhi, India.
3. Mohan Braj "History of Mathematics" Hindi Samiti Information Department U.P., India.
4. Handa Nidhi "Ancient Hindu Mathematics an Introduction" Oshina Publications, Indore (MP), India, 2018, FirstEdition.
5. "Vedic Ganit Nirdeshika" Vidya Bharti Sanskriti Shiksha Sansthan, Haryana, India, 2017, Seventh Edition.
6. Singh Shivraj , Kumar Anil ,Gupta Soniya ,Yadav Rashmi "Vedic Ganit", Pragati Prakashan, Meerut,India,2022, First Edition.
7. Chauthaiwale, Shriram" "Enjoy Vedic Mathematics" Art of Living international Bangluru, India
8. Chauthaiwale, Shriram, Verma, Deviprasadand and Deshmukh, Devendra, "Eminent BharatiyaMathematicians".


**This course can be opted as an elective by the students of following subjects:** Open for all

**Suggested equivalent online courses (MOOCs) for credit transfer:** NA

# APPENDIX-II

**Guidelines for preparing Research Project/Dissertation is available at link:**

http://14.139.237.190/upload_pdf/01_02_2023_Guidelines_fo_Project_Lit_Survey_Dissertation.pdf